Going Back to the Future

A Modernized Personalized System of Instruction (MPSI)

For CEGEP Physics

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Dedicated to Robert G. Fuller (1935-2012)

Professor Emeritus – University of Nebraska-Lincoln

ABSTRACT

The Personalized System of Instruction (PSI), also referred to as the Keller Plan, was used in the 70s and early 80s in both science and non-science disciplines at colleges and universities.

Fred. S. Keller, together with J. Gilmour Sherman (Keller & Sherman, 1974), perfected PSI in the late 60s while teaching psychology at the University of Arizona. From there, PSI was adopted by other disciplines and universities and the number of users of this method peaked in the 1970s and 1980s. However, by the mid-80s the use of PSI declined dramatically and virtually died out in Physics.

In a PSI course the material is divided into a series of study units or modules and each one must be mastered in order to permit the students to advance independently at their own pace. The teacher, the proctors, and the assistants would be writing, preparing and administering tests and then correcting them for quick feedback. Without computers, it was just too much work for everybody involved (Fuller & Winch, 2005).

A modernized PSI, technology-based, would establish a dynamic, student-centered, active learning/teaching environment with well-defined learning objectives, activities and assessments. It would move the traditional classroom to one that is student-based. In addition, this method would have the potential of meeting the needs of the diverse student population in our CEGEPs that we have today.

PSI is an “instructional delivery system” that successfully interfaces with the reform and competency-based education. It would utilize computer-based resources, online databases and would be supported by textbooks that have eBook and online assignment-tutorial features.

This report will present past PSI experiences to see what worked and what didn’t work. A “modernized” PSI (MPSI) for first-year CEGEP Physics NYA (Mechanics) will be presented based on the results and evaluations from actual teaching experience of a class taught at Marianopolis College in the 2012 Winter semester.

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I would like to thank Simon Sabik, Science Chair, for believing in my project and making it possible for me to teach my Winter 2012 NYA (Mechanics) physics class using the PSI format.

Special thanks go to the late Robert G. Fuller who led his PSI team at the University of Nebraska-Lincoln in 1975 to produce perhaps the most complete set of Physics modules used in PSI courses. These study guides sparked my initial interest in PSI and I used them with great success in the early 1980s. Professor Fuller was a firm believer in PSI, supporting its use. As recently as 2010 he oversaw the digitization of the 1975 Keller Plan Calculus Based Physics (CBP) modules. Due to this project the modules are now on the UNL physics digital commons website as pdf files and available free to the public at large. He gave me much encouragement just before his untimely death in April, 2012. The study guide for the Newton's Laws (1975) CBP module, in part, is incuded in Appendix I.

I am indebted to Alain Léger, a colleague at Marianopolis College, who gave me valuable advice and support. Upon his suggestion, I also contacted Pierre-Luc Gilbert-Tremblay, a psychology professor at Collège Jean-de-Brébeuf, who also gave me considerable advice and suggestions regarding the grant application.

Many thanks go to Don Hetherington, Dean of Science at Vanier College (retired), who informed me of Vanier's MISP (Modularized Integrative Science Program) given in the 1970s and 1980s. It was very similar to the Keller Plan (PSI) and a study guide for one of the MISP modules has been included in Appendix II with his permission.

Perhaps the only Quebec CEGEP that used the Keller Method extensively in the 1970s and 1980s in all its physics courses was André Grasset. I wish to thank “le Plan Keller” team of André Blais, René Cossette, Roland Simard, Tomasso Donato and Benoît Villeneuve for sharing their numerous experiences with me.

I am indebted to the Marianopolis College library staff for helping me obtain the harder-to-get articles and older books only available from other institutions and much needed for my research. In particular I want to thank Amy MacLean, Matthew Flanagan and Elaine Greer.

My “Modernization” of PSI (MPSI) would not have been possible without support from the MasteringPhysics (MP) product management team at Pearson Education. Numerous suggestions on the various aspects of MP were made and my MPSI all came together with the “Assign-by-Group” feature of MP.

Both students and instructors have benefited greatly from Randall D. Knight’s textbook: *Physics for Scientists and Engineers – A Strategic Approach*. It highly promotes active learning and comes with a wide range of excellent resources for students and instructors. In particular, I would like to thank him for the excellent Instructor Guides found in the Instructor Resource DVD. With permission from Pearson Education, extensive use was made of these Instructor Guides to produce the student Study Guides for my MPSI modules.

Soon after my presentation at the May 2012 ACPQ conference, Norman Spatz, who represents the English side of Profweb, approached me and suggested I write an article in Profweb based on my presentation. I wish to thank him for his encouragement and hard work for getting the publication out in the fall of 2012. A copy of this publication is found in Appendix V.

I wish to thank Monica Lopez, Academic Resources & Development, for her professional work in putting together an online (Omnivox) student questionnaire that was used in evaluating my Winter 2012 PSI class. The details of this questionnaire, including the results, are found in Appendix IV.

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Chapter 1 Introduction

1.1 Programmed Instruction

Certain educational practices may, at different periods in history, be referred to by different names, but in fact may have strong common traits. The Personalized System of Instruction (PSI) is no exception. In fact, a much earlier system going back to the 1920s, was based on John Dewey's work (Dewey, 1964) and was referred to as a "programmed" system of instruction. This was the Winnetka Plan, an educational experiment held in the Winnetka, Illinois-based Winnetka School District 36, developed by Carleton Washburne who was the district superintendent (Britannica Online, Winnetka Plan, 1919). In this Plan, students were required to demonstrate mastery to advance, resulting in students advancing at different rates. Students who fell behind received one-on-one help from a teacher while the stronger students moved ahead at a quicker pace. It is interesting to note that the secondary school Reform Program (MELS, 2005) here in Quebec, a competency-based system, follows Dewey's philosophy of learning by doing. Dewey believed that students learn best when they interact with the curriculum.

1.2 The Keller Plan

Fred Keller's Personalized System of Instruction was originally referred to as the Brasilia Plan and later as the Keller Plan (Keller, 1968). Keller was influenced by the works of Burrhus Frederic ("B. F.") Skinner (Skinner, 1955, 1984) and Benjamin Samuel Bloom (Krathwohl, 2002). The latter had employed principles of reinforcement and mastery learning methods in their own work.

In the late 1960s PSI was perfected with the help of J. Gilmour Sherman while he and Keller were teaching psychology at the University of Arizona (Sherman,1974).

The basic features of PSI that distinguish it from traditional teaching practices are:

1. A PSI course is broken up into units or modules. For example, the number of modules can correspond to the number of chapters from the course textbook. However, the department may decide to set up a certain number of modules (say 15 or 30, etc.) and use several textbooks as references. A detailed study guide acts as the written word for teacher-student communication with explicitly stated learning objectives.

2. Each module contains a number of mastery tests. Students must demonstrate mastery (for example, obtain at least 80% or more on a mastery Test) before proceeding to other modules. If the first mastery test is not completed successfully, then another must be taken and so on.

3. Self-pacing in a PSI course naturally follows from the mastery requirement. Students will hence proceed according to their abilities, interests, and personal schedules completing modules and working at their own pace.

4. A PSI course can be run totally outside the classroom with the students working on their own in various allocated study areas. In fact, lectures are not used for delivery of course content, but could be given for motivational reasons and may have no connection to the course material. For example, a motivational and “rewarding” lecture could be one on astronomy for students who are taking a mechanics course.

5. This does not mean that the student is left isolated in the course without personal interaction. On the contrary, there is extensive use of proctors and peers. The mastery tests are corrected and there is immediate feedback. Tutoring and personalized instruction are available if needed.

There is no doubt that PSI students will put more time and effort in a PSI course. The focus of a PSI course is very much on student learning by doing rather than teaching via direct material delivery from the front of the classroom. PSI puts the student in charge of his or her learning. In fact, superior performance was reported for most PSI courses given in the 1970s compared to conventional classroom teaching.

One of the many articles that reports on the superiority of PSI over the traditional classroom lecture-format is that of James A. Kulik, Kevin Carmichael and Chen-Lin Kulik (Kulik et al., 1974). In their article, "The Keller Plan in Science Teaching - An individually paced, student-tutored, and mastery-oriented instructional method is evaluated", five main points are brought forward. To quote directly from their article:

> " 1) The Keller plan is an attractive teaching method to most students. In every published report, students rate the Keller plan much more favorably than teaching by lecture.
>
> 2) Self-pacing and interaction with tutors seem to be the features of the Keller courses most favored by students.
>
> 3) Several investigators report higher-than-average withdrawal rates for their Keller sections. The conditions that influence withdrawal and procrastination in Keller courses have been studied, and it seems possible to control procrastination and withdrawal through course design.
>
> 4) Content learning (as measured by final examinations) is adequate in Keller courses. In the published studies, final examination performance in Keller sections always equals, and usually exceeds, performance in lecture sessions.
>
> 5) Students almost invariably report that they learn more in PSI than in lecture courses, and also nearly always report putting more time and effort into the Keller courses."

1.3 A Modernized PSI (MPSI)

The reform stresses learning outcomes and emphasizes the process leading to learning outcomes. It also promotes integration of learning and fosters the development of more complex intellectual problem-solving skills (MELS, 2005). In fact, it has been suggested "that when PSI is implemented correctly, it produces higher levels of achievement among students than the lecture-discussion format. Hence, PSI students may be more likely to develop the necessary knowledge base and problem-solving strategies. Research has demonstrated that students enrolled in PSI improved higher order cognitive skills" (Reboy et al., 1991).

PSI is an "instructional delivery system" and as such would not dictate course content. A competency-based structure would be easily accommodated by PSI. Also, the integration of several subjects can be easily made (e.g. Physics and Mathematics) through appropriate modules. To top it all, we would have extensive integration with technology as all of the modules and tests would be computer-based and online (Pear et al., 2002). Computer-based instruction makes for a more active learning experience by allowing students to receive ongoing feedback and evaluation of course content.

A modernized PSI for science instruction would establish a dynamic, student-centered, active learning teaching environment with well-defined learning objectives, activities and assessments. It would move the traditional classroom to one that is student-in-charge. "Numerous teaching methods, based on educational research, have demonstrated that greater student involvement in the classroom enhances learning. This research has demonstrated that students learn more if they are actively engaged with the material they are studying." (Paulson et al., 1998 – 1, 2)

1.4 Active Learning

In most educational institutions, there has been more focus on student "*Learning*" rather than "*Teaching*". As teachers, are we just passing on information to our students or are we addressing a deeper knowledge/skill acquisition? Since 2005 to date, the ACPQ Pedagogical Conferences have had themes addressing personal development, learning skills, motivation and desire to learn, responsibility and innovation in teaching.

Many of these research-based findings emphasize the need to change the traditional teacher-at-the-front of the class teaching methods to ones that ensure student participation in their learning, referred to as Active Learning.

Active Learning practices have attracted the attention of educators around the world. Since it was described by Bonwell and Eison (Bonwell et al., 1991) it has appeared in the form of Problem-based Learning, Project-based Learning, Peer Instruction, and many others. In essence, Active Learning is the assertion that learning is deeper and longer-lasting when learners cognitively engage with the matter being studied.

Put another way: students learn by doing and thinking about what they are doing. Active Learning environments have been devised and used with great success. For example, Eric Mazur, at Harvard, has been using Peer Instruction with clickers. His technique engages students to exchange ideas amongst themselves (Mazur, 1997) and enables him to address common difficulties that students have.

A conference at Dawson College in April 2012, entitled “Taking Active Learning to the Next Level”, was a source of learning about Peer Instruction and PhET sims (Schell et al., 2012). Using Active Learning Classrooms (ALC), where Smartboards and large oval desks are used for students to work cooperatively, promotes Active Learning to a very high degree. There is no “front” to an ALC room and the teacher is not the center of the classroom physically or pedagogically.

The Flipped-Classroom approach (Bennett et al., 2011) has received quite a bit of attention and has been shown to be effective in certain circumstances. In this approach, the students view the lecture at home via prepared videos in place of direct instruction. This then allows the students to work cooperatively in class and get individualized attention. The flipped classroom increases interaction and the students take responsibility for their learning. It is a classroom where the teacher is not the “sage on the stage” but the “guide on the side”. It is a blending of direct instruction with constructivist learning.

1.5 Research Objectives

The general objective of the present study is to investigate the past use of PSI at a time when it was a “breakthrough” strategy resulting in superior student learning but that later faded to oblivion. Then, in light of our modern technological advances, and keeping in mind our present pedagogical philosophies, present a method to revitalize it in Physics.

Here again we should keep in mind that PSI is an "instructional delivery system". Hence it would have the flexibility of accommodating changes if need be.

The specific objectives of the project are to address the present expectations of our educational system that would have to be supported by a PSI strategy. PSI supports a competency-based learning system. The modules would carefully identify the competencies to be achieved. The assessing criteria would also be stated explicitly and evaluation of each of the competencies specified would be included in the mastery tests. The self-pacing aspect of PSI would allow the students to progress through the course material at their own rate. Online work would give the student instant feedback of the competencies attained.

The present day classroom environment is still mostly "chalk and talk". PSI removes the need for a lecture-only classroom. It transforms the teaching/learning experience into one that is student-centered and student-in-charge. It would certainly be an "Active Learning" approach as many of the learning responsibilities are now transferred to the student. An Active Learning PSI classroom could have computers where mastery tests and online tutorials are given. Such a classroom can also be adopted for cooperative work. Finally, the students who are advanced can be mentors for those that are moving at a slower pace.

1.6 Methodology

Some CEGEPs used PSI in the 1970s and 1980s and their experiences will be discussed. This will give us an insight of what were the pros and cons of such a system in the past.

There are few users of PSI presently. One user is the University of Manitoba (Pear et al., 2002). Via private communication, Dr. Joseph J. Pear maintains that there has been no recent survey on the extent to which PSI is being used today. There is no longer much research being published on it, so it is difficult to tell how extensively it is being used. Several instructors at various institutions are using the Computer-Aided PSI (CAPSI) system that Dr. Pear and his associates have developed. However, CAPSI lacks mathematics calculation capabilities and cannot be used to solve Physics problems online for instant feedback that is needed in PSI.

A “Modernized” PSI (MPSI) will be presented based on the results and evaluations from actual teaching experience of a course taught at Marianopolis College in the 2012 Winter semester. The MasteringPhysics (Pearson) online system was used for the mastery tests. Several evaluations were undertaken that gave valuable feedback from the students to arrive at constructive conclusions.

1.7 Use of PSI in Quebec CEGEPs

A Modernized PSI (MPSI) could be an interesting alternative learning/teaching strategy for CEGEP science students. It is an “instructional delivery system” that successfully interfaces with the reform and competency-based education. It has all the aspects of “Active Learning” and “Student-based-Learning”. It utilizes the most up-to-date technology with computer-based resources and online databases. In fact, it is supported by most science textbooks that have eBook and online assignment-tutorial features. PSI would require more work on the teacher’s part the first time he or she taught the course, but it would certainly be worth the effort!

Chapter 2 The Use of PSI

2.1 PSI in the 1970s

This chapter addresses mostly the past use of PSI in physics with some mention of its use in other disciplines. Most PSI users were post-secondary institutions outside of Quebec. The use of PSI (the Keller Plan and morphed formats) was relatively rare in Quebec institutions in the 1970s and 1980s. Then, in the mid-80s, there was a dramatic decline in the use of PSI everywhere.

As it has already been mentioned in the introductory chapter, Keller together with Gilmour Sherman (Keller, 1974), perfected the PSI method while teaching Psychology at the University of Arizona. From there, PSI spread to other disciplines and to other universities (Sherman, 1974). Some of the universities in the USA that developed PSI courses were: MIT (Physics - Green, 1971), University of Nebraska-Lincoln (Physics - Fuller, 1975), University of Michigan (Physics - Austin and Gilbert, 1973), Barrington College (Chemistry - Leo, 1973) and University of Texas at Austin (Mechanical Engineering - Koen, 1970 and Library Science - Knightly, 1972).

The *PSI Newsletter*, published by the Center for Personalized Instruction (non-existent today), reported knowledge of 410 PSI courses in 1974 in several disciplines as shown in the table below.

Survey of PSI Courses Offered (Keller, 1974)

Psychology	157
Physics	53
Engineering	49
Mathematics & Statistics	49
Chemistry	31
Biology	21
Sociology	16
English	11
Other	23
Total	410

2.2 Use of PSI in Physics (outside Quebec)

As can be seen from the table above, Physics was the largest user of PSI in the physical sciences and second only to Psychology in overall use. The work of Ben A. Green, Jr. who developed the Keller Plan at MIT (Green, 1971) caught the interest of one of the teachers at Collège Jean-de-Brébeuf (Maillé, 1972 – 1, 2) and her experience was the first recorded use of PSI in a Quebec CEGEP.

The most complete set of physics modules was created at the Calculus-Based Physics (CBP) Workshop held at the University of Nebraska-Lincoln in 1975 under the leadership of Robert G. Fuller. This work covers Classical Mechanics, Electricity & Magnetism as well as Thermodynamics and Optics (Fuller, 1975 – 1, 2). These modules were used in a PSI course that was developed at Marianopolis College in the early 1980s by myself and given to a small group of highly motivated students. Fuller maintained a keen interest in PSI over the years (Fuller, 2005) after its decline. He had strongly supported its revival right up to his untimely death in 2012. I had the opportunity to exchange several emails with him in 2011, when he informed me that the 1975 work had been digitally redone and available to the public without cost:

"Dear Rocco,

Last summer we had some summer interns scan the 1100 pages of the Keller Plan CBP modules that were created by the NSF funded workshop and they are now on the UNL physics digital commons website as pdf files.

http://digitalcommons.unl.edu/physicsinstructional/

They are individual files so you can select the ones you want. They were keyed to five different physics textbooks of 1975. The files include the mastery tests and grading keys.

http://digitalcommons.unl.edu/calculusbasedphysics/

I also added the articles about PSI we had written at UNL.

http://digitalcommons.unl.edu/physicspsikeller/

Cheers,

Robert Fuller
Professor Emeritus"

In his honor, and to demonstrate the high quality of this work, I have included one of the study guides (Newton's Laws) with some mastery tests in Appendix I.

2.3 Use of PSI in Physics (Quebec CEGEPs)

A thorough search of the use of PSI in Quebec CEGEPs, in the 1970s and 1980s, revealed that only a few institutions were significant users of this method of student learning. Obtaining information even from these institutions was quite difficult as many of the professors that were involved with PSI have by now retired and are no longer connected to the institutions. Most teachers today that are in physics departments where PSI was used decades ago are not aware of the PSI format. In fact, very little if any material was stored on computers in the 1970s and 1980s and much of the paperwork has been destroyed. Since little was done as "educational research" at that time, very few publications exist.

The CEGEPs that used PSI in the 1970s and 1980s are Collège André-Grasset, Vanier College, Collège Jean-de-Brébeuf and Marianopolis College. Of these four colleges only two used it extensively over a significant number of years.

2.3.1 Collège Jean-de-Brébeuf

In the summer of 1971, Gabrielle Maillé (Maillé,1972 – 1, 2), thanks to an NSF (National Science Foundation) grant, attended a two-week AAPT workshop on the Keller Plan at MIT. Development of the Keller Plan was due largely to Ben A. Green, Jr. at the Education Research Center (ERC) at MIT (Green, 1971). From this experience, Maillé applied the Keller Plan to her own physics teaching at Collège Jean-de-Brébeuf. In her article (Maillé,1972 – 1, 2), she describes the Keller Plan in detail and reports very favorable results. The students' feedback was that this method allows for better comprehension of the subject matter and better retention. It was also well received by the administration, noting that it was not more expensive to run versus a conventional course. However, since that date, there has been no follow up on the Keller Plan at Brébeuf nor has there been any mention of its usage beyond this singular session.

The Keller Plan was also given a positive review in an article “Évaluation de renseignement des sciences au secondaire en fonction des objectifs généraux et particuliers de cet enseignement” (Ste-Marie, 1981): “Des efforts ont été tentés pour améliorer l'enseignement des sciences. Une méthode d'enseignement, la méthode Keller, axée sur la personne et le travail individual soutenu par des pairs agissant comme tuteurs, a été utilisée dans le but d'aider la croissance personnelle de l'étudiant. Cette méthode a été utilisée surtout en physique au niveau du début du collégial. On avait découvert que les étudiants des options en sciences étaient moins avancés dans la réalisation de soi, l'acceptation de ce qu'ils sont, la conscience de leur potentiel, l'épanouissement de leur personnalité que les étudiants en arts et les étudiants en sciences humaines.

L'application de cette méthode d'enseignement a permis aux étudiants de science de rejoindre les étudiants en sciences humaines dans la prise de conscience de leurs valeurs et de leur potentiel. Cette méthode demande un travail plus intensif de la part de l'élève; mais en consacrant moins de temps à l'étude, ce dernier arrive à des résultats meilleurs que les élèves des cours à présentation traditionnelle. Enfin, cette méthode engendre une atmosphère agréable de travail et procure beaucoup de satisfaction à l'élève. Il convient encore de noter que c'est la méthodologie de présentation qui est responsable de ces heureux effets.

On a pratiqué en science l'enseignement par objectifs. Le nombre et la fréquence des évaluations des objectifs, à la longue, ennuient les élèves, et cet effet se reflète sur le cours entier. L'enseignement par objectifs ne réussit pas à enrayer la perte de faveur des cours de science.

L'enseignement individualisé demande souvent à l'étudiant de lire beaucoup : fiches de travail, guides d'activités, plans d'études qui s'ajoutent aux manuels de référence. Or il est reconnu que nos élèves ne savent pas lire. Cette technique ne fournirait-elle pas une occasion, par la pratique, d'améliorer la compréhension de lecture des élèves? Il ne semble pas que ce soit le cas. Les seuls points où il y a eu amélioration sont l'évaluation, l'interprétation et l'inférence, habiletés très reliées et qui sont celles que veut developer la science et de plus sont des habiletés qui se développent normalement chez les élèves du secondaire au cours des années."

2.3.2 Collège André-Grasset

The Keller Plan was used at Collège André-Grasset from 1972 to 1989. I have had the opportunity to talk to several retired professors who taught at the college over that period of time. At an initial meeting in the fall of 2011, I met with André Blais and Tomasso Donato, both very much involved in teaching physics using the Keller Plan (le méthode Keller). More recently, I met with Roland Simard who had a more active role directing the program at the college. I have also met with Alain Léger who now teaches at Marianopolis College and was a student at Collège André-Grasset where he took all his CEGEP physics courses using the Keller Plan.

Their recall of that time period was with mixed feelings of the Keller Plan, noting both advantages and disadvantages. The following is a summary of their input.

« Système d'enseignement personnalisé (méthode Keller) au département de physique du Collège André-Grasset 1972 à 1989 (Simard, 2012).

Nous nous sommes inspirés du professeur Fred S. Keller (Keller, 1968) du département de psychologie de l'Université Columbia; il avait mis au point une méthode d'enseignement qui supprimait les cours magistraux. Les étudiants devaient étudier par eux-mêmes, avec de l'aide individuelle du prof, d'un tuteur et du matériel qu'on mettait à leur disposition; ils devaient réussir des tests échelonnés dans la session pour démontrer leur maîtrise du sujet. Nous avons consulté Mme Gabrielle Maillé qui avait expérimenté cette méthode d'enseignement en physique au Collège Brébeuf; en 1971 elle avait suivi un stage auprès de Ben Green du MIT.

Le cours de physique était divisé en modules ou unités, chacun correspondant en général à un chapitre du manuel. Pour chaque module, nous présentions le contenu, les objectifs d'apprentissage (3 ou 4), un guide d'étude, et nous rédigions des tests (4 ou 5) que les étudiants devaient réussir au moment de leur choix (durant les périodes de cours), lorsqu'ils croyaient maîtriser la matière du module. Il n’y avait pas de pénalité rattachée à l’échec à un test, mais l’étudiant devait reprendre un autre test du module jusqu’à ce qu’il réussisse.

Pour éviter que le professeur ne soit continuellement accaparé par la correction des tests, nous choisissions parmi les meilleurs étudiants en physique les quatre que nous considérions les plus aptes dans des groupes d’au plus 32 étudiants et les nommions tuteurs (équivalents des *proctors*). Leur tâche consistait à réussir les tests avant les autres (ils devaient se présenter en dehors des périodes du cours pour passer les tests); durant les périodes de cours, ils corrigeaient les tests à l’aide de guides que nous avions rédigés. Ils devaient passer les examens périodiques comme tous les autres, mais étaient exemptés de l’examen final, s’ils avaient accompli leurs tâches correctement et maintenu une moyenne minimale de 80% dans les examens et les travaux de laboratoire.

Pour avoir le droit de se présenter à l’examen final, tous les étudiants devaient avoir réussi les tests de maîtrise d’au moins 80% des modules du cours.

Avantages de la méthode.

1. En principe, les étudiants développent leur autonomie en étant responsables de leur apprentissage; en outre, ils savent à tout moment quelle fraction du cours ils ont maîtrisé.

2. Les étudiants peuvent consulter les tuteurs ou le professeur et bénéficient d’explications précises et personnelles sur ce qui leur cause problème.

3. Nous avons montré clairement que la réussite dans ces groupes était supérieure de façon significative à la réussite dans des groupes de contrôle.

4. Nous avons montré que le temps d’étude, malgré l’impression des étudiants, était inférieur dans les groupes de l’enseignement personnalisé.

5. Nous avons montré que la satisfaction y était significativement supérieure à celle obtenue dans les groupes de contrôle.

Désavantages de la méthode.

1. Certains étudiants sont insécurisés par ce qu'ils voient comme un manque par rapport à l'encadrement relié au cours magistral.

2. Plusieurs considèrent qu'il leur faut bien plus de temps pour comprendre par eux-mêmes certains sujets plus difficiles ou abstraits, et qu'ils prendraient moins de temps dans un cours magistral.

3. Durant les périodes de cours, le prof ne peut être disponible à tous en même temps.

4. Il se produit des périodes aigues de pointe vers la fin d'une session, car il y a toujours des étudiants en retard qui risquent de ne pas pouvoir se présenter à l'examen final. Ces retardataires mettent parfois une pression indue sur le tuteur (et le professeur).

5. Les tuteurs ne sont pas nécessairement de bons pédagogues. Certains sont arrogants. Parfois ils font des erreurs, car ils n'ont pas le bagage du prof. Malgré tout, la majorité d'entre eux effectuaient un bon travail. »

(Principaux professeurs impliqués : André Blais, René Cossette, Roland Simard, Tomasso Donato, Benoît Villeneuve)

2.3.3 Vanier College

Over the period from 1973 to 1986, Vanier College offered a program known as the Modularized Integrative Science Project (MISP) that applied to physics, math and chemistry. It was not based on the Keller Plan but was very much PSI in nature. Modules were prepared for both PHY 102 (Health Science and Technology) and PHY 101 (Pure and Applied Science). Although intended for students of all abilities, the reality was that only students with some ability and motivation were successful. Only one section was offered most years based on student demand.

I had the pleasure of interviewing Don Hetherington (Hetherington, 2011), Dean of Science at Vanier College (retired), who was instrumental in developing the study modules for the MISP program. Part of a calculus-based module is included in Appendix II. The MISP program philosophy was based on the premise that "most of the time spent sitting in a large room listening to a teacher is time wasted, whereas the time spent struggling for the answers to questions and problems and discussing them with your friends and teacher is the time when the most meaningful learning takes place. Thus the amount of time spent in large classes has been minimized (eliminated for all but those who want it) and more time is devoted to working on your own or in smaller groups…regular séances, where you sit at the feet of the grand master and sleep, have been eliminated…." (taken from "Introduction and Orientation" to the PHY 102, 1974 modules).

Hetherington goes on to point out that "the organization is also based on the fact that not all students learn at the same rate or in the same manner. Therefore, the course is organized so that each of you can progress at your own pace using the methods which you prefer…"Thinker's Problems" have to be done as well as mastery quizzes before going on to another module."

Deadlines were imposed as well for the completion of the modules and quizzes. The main incentive for further assessments was extra marks. Hence, a C grade would be obtained if all the modules were completed successfully. The passing of a final exam entitled the student to a B grade. An A in the course could be had if extra, advanced problems were successfully done.

2.3.4 Marianopolis College

In the early stages of my teaching career (1970s), I became interested in PSI mainly to address the needs of advanced-standing students. As today, we had to deal with classes that consisted of students at different levels of academic standing. Some of these students were very high achievers and others not so. So the question I asked myself: was there an instructional mode that would address the needs of the high achievers?

After some research, I came across Professor Robert G. Fuller's PSI system of study guides and mastery tests (Fuller, 1975 – 1, 2). I designed a calculus-based PSI physics course at Marianopolis College for a selected group of students that were very motivated to try this new method of instruction. The students recognized that they would have more responsibility for their learning with this system of instruction.

I held a traditional Physics class with lectures, assignments, tutorials, labs, office meetings, term tests and a common final exam. The select group of students enrolled within the normal group and at the same time had agreed to participate in my PSI project. In effect it became an independent study group.

The select group was welcome to attend some of the class lectures with the rest of the students if they wanted to. So they were informed of the class times and tutorial session times. I also kept them informed of what was being covered in the class lectures. They all had to do the prescribed labs as well as the term tests and final exam just as the other students did. Hence, there were "deadlines" that they had to meet in terms of covering specific material. Some came to the tutorial sessions and participated in group work. Others worked totally on their own relying mostly on the Fuller study guides. These guides had clear objectives and performance criteria that led the students to specific text references and explanations. When a student felt that he or she had learnt the material, the student then attempted a mastery test which I would administer from my office. A "failed" test (less than 80%) meant a re-take until the appropriate "passing" grade was obtained.

They greatly enjoyed the PSI format and, needless to say, all did very well. Several students completed the course before the end of the term and so had time to concentrate on other courses. One of the students decided to do all the mastery tests for practice! At the end of term she submitted a thorough critique (very positive) of the PSI method that we had used.

However, this was the end of my PSI experience as the college was not prepared to offer PSI for regular class groups.

2.4 The Decline of PSI

In one of my email discussions with the late Professor Fuller last year (2011), he was able to summarize the reason for the decline of PSI in Physics as follows:
"As far as I know the Keller Plan, or PSI, has almost completely disappeared in physics. There was too much work and too little reward for faculty."

Many others have also speculated on the reasons for the decline of PSI. A more recent report on PSI by Charles H. Roth at the University of Texas at Austin (Roth, 1998) makes the following points (taken directly from his article):

"**1** - Production of high-quality, well-designed instructional materials is important for the success of a PSI course since the course relies primarily on written materials. This initially requires a large amount of instructor time, but in the long run, operation of a large self-paced course can reduce the faculty time required per student.

2 - Many administrative and logistic problems can occur. Recruitment and training of proctors is a big issue, especially if adequate funding to pay proctors is not available. Suitable facilities for testing, grading, tutoring, and studying must be provided. The administration and other faculty are sometimes suspicious of a course that produces too many A's.

3 - Procrastination can be a problem if a large number of students come in to take unit tests near the end of the course. It is particularly a problem for students who are overloaded, and we often counsel such students to drop the course and take it when they have a less demanding schedule. We give students who finish the course early an opportunity to take the final exam early, and then repeat the final if they are not satisfied with the first score. This motivates many students to progress faster in the course.

4 - There is a tendency for some instructors to modify the PSI method. Some students want deadlines, so the first thing to go is often self-pacing. You can't have rigid deadlines and demand mastery, so mastery is next to go. Then tests are given at scheduled times and graded off-line, so the personalized element is gone. What is left bears little resemblance to the original Keller plan. And then the instructors wonder why student achievement is less than expected."

It is, therefore, clear that one must overcome the possible obstacles outlined above to run a proper PSI course. My proposal (next chapter) of a "Modernized" PSI (MPSI) suggests some significant modifications to the original features of the Keller Plan. As such I expect criticism from those that maintain a "real" PSI course must be one based rigidly on the original Keller Plan principles. The evaluations obtained from a MPSI NYA physics course given in the Winter of 2012 suggest that some alterations to the Keller Plan can be made and still retain a PSI structure that can satisfy administrative concerns while at the same time ensure student learning and success.

2.5 Use of PSI in Other Disciplines

Throughout the literature there are several publications that describe the use of PSI in disciplines other than Physics. All report positive results when comparing the PSI format compared to the traditional lecture delivery system. If not superior, it is reported to be at least equivalent in terms of learning outcomes. Most of these PSI users have adopted a modified format relative to the original Keller Plan with computer-aided platforms or are Web-based.

M U S I C ~ Joseph Jumpeter (Jumpeter, 1985), at Pennsylvania State University, conducted a study to determine whether PSI would have a different effect on student achievement compared to the traditional lecture method in teaching a music appreciation course. His study was based on the premise that since researchers had found PSI to be more effective in scientific disciplines then this method might be effective in teaching a music appreciation course. More specifically, the study was designed to determine whether PSI would have a different effect on the results of a factual knowledge and listening test compared to the lecture format and whether the students themselves had different opinions about the two methods through students' evaluations of PSI. A pre-test and post-test were administered as part of the evaluation. The results indicated that (a) PSI was an "above average" method of instruction (b) final exam results were not different (neither was superior) (c) some students had difficulty coping with self-pacing and (d) opinions for different music increased due to more learning and understanding about the different types of music. It was also noted that since courses have the time restriction of a term or semester, self-pacing needs to be altered, much along the lines of my own findings.

M A T H E M A T I C S ~ Willem-Paul Brinkman, Andrew Rae and Yogesh Kumar Dwivedi (Brinkman et al., 2009) have conducted a study of a university course in discrete mathematics using an online learning environment (OLE). A "modified" PSI structure permitted the students to use the OLE platform. The experimental group (170 students) was examined with respect to students' attitude, learning strategy and academic achievement over a period of two years and compared to that of a more traditionally taught course. Their conclusion was that PSI can be used to enhance both student appreciation and achievement in a course that is supported by an OLE. It seems that self-pacing was for some quite frustrating when mastery tests took longer than usual and a student wanted to move on to the next unit. However, the online feature for testing was found to be "great…and helps me to learn and prepare for the exam…".

P S Y C H O L O G Y ~ It is interesting to note that PSI was originally used in the teaching of psychology (Keller, 1974) and the largest number of psychology courses (157) were taught using the PSI format in USA universities in 1974. Today a modernized PSI for that discipline is in place at the University of Manitoba. Due to Joseph J. Pear and his colleagues (Pear et al., 2002), PSI was computerized to relieve the administrative burden of using PSI, one of the main reasons it died out in the 1980s. Computer-aided PSI (CAPSI) can store tests with answers and therefore can give quick feedback in a course. Other members of his team have studied the relationship between student engagement, higher order thinking, and learning in both online and hybrid communities. This work has been done at the University of Manitoba and at Delta State University in Mississippi. CAPSI applications have now become Web-based and WebCAPSI is used to teach a variety of subjects such as behavior modification, history and systems of psychology, educational psychology, learning, psychological statistics, research methods, sport psychology, the basics of writing, and APA style. Lack of a math editor, however, would not make WebCAPSI a practical OLE platform for physics.

Chapter 3 A Modernized PSI (MPSI)

used in CEGEP Physics NYA (Mechanics)

3.1 MasteringPhysics Online Assignments

In the winter of 2005, I was called upon to teach Mechanics to the first student cohort of the newly established Arts and Science program at Marianopolis College. Also, that same term, I had volunteered to teach the single section of the enriched Electricity and Magnetism class. I wanted to do something "different and special" for these groups. The Arts and Science program attracts students that love to explore and discuss and even though their workload can be very demanding many of them do very well overall. "Enriched" physics usually means that it is a calculus-based course and more challenging than the "regular" course and attracts the high achievers. As long as the main common content is covered, it is usually left up to the teacher to decide how best to run these classes, taking into account the students backgrounds, interests and their needs.

Applying technology to teaching was very much being encouraged at that time, so I decided to try a new technological aspect to both courses at the same time satisfying course content and level requirements. I had reviewed the textbook by Randall D. Knight (Knight, 2013) and I liked it a lot. It supports physics education research and active learning (Knight, 2004). As far as level was concerned, it catered to both a non-calculus based course as well as a calculus based one that could be usually available for the high achievers (such as an enriched physics course). Well laid out and easy to read, it offered students a plethora of preparation resources and a wide variety of exercises: conceptual questions, short exercises and problems at all levels including the more challenging ones. But what caught my curiosity the most was the sealed leaflet that came with the book and contained an access code to "MasteringPhysics". At the back of the leaflet was a description of MasteringPhysics with a note that "…it is the most widely used and educationally proven physics homework, tutorial, and assessment system available." So this was it, we were going to use an online system to do the assignments!

The only problem was that the students already had a textbook and it would be unfair to make them purchase another one at considerable cost. So I contacted the Pearson representative and explained the situation. They were more than willing to give the students (in both classes) free copies, of the respective volumes, with the condition that they do a survey for them (a textbook evaluation) at the end of the term. It was a win-win situation for all of us and eventually the Physics department decided to adopt Knight in 2009.

The full details of using MasteringPhysics (MP) are clearly explained on the internet site at www.masteringphysics.com. My experiences with those two groups using MasteringPhysics were reported at an ACPQ pedagogical workshop entitled "Another Way" (Iafigliola, R., 2005). Ever since the textbook was adopted I have continued to use MP for assignments. The complete weekly assignment work also includes a written hand-in component made up of some end-of-chapter problems. This way writing skills are maintained. When the students do online work it is corrected by the system thus giving them instant feedback specific to wrong answers and provides simpler sub-problems when they get stuck as well as partial credit. Some of the online work is for practice and some is considered for the assignment grade. As will be explained later, additional features of MP have been utilized to produce the Mastery Tests essential for PSI. Inherently this system also allows for self-pacing which is another important aspect of PSI.

3.2 Technology and Active Learning

Over the years, after my first experience with MP, the hot topics (that got hotter and hotter and are sizzling today!) were the application of Technology to teaching practices and Active Learning. The Keller Plan (PSI) came to mind and connections to Active Learning as well as applications to technology started to form. That short PSI experience many years back was still very close to my heart!

Active Learning has attracted the attention of educators around the world. Since it was described by Bonwell and Eison (1991) it has appeared in the form of Peer Instruction, the Flipped classroom, and many others. In essence, Active Learning is when students engage (doing and thinking) with the matter being studied rather than just passively listening to lectures.

Peer Instruction (PI) using Clickers, also referred to as Classroom Response Systems (CRS) and Classroom Performance Systems (CPS) (Duncan, 2005; Broida, 2007), has had and continues to have many dedicated followers thanks to the work that was initiated by Eric Mazur (Mazur, 1997) at Harvard. Crouch and Mazur (Crouch et al., 2001), demonstrate that PI greatly improved students' learning, presenting results over ten years of experience at Harvard.

Through the use of the Force Concept Inventory (Hestenes et al., 1992) as well as the Mechanics Baseline Test (Hestenes et al., 1992) as pre- and post-tests, they were able to compare the traditional lecture class results with those using PI. Without doubt, the scores for classes using PI were superior to those of the traditional class format.

Dr. Mazur also utilizes Just-in-Time Teaching or JiTT for short (Novak et al., 1999) where lectures are student-driven by pre-lecture questions and exercises that the professor receives before the lecture. Hence, lectures are interactive reflecting student input as to what they do and don't understand.

Another Active Learning practice that has been introduced in many guises is the Flipped-Classroom (Bennett, 2011). The original flipped-classroom system had students watch videos of lectures at home rather than listen to them in a classroom. This then allowed the students to use their class time to work cooperatively as well as get individualized attention. The flipped approach increases interaction and gives the students more responsibility for their own learning. So "the sage at the front of the stage becomes the guide on the side".

The role of Active Learning can also be extended to online computer-assisted platforms. A very effective system has been developed by Dr. Joseph Pear (Pear et al., 2002) at the University of Manitoba. It is based on the Keller Plan (PSI) and is called the Computer-Aided Personalized System of Instruction or CAPSI for short. It is used mostly for psychology courses; CAPSI can be adapted to other courses as well. In fact, I had considered adapting CAPSI for my research. However, it does not have a math editor with interactive physics problem-solution capabilities and instantaneous online feedback would not be possible.

All these Active Learning practices have one major common objective: to focus on student *LEARNING* by reducing face-to-face interaction with the teacher at the front of the classroom (passive listening via transmission of content) and thus encourage the student to take charge of his/her learning (active learning by doing).

3.3 Active and Personalized Learning

Let's go one step further. As teachers we are asked to recognize the educational institution as student-centered and to take into account the different needs of the students. Slow learners may need help. In the CEGEP system today, Learning Centers are staffed by counselors that monitor students' progress and, with the teacher, will determine if additional help is needed. Free Peer Tutoring is available if, despite working as much as possible, a student is failing term tests.

Also, more and more, attention is given to special-needs students. Students who have ADD, ADHD or are autistic may have difficulty following a normal class or doing tests with allotted time periods. In this case time accommodations may have to be made. In extreme cases an autistic student may need a note taker during class.

Advanced and special program students, such as those in Arts & Science and Science & Music, may benefit from being exposed to different or advanced material in a course. Special topics may be beneficial to these students and for those that have taken calculus, challenging problems may be welcomed.

Hence we can ask: Would a "personalized" teaching environment make sense within our educational system today to address the different needs of the students and promote active learning at the same time? Can the Keller Plan be "modernized" to meet these needs? Could present technological resources help make this happen?

The PSI model supports a competency-based system (Reid, 2004). Study modules clearly state objectives, required competencies and mode of achievement as has been discussed in Chapter 2. Self-pacing could address special needs students as well as advanced students within an Active Learning, student-in-charge environment with less lecturing and more student-directed activities.

3.4 A Modernized PSI (MPSI)

Several obstacles, as indicated in Chapter 2, led to the decline of PSI in the mid-1980s. However, if one compares what was done in PSI courses in the 1970s and 1980s and the Active Learning activities undertaken today, it is quite clear that PSI offers an excellent Active Learning platform. Can there be a comeback? How can it be “modernized”? How can we re-apply Keller’s five-step plan to avoid the pitfalls of the original method that led to its decline?

Mark Cracolice and Vicki Roth (Cracolice et al., 1996) wrote: “What would you do if you discovered an instructional strategy that raised the scores of your students from the 50th percentile to the 70th percentile? What if that strategy required more work on your part the first time you taught the course? Would it be worth the effort? Such a strategy has been known for more than 25 years, yet it is virtually ignored (referring to PSI).”

Lyle K. Grant and Robert E. Spencer (Grant et al., 2003) wrote: “What if students also liked this teaching method more than lectures? What if the strategy meshed well with computer-based learning, online learning, and distance education?”

My present research supports much of what the authors quoted above believe: that a revival of PSI could be an important educational platform, student-centered and technological. A “Modernized” PSI would have several features that would not have been available in the 1970s and 1980s. First and foremost is the use of the computer. The large amount of paperwork is effectively eliminated with the mass storage capabilities of today’s desktop and laptop computers, not to mention the small new versatile tablets such as the iPad.

The second most important is the mode of communication. The internet today allows us to not only communicate, such as with email, but also to work online, exchanging massive amounts of information in the form of Word and pdf documents. In addition, we can link to institution specific services such as Skytech’s Omnivox (LEA and MIO) system. Numerous course related documents such as study guides, power point presentations and assignments can be uploaded and available online.

Finally, mastery testing could be achieved using online platforms that exist today in various forms and for different disciplines. For example CAPSI (Pear et al., 2002) is an extremely versatile online platform that is used for disciplines such as psychology and English. It could also be adapted to the sciences (e.g. biology). However, as was mentioned earlier, its drawback is that it does not have a math editor that is necessary if one wishes to use it in a math or physics PSI course. It is not capable of allowing students to do problems that are then corrected by the system for immediate feedback. MasteringPhysics can do this.

So my design of a Modernized PSI (MPSI) has included all of the latest online resources available to the students. These resources are textbook specific and allow for easy referencing to course material and problem solving.

In addition to the research done to establish whether PSI can be revived or not in physics, study guides were also produced for a mechanics NYA physics course that was given in the Winter 2012 term. The mastery tests were administered via the online MasteringPhysics system.

As will be seen in the next chapter, from the students' evaluations, this course was a success both from the students' point of view and my own. On the very first day of class, the students were asked to form teams of three. Since there were twenty-five students in the class, one of the teams had four students. Remarkably, the team members so enjoyed each other's company that not only did they stay together for the cooperative sessions throughout the duration of the term, but some teams gave themselves names (e.g. the Gear Group)! In the lab sessions they also maintained their established team formations. This was remarkable since *the students did not know initially they would be in a PSI class!*

The following sections present the details of my MPSI "experimental" class. I have used the headings of the original Keller Plan features with the modernized changes.

3.4.1 Written word for teacher-student communication

Throughout the course, the students were able to use several electronic "real time" communication channels in addition to the teacher office-hours that were made available to them. The Skytech based Omnivox (LEA and MIO) college system was heavily used for student-teacher as well as student-student communications.

Since the PSI experimental class represented one section out of the ten physics NYA classes, the common Course Outline had to be modified and made more detailed to include optional and advanced topics as well as Module Completion Dates (MCD). The MCD are explained later. Both the common Course Outline and the MPSI Course Content were made available to the students via LEA. The MPSI Physics NYA Course Content is found throughout the study modules in Appendix III.

The complete laboratory manual was also uploaded to LEA. Pre-labs, when needed, were uploaded to the Assignments section of LEA. A pre-lab was due the day before the respective lab had to be done. It could be submitted as a hard copy to me personally (at my office) or it could be sent electronically to the LEA assignment Dropbox. In fact, during the term many assignments were sent electronically either to the Dropbox or as an attachment (Word, pdf, etc.) via MIO.

Power Point lectures with Peer Instruction clicker questions were also uploaded to the Documents section of LEA. Often, when a Power Point lecture was used in class, students could view the Power Point from their laptops making it unnecessary to spend time taking notes but paying attention to the explanations given. Peer Instruction questions were available for each chapter. All the Power Points used in the course, and many other resources, were made available from the two Media Manager CD-ROMs that were provided by Pearson Education and based on Knight (2008).

The students greatly appreciated the Reviews section in LEA where pre-term test review banks were uploaded. All cooperative session problem sets were also uploaded to LEA for students to view before the sessions took place.

In fact, all course material uploads were done before class so that students could go through them and prepare themselves before the upcoming class session (which could have been a lecture, PI session or cooperative work period). Often, students would send me a MIO asking for clarification of a concept in a pre-lab or in an assignment. Either I would respond quickly to the MIO or, if I felt others would benefit from it, bring it up in the following class or cooperative session.

A student-teacher forum was also available on LEA. Although the students were encouraged to use it for discussions amongst the teams, it was rarely used. Nevertheless, the communication aspect of the course received the highest rating in my students' survey that will be discussed later and shown in detail in Appendix IV.

MIO message response time was very quick. A MIO message sent via Omnivox would create an alert in my college Outlook email inbox as "Omnivox – you have received a new message from (student name)". Simultaneously I would also receive an alert on my smartphone of the Outlook email and hence the Omnivox message details could be seen. Hence, it was possible for me to get back to the student in as short a time delay as possible whether I was sitting in front of my computer or in the bus!

Another very important PSI component is the module study guide. The NYA course material was put together as 12 modules, corresponding to the first 12 Chapters of Knight. For each module, a Study Guide was created. To keep the Knight "spirit" throughout, extensive use of the Instructor Guides was made. Considerable time was spent to carefully transform them into Student Study Guides. The Instructor Guides are found in the Pearson Education Media Manager CD-ROM. A Study Guide contains an introduction, short exercises and tables for prerequisites, objectives, course content and problem-solving resources. All 12 Study Guides are found in Appendix III. However, unlike earlier textbooks, the Knight textbook is set up in a way that allows the student to find the Study Guide information quite easily without need for extensive additional help. This was the main reason for keeping the Study Guides as short as possible.

The Study Guides were uploaded to both LEA, in their respective section, as well as to the "Manage Documents" area on the MasteringPhysics home page.

3.4.2 Lectures and Demonstrations

In Keller's original PSI, lectures were not meant for delivery of course content but for motivational purposes. However, in my MPSI format lecturing does take place. There are several reasons for this. First and foremost it was one of the conditions of the department since I was teaching one class in a multi-section course.

Second, the students were not initially aware of the PSI nature of the course. It was decided at registration that my course section fill up in a “normal” way and then I would announce on the first day of class the “special” teaching method I would be using in this course. So the students did expect class presentations of the course material and especially some of the more difficult concepts. As I soon realized, my MPSI would resemble more the Vanier model rather than the original Keller Plan.

The two-lecture teaching week became a one-lecture (75 min) teaching session with the second lecture replaced by a cooperative working session that was held in the same classroom. In these sessions the students worked in teams. Some exercises (conceptual and problem-based) were prepared before the session and uploaded to LEA in the Cooperative Sessions section. Sometimes this session took a different route as students were also encouraged to ask questions and present common difficulties. Peer Instruction (using clickers) was also part of these group discussions and interesting demonstrations found a comfortable and relaxed audience that enthusiastically participated. Those students who were well ahead could choose to not have to come to the class lectures or the cooperative sessions. Seven 2-hour experimental labs were held in the term. When there was no experimental lab, the room was used mostly for cooperative work and for pre-test reviews or tutorials.

3.4.3 Use of proctors and peers

In the cooperative sessions students worked in teams of three or four doing exercises, participating in Peer Instruction using Clickers and participating in demonstrations. To ensure a personalized student experience, a student assistant who had taken the course the previous term, as well as myself, were available for consultation. I handled all the Peer Instruction sessions. Those that got ahead moved on to other chapters or worked on an upcoming module or assignment. A few skipped the session to study other subjects. Several students asked for and completed enriched problems (calculus-based). However, there were a significant number of students that had gotten ahead but decided to come to the session anyway and ended up helping their teammates who had slowed down somewhat. I always made sure that the priority was given to the slower students (or teams). Often I would ask my assistant before the class started to pay special attention to a particular student or team that had fallen behind.

3.4.4 Mastery

One of the most important features of PSI is unit mastery. A student must demonstrate that he or she has mastered a particular unit (module) before moving on to the next unit. In my case a unit represented a chapter in the Knight textbook. Roughly, about a chapter per week was covered (for some chapters we needed a bit more time and for other chapters a bit less time). The students were encouraged to read the chapter as well as the associated study guide for that chapter before coming to the lecture. During the week they were expected to do the practice exercises in MasteringPhysics (MP) that included end-of-chapter problems, true-false questions, conceptual questions, possibly some PheT animations (Physics Education Technology) and video tutorials. In addition, students were asked to submit a hand-in assignment per week. Once students felt that they had done sufficient work to achieve “mastery” of the module, then a mastery test could be requested. The request for a particular mastery test would be sent to me via a MIO message. I would then asap assign the test, on MasteringPhysics, to one or more students depending on the requests received.

How exactly is a mastery test processed in MP?

Initially, students are given a MP course ID which is then used to enter the MP course. As they sign in, the class roster gets populated with student names until the class is filled up.

I had the privilege of getting considerable help from the Pearson group to set up and use the “Assign-by-Group” feature that is available in MP, for the mastery tests. The tests were found under the assignment category with the “test” labels on them (e.g. Mastery Test 1 or Module 1 Test, etc.) and had a grade value on 10 (as opposed to the practice assignment problems that had no grade value). They were on average about 20 to 30 minutes long and contained conceptual and T/F questions as well as long multi-step problems. Students had to obtain a score of 8/10 or higher to demonstrate mastery and move on to the next unit (chapter).

View and due dates were initially assigned so that none of the tests was available to the students. The class roster contained the group names corresponding to the different mastery tests. When a student requested a mastery test, the test group name would be entered from a drop down menu and the student would “see” the test for a specified time period which could be adjusted. In other words, specific tests for the different chapters or modules were to only be available to students in a particular group. There also existed the option of re-setting the same test or deleting it and add a new one up to the due date/time. After the due date/time the system would no longer accept any more changes from the student and the grade for that test became final.

Students were free to do the tests anywhere within the prescribed time period before the due date/time. One can question how this could ever be a “test” if a student is not supervised. The following factors were taken into consideration:

1) A new online mastery test format was being tested and so stringent test conditions were overlooked to make the students feel at ease and avoid anxieties that are usually associated with “testing”. I also wanted to give the students the liberty of doing the tests when they were ready which often meant at night or during weekends.

2) The test grades were actually part of the overall assignment mark (2.5%) and, therefore, assignment conditions prevailed. It was made clear to the students at the beginning of the course that even though the total grade assigned to the mastery tests was not that significant, the learning process was.

3) In my MPSI proposal I have considered the mastery tests to be more of “mastery assessment guides” rather than real “tests” as the Keller Plan maintains. The students in the class are formally assessed through two term tests and a common final exam.

Yet, the students took their mastery tests seriously and kept me quite busy assigning them! The pace at which they worked enabled me to see who was doing well and who was not. The fast-paced students worked on enriched problems as well, earning them bonus points on the term tests. The slow ones were given extra help during the cooperative sessions.

However, if an instructor were to decide to give the mastery tests considerably more weight (e.g. 25% of the overall course grade) then it would make sense to have the students properly supervised while taking these tests. In today's colleges this is not a problem. The students could easily sign up for computer lab time where supervision would take place with either student monitors or the teacher.

On the next page is a screenshot (instructor view) of a typical MasteringPhysics online mastery test. Students could view the test questions, work on them and then enter the results before doing a final submit. This test contains a conceptual question, two word problems that are found at the end of the chapter and two true-false questions from the test bank. This student received 87.6% and was allowed to move on to the next unit (chapter).

MasteringPHYSICS

Logged in as Rocco Iafigliola, Instructor | Help | Log Out

PHY NYA 01 W2012 PSI (MPIAFIGLIOLA51498)
My Courses | Course Settings

Physics for Scientists and Engineers, 2e
Knight

Course Home Assignments Roster Gradebook Item Library Instructor Resources eText Study Area

Assignment Grade for Student

Due 03/23/12 at 11:47pm (You will receive no credit after the assignment is due.)

#	ITEM TYPE	TITLE	FINISHED	POINTS (AWARDED/ASSIGNED)	SCORE %	LATE PENALTY
1	End-of-Chapter	Conceptual Question 7.15	03/19/12 at 01:40am	2/2	100%	
2	End-of-Chapter	Problem 7.12	03/19/12 at 01:43am	2/2	100%	
3	End-of-Chapter	Problem 7.32	03/19/12 at 01:51am	3.76/4	94.0%	
4	Test Bank	True/False Problem 7.4	03/19/12 at 01:52am	0/1	0.0%	
5	Test Bank	True/False Problem 7.6	03/19/12 at 01:53am	1/1	100%	
		Grade Adjustment:		0		
		Total:		8.76/10		

Adjust Settings per Student

Adjust Total Points by (+/-):
Points added to or subtracted from the calculated POINTS (AWARDED/ASSIGNED) for the items above.

Exempt from Assignment

Extended Due Date/Time:
Original Due Date: 03/23/12 at 11:47pm

Availability to Student:
From: Original Date: 02/24/12 at 11:47am
Until: Original Date: 06/30/12 at 11:59pm

Reset Assignment:
Delete all work for this assignment and allow student to restart

Save

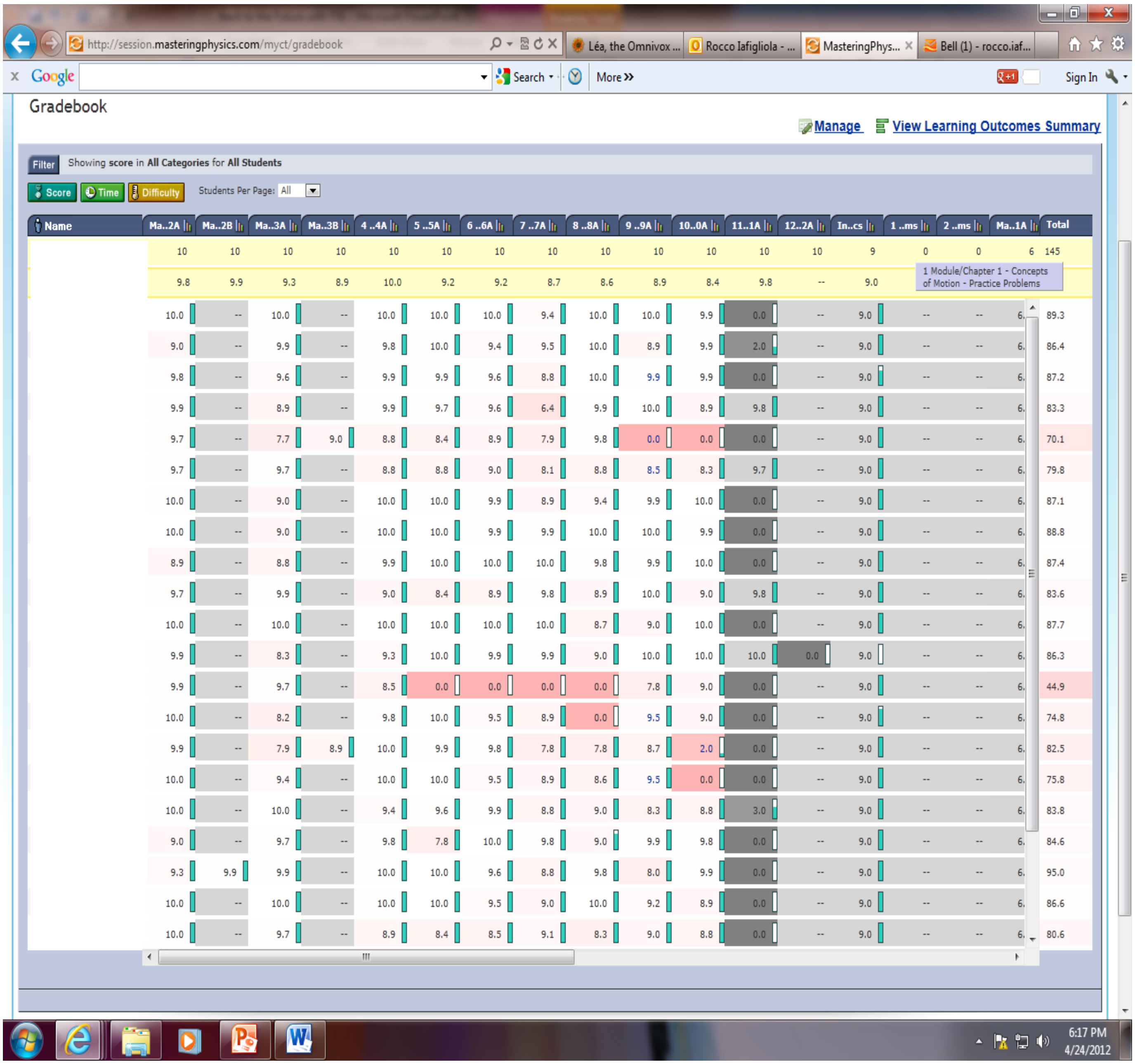
3.4.5 Self-paced

Keller's statement regarding self-pacing: "students can proceed according to their abilities, interests, and personal schedules completing modules (units) working at their own pace" (Keller, 1968) seems to indicate that there cannot be a well-defined end to the term if one is using PSI. This was one of the reasons that PSI eventually declined. Many students had to drop out of a PSI course due to the fact that they had fallen behind and had no chance to cover all the material within the term time frame.

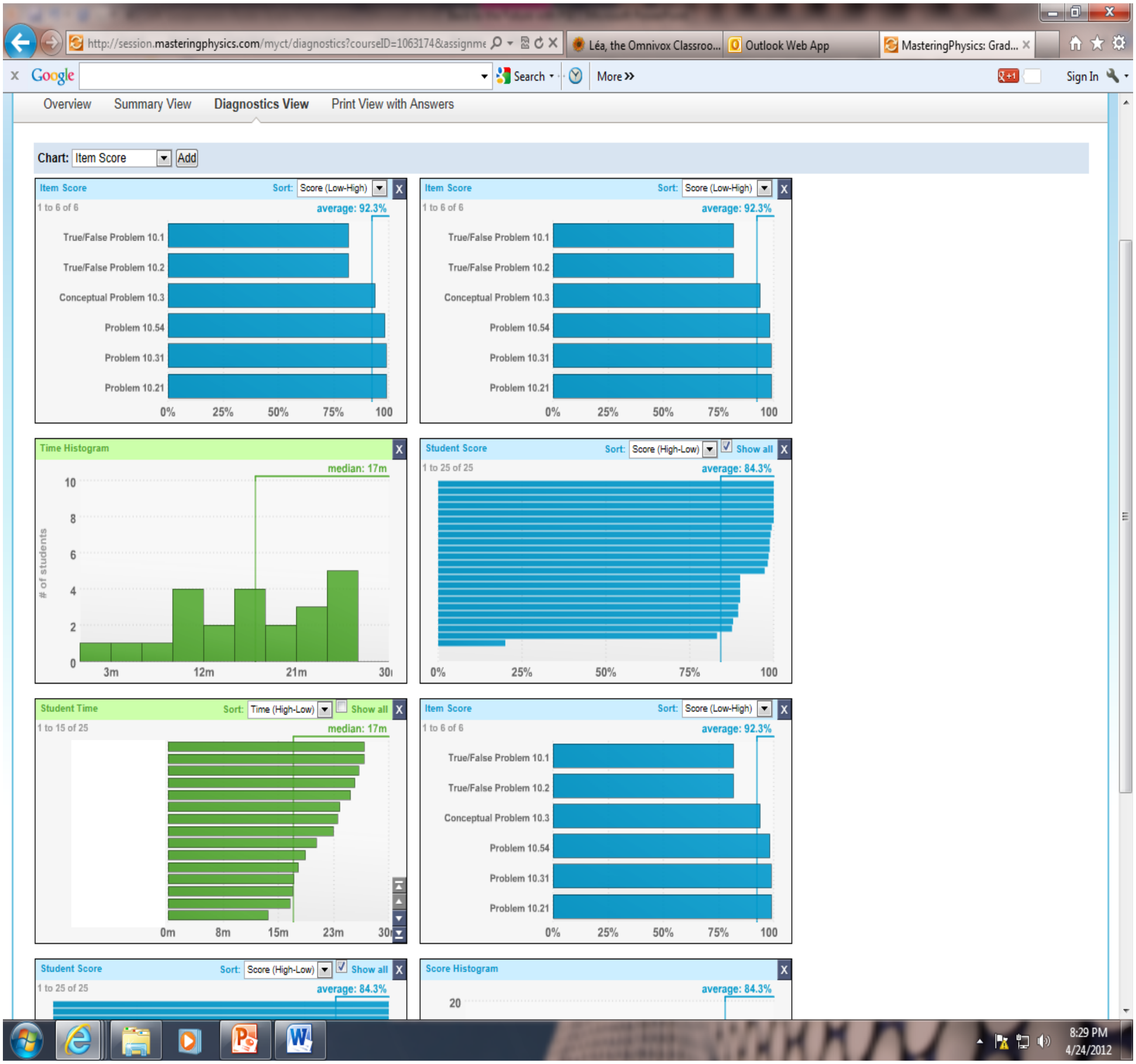
So if PSI were to make a comeback and be accepted by our present college institutions, its format would have to respect the well-defined course duration. In fact, not only is there a specific date that marks the end of the term, but there are also term-test dates that must be adhered to in a multi-section course. A process must be in place that allows self-pacing within "limits". In other words, the quick learners would have no problem keeping pace or advancing on their own. However, particular attention would have to be given to the slower students so that they do not fall hopelessly behind.

In my MPSI class, from the first week onward, self-pacing was evident. The students knew that they had to do more work on their own. Given the many resources at hand, such as the chapter study guides, practice problems, a textbook that provided clear learning objectives and many MIO reminders from me, students showed a strong willingness to keep pace or move ahead. By the third week of the course some students were already on Chapter 5 (and a few had requested Mastery Test 5!) while the very slow ones were finishing Chapter 2. Hand-in assignments, practice problems and tests were scheduled to encourage all the students to keep up. We all agreed at the beginning of the course which chapters were to be covered in the first-term test as that test date had already been set by the department. We did the same later on in the course for the second-term test. In the course content section of the study guides, I included Module Completion Date (MCD) guidelines. These were not absolute "must-finish" dates but reminders to the students which material they should have "most likely" covered. These dates often changed during the course and I saw this as a needed flexibility within a PSI course.

Below is a screenshot of the class workbook. The grey regions with grades indicate that the mastery tests were still “open” and being worked on. One student was clearly ahead of the others. White regions with grades indicate “closed” or completed tests. A few students fell behind considerably and missed out on several mastery tests (affecting their overall assignment grade but were allowed to continue to other units).



MP monitoring also included a diagnostics view. This view allowed me to see who was doing what, when and how. Below is a screenshot of a mastery test diagnostic view showing individual problem (item) score, time histogram, student time and student score.



3.4.6 Summary of MPSI

Below is a summary of the MPSI course structure.

TEXTBOOK

The textbook is a very important source of information – concepts are explained, expressions are derived and problem-solving techniques with examples are presented. Students are encouraged to read and review solved problems.

MODULES (UNITS)

One Module (unit) corresponds to one chapter. The various components below form a Module.

Study Guides

Online Practice Exercises (MP)
Cooperative Session Exercises

Online Mastery Tests

LEARNING ACTIVITIES

Cooperative Team Sessions – Demonstrations – Laboratory Experiments
Interactive PowerPoint Lectures and Peer Instruction (Clickers)

ASSESSMENTS

Online Exercises (MP) – Hand-in Assignments – Mastery Tests (MP) – Term Tests – Final Exam

Chapter 4 Evaluation of MPSI

4.1 Student Learning

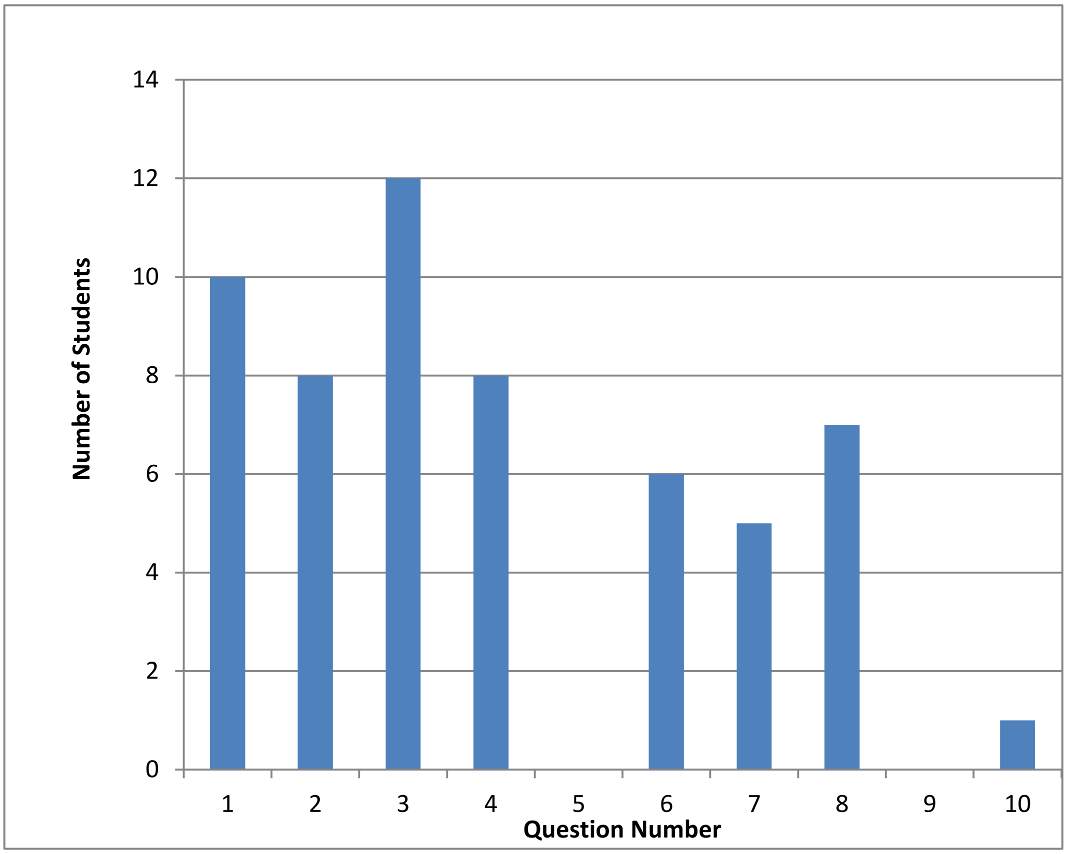
Initially, the students were given an informal questionnaire (called assignment 1) on what they considered was the best way for them to learn. This was meant to be more of an ice-breaker and was an easy way to introduce the students to the college's Omnivox online assignment hand-in system.

They were asked to send a Word, pdf or Excel file via LEA (Omnivox) of not more than 250 words answering the following question (this was their first electronically submitted assignment!):

What methods of learning work best for you? Choose 3 from the list below and briefly explain your response using less than 250 words:

1 - Reading the textbook and doing problems
2 - Listening to a lecture
3 - PowerPoint presentations
4 - Taking notes in class or when reading the textbook
5 - Participating in class discussions
6 - Working alone with notes and textbook
7 - Working in groups
8 - Working from prepared notes, study guides, solved problems handed out by the teacher
9 - All of the above
10 - Other (please specify)

A histogram of the answer distribution is shown on the following page. One student gave 10 as the answer and explained that he likes to do theory-type problems. Surprisingly no one felt participating in class discussions was a way to learn physics. The students were in for a big surprise!



4.2 Evaluation Procedures

The MPSI class was thoroughly evaluated using several evaluation procedures. According to many physics educators, the Force Concept Inventory (FCI) is proven standard to assess student understanding before a mechanics course is taught. Hence, I administered the FCI as the pre-test at the very beginning of the term before any material was taught. At the end of the course three evaluation procedures were used. First, the Mechanics Baseline Test (MBT) was administered as a complement to the FCI. Second, a detailed questionnaire (anonymous) on MPSI was administered via Omnivox. Third, a student-teacher course evaluation, also anonymous, was conducted by the college. The latter two solicited comments from the students in addition to the standard multiple-choice answers to the questions.

4.3 The FCI and MBT

David Hestenes, Malcolm Wells and Gregg Swackhamer (Hestenes et al., 1992-2) have described The Force Concept Inventory (FCI) as “a multiple-choice "test" designed to assess student understanding of the most basic concepts in Newtonian mechanics.” The FCI, they suggest, “can be used for several purposes, but the most important one is to evaluate the effectiveness of instruction.” The FCI was administered to the class as a pre-test given at the very beginning of the term, having covered no material whatsoever.

According to David Hestenes and Malcolm Wells (Hestenes et al., 1992-1), “the Mechanics Baseline Test (MBT) is the next step above the Inventory in mechanics understanding. Questions on the FCI were designed to be meaningful to students without formal training in mechanics and to elicit their preconceptions about the subject. In contrast, the MBT emphasizes concepts that cannot be grasped without formal knowledge about mechanics. The two tests are complementary probes for understanding of the most basic Newtonian concepts. Together they give a fairly complete profile of this understanding.” The MBT was given as a post-test near the end of the term by which time all topics had been covered.

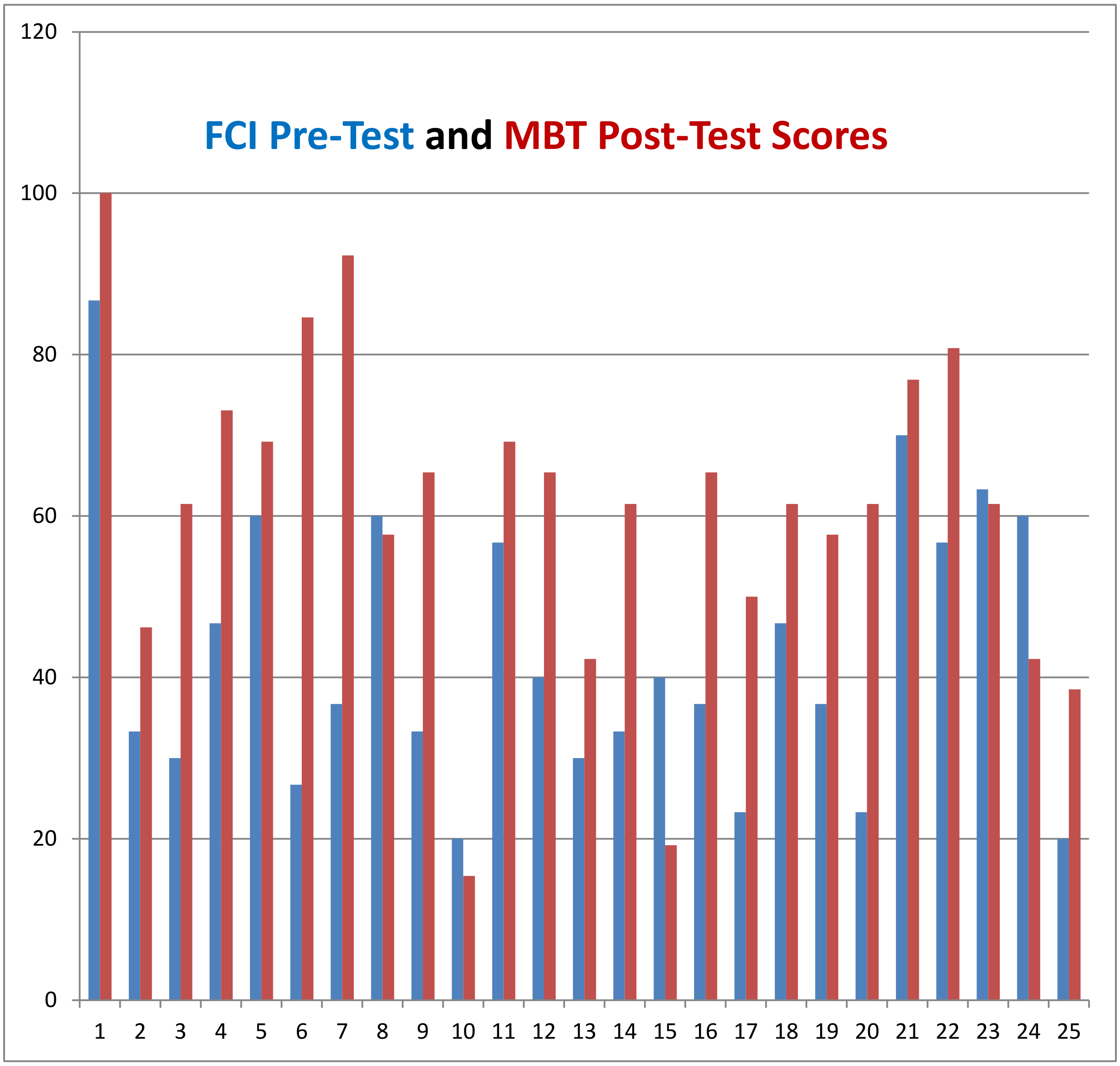
Students were made aware that they were going to do a pre- and post-test and that the grades would not penalize them in any way.

Unfortunately, the tests cannot be viewed, neither in total nor in part. They are password protected and permission (and instructions) to use them must be obtained from Dr. David Koch FCIMBT@verizon.net. In his words (by email) “The Modeling Instruction staff at Arizona State University respectfully denies permission to include the FCI in any doctoral dissertation or masters degree thesis or publication. We specifically ask you NOT to include the FCI or MBT in an appendix. Rather, we suggest that you post the URL for our website http://modeling.asu.edu/R&E/Research.html , and state that interested parties can request a download password from us.”

The following table and histogram show and compare the results of the two tests. I have not included student names for privacy purposes but simply numbered them.

Results (%) of FCI & MBT Physics NYA (Mechanics) MPSI Class – Winter 2012

Student	FCI	MBT
1	86.7	100
2	33.3	46.2
3	30.0	61.5
4	46.7	73.1
5	60.0	69.2
6	26.7	84.6
7	36.7	92.3
8	60.0	57.7
9	33.3	65.4
10	20.0	15.4
11	56.7	69.2
12	40.0	65.4
13	30.0	42.3
14	33.3	61.5
15	40.0	19.2
16	36.7	65.4
17	23.3	50.0
18	46.7	61.5
19	36.7	57.7
20	23.3	61.5
21	70.0	76.9
22	56.7	80.8
23	63.3	61.5
24	60.0	42.3
25	20.0	38.5
Average	42.8	60.8
STDEV	17.3	19.8



Most students had a substantial grade increase in the MBT over that of the FCI. However, some students did poorly and the MBT score was less than that of the FCI. There were a number of reasons for this. A few students had other exams to study for and decided to do the MBT quickly and in much less time than required. One student came in late and had about half the time remaining to complete the test.

Overall, however, I am pleased with the substantial increase in the average of the MBT over that of the FCI. Remarkably, one student received 100% and later obtained the same for his overall course grade. He, and many others, told me that they highly enjoyed the PSI course format.

These results were sent to the Modeling center at Arizona State University to establish whether they were in line with other results. They have accumulated numerous FCI-MBT data. In a private communication (email), the response indicated that my results were consistent with "….post-test scores typical of traditional lecture-based instruction...". This implies that the PSI class did as well as a lecture-based class would have done. So my students had not "suffered" from the omission of 50% of the lectures and that they were able to work on their own to cover the material. Hopefully, this will also translate in their retaining more of what they have learnt for future courses through their PSI experience!

4.4 PSI Omnivox Questionnaire - Winter 2012

A detailed questionnaire covering all facets of the course was created and administered anonymously via the college Omnivox system from April 25, 2012 to May 18, 2012. Eighteen students participated in this evaluation and the numerical results as well as comments were given to me after the deadline date that occurred after the final course grades were submitted. The complete questionnaire with results is shown in Appendix IV. I estimate an overall evaluation of the PSI approach to be about 70% satisfaction. This may not seem too impressive but some of the student comments were quite supportive of their PSI experience. Below are these comments.

Comment 1 ~ "I like the idea of learning at your own pace but with a schedule comprised of 7 classes it becomes very hard to keep up with the readings! Not all of us are autodidacts and physics can be hard to understand by ourselves... I would recommend this method of teaching (in reality my evaluation would be between fair and good) but perhaps not in an academically-demanding environment like the one at Marianopolis."

Comment 2 ~ "At first I was skeptical about the method: PSI entails that the student must work extra hours apart from the heavy course load they are already given... I was actually strongly considering switching into another section of Mechanics.

However, I am very content with my decision to stay in the PSI course! Learning most of the concepts on my own deepened my understanding of the topics and I feel more confident when faced with a problem I need to solve. Learning by myself (or in my group) has shown me that a traditional lecture is not always preferable and that the best method of learning is by using your own knowledge and logic!"

<u>Comment 3</u> ~ "One of my favorite aspects of PSI is the relationships we were able to create. My peers were not only my classmates but my friends! Whenever somebody needed help nobody was ever shy to ask... This promotes success knowing that there is always somebody to help you when you need it. The teacher and peer tutor also provided much help. The teacher was always available and helpful during office hours and the peer tutor was a great help since we got along and he was able to help us without being too authoritative. One thing I would change is the class scheduling: having a lecture before a collaborative session would be preferable this way the student may grasp the topic before attacking problems with his or her group.

Otherwise I am genuinely happy with my outcome! PSI has been a great experience and hope to be able to be a part of it sometime in the near future. Not only did I learn Newton's Mechanics but I have acquired time management and discipline skills that are very much necessary to becoming successful."

<u>Comment 4</u> ~ "The MP Tests minimal grade of 80% is too low for my liking if a student has really mastered the chapter. He/she should get 97-100 (1 mistake allowed). Either increase the minimum grade or make harder problems to really make sure the students master the chapter. Overall it was a GREAT PSI program. I loved it and even tried to apply it to my other courses. IT'S SO MUCH BETTER THAN FALLING ASLEEP DURING LECTURES!"

<u>Comment 5</u> ~ "I believe that PSI is a good concept to be used for Mechanics classes. However, if I had to change something about it I would have made the lectures at the beginning of the week and make the cooperative sessions at the end of the week. The reason for this is because although people should have been doing the readings, they did not read the chapters in the textbook prior to the cooperative sessions. Thus they would not do much work in the sessions because they had no idea what the chapters were about. If the lectures happen first people would understand first and then I believe more work would be done. On the other hand I think this program can be very good for students especially those who tend to learn on their own and tend to get ahead."

Comment 6 ~ “In impelling students to seek divide and conquer material individually within the scaffold framework of PSI's study guides scientific concepts are more robustly assimilated and incorporated within a broader scholastic framework. As a student hitherto subject to the conventional chalk-and-talk methodology my apprehensions pertaining to PSI were soon assuaged as the study guides in conjunction with the in-class and cooperative sessions provided sufficient support and guidance as per the treatment of specific physics concepts. A synergy between my own textbook endeavors mastery tests and discussions with the professor during his office hours allowed me to allocate study and problem-solving time reflexively and ultimately approach the material in a manner which maximized my personal mastery. Hence the efficacy of the PSI approach resides in its individuality and scalability to student demands without compromising the global scope of the course. I am thus certain that should study guides, cooperative sessions and ample professor office hours be invoked as it was here the PSI pedagogical paradigm would find ample applicability in ALL science and mathematics courses.”

Comment 7 ~ The following was a special note sent to me by one of my students well after the final exam and once the final grades were sent out.

“PSI PERSONALIZED SYSTEM OF INSTRUCTION: A Student’s Perspective”

Summary of my Experience

At first I was skeptical, not of the program mainly but because PSI would represent change, and in today’s world, where everything is changing at such a rapid pace, I feared my need to adapt and learn the new PSI program.

However, over time, PSI has actually shown me that its program is far superior than the traditional, lecture-based system. In PSI, my reliance on my teacher to channel direct information to me during lectures was diminished and the encouragement to learn on my own time and own pace was greatly encouraged. I found myself more independent and more eager to advance in the course.

I also viewed my teacher with a completely different outlook. The teacher was my guide through the course. To me, he steered me in the right direction and was an excellent aid in understanding some blurry concepts. Unlike in a regular system where the teacher diffuses the same repetitive information to the entire class, the teacher provided me with the individual guidance where I really needed and when I needed it. Because the teacher was not bound to lecturing the class, the teacher was an excellent personal assistant in my journey through the course.

I found that because my knowledge of the course did not come from the audio lectures given out by my teachers, I was able to retain more knowledge and concepts. Because I learned the material on my own time and own pace, I was able to recall formulas and theories because I taught it to myself. Also, any unclear concepts that I could not decipher on my own was not quickly brushed over like in a traditional classroom-paced system, but could be brought up to the teacher who had the time to explain it personally to me.

Overall, I found my experience in PSI more rewarding than the traditional system. I found that PSI offered many opportunities not present in my regular courses. The four things that I enjoyed the most about PSI:

1) ***The abundance of resources at my disposal***
   I had chapter PPTs, module study guides for EOC problems, clickers for theory comprehension, MasteringPhysics problems and Cooperative Session problems. All these resources were easy to access and allowed me to approach a chapter from many different perspectives and at anytime and anywhere.

2) ***Being able to work at my own pace***
   I really loved this aspect. Working at my own pace allowed me to advance further into the course when I had free time and be tested immediately with a Mastery Test to see if I had understood the chapter. By advancing personally and not being restrained by the class pace, I could put myself ahead when I could and when things got busy, I didn't have to worry about falling behind in class.

3) ***The enriched material***
   The enriched material offered quite a challenge that really tested whether I understood the core concepts of the course. Also, the enriched material tied the material covered with many practical, real-life applications such as drag, fluid dynamics (viscosity), etc. The bonus marks for the enriched material was also definitely an incentive.

4) ***Working in groups***

In all my other classes, everyone is usually silent during the entire lecture and everyone is afraid to ask questions (on something their unclear on) for fear of holding back the professor or sounding unintelligent. Also, I noticed that the back half of the class is usually unattentive and is usually playing on their mobile devices. However, in our cooperative sessions where we were in groups, no one was afraid to ask either their teammates or our tutor on concepts we were unclear of. In addition, by presenting the problems to a group rather than a single student, I found that my classmates were much more enthusiastic about solving the problem together.

4.5 In-Class Student Evaluation - Winter 2012

When required, teachers are evaluated by their students in the courses they teach. This is a highly formal procedure. An invigilating teacher enters the class of the teacher to be evaluated. A questionnaire is handed out (Appendix IV) along with computer cards. A Course ID is supplied to the students and instructions are read out. The students then have a certain amount of time (about 15 - 20 minutes) to fill out the computer cards. The cards are collected, placed in an envelope that is signed by the invigilating teacher and a student across the flap seal. The students are finally reminded that they could also send comments via Omnivox up to a specified date. All materials are then brought to the Office of the Academic Dean by the invigilating teacher.

Well after the final grades have been sent to the students, the teacher that has been evaluated receives a comprehensive report of the student questionnaire responses as well as the comments.

My overall evaluation was very good. In fact it was better than some of my past evaluations and with no major discontent that may have raised flags. To respect the college’s policy on evaluations, I have not included the actual results. Hence, despite the very different technique that was used for teaching the course (PSI), the student evaluation, designed for teaching using traditional classroom lectures, still indicated overall student satisfaction.

Below I have included the student comments.

Comment 1 ~ "Clicker questions are fun but don't help much. It'd be easier to work as a group on what each individual needs to improve instead of on the cooperative work problems."

Comment 2 ~ "Class is optional. It helps during midterm sessions. More lecture more explanation before assigning work. Less use of the textbook because it is not very heavy but it is also very unclear on explanations. We can't rely on only the textbook in order to pass the course. (The teacher) Responds to MIO very quickly and responds to requests immediately. Make clearer explanation of concepts instead of going through all sub-chapters quickly."

Comment 3 ~ "We get to cover many different types of problems which relate to different situations that occur in real life. He is very kind and is always willing to help when a student doesn't understand something. Gives good explanations, brings props to class, and lectures are clear and organized."

Comment 4 ~ "The cooperative sessions are amazing practice for midterms. Useless Power Points... they are just scans from the manual. It's actually unnecessary to attend class lectures when the PowerPoints the teacher uses in class are just copies of the manual. He is willing to help his students since he is always available to help students with problems - very helpful in office hours."

Comment 5 ~ "The cooperative sessions and problems are really interesting. The fact that we worked in teams brought the class to get to know each other. I guess it is part of the PSI system. I am not saying PSI is bad I think that it is an interesting approach to the learning process but students have a lot of freedom to go at their own pace. Given that we have little time to truly sit down and read whole lengthy chapters at home because we have various assignments to do the PSI system is rendered less effective. My suggestion is to give a quick overview of the chapter as a lecture and then do cooperative sessions. He is funny. I loved the physics jokes. He never gave the answers directly only asked questions to guide you in your reasoning. Very active on Omnivox and MasteringPhysics."

Comment 6 ~ "PSI... at first I thought it`s going to be (not nice) but as the semester progressed I realized that PSI is a great way to teach and I honestly prefer PSI to normal boring lectures...Should have harder Midterms because the class average is TOO DAMN HIGH! Awesome teacher is awesome... Enthusiastic, funny and knows his stuff teaches well too it`s an all-in-one package deal right there."

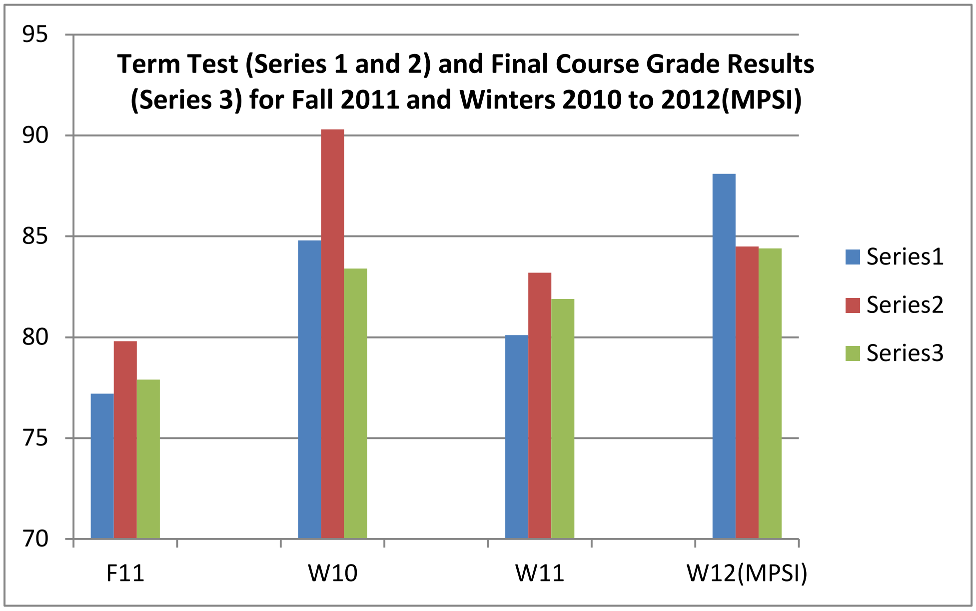
4.6 Term Tests and Final Exam Performance

The students sat in class as a whole for the two term tests and took a common final exam with the rest of the PHY NYA (Mechanics) groups.

Performance on the term tests was very good and comparable to past performance. Factoring in additional marks for enriched, calculus-based bonus questions, the class averages were a little higher than those of past tests where bonus marks were not available. The final exam class average was somewhat less than the term averages but this is common. In my view, the students face a much more demanding comprehensive assessment of the course in a three-hour final exam time period.

So all this is to say that the MPSI format did NOT hurt student grades! If anything, the inclusion of bonus questions resulted in a higher final class average as the better students successfully attempted these questions. At the same time there is no evidence that the poorer students were penalized by PSI. In fact, the worst performing student in my group during the term (the student failed both term tests) passed the final exam and with the labs and assignments factored in, managed to pass the course!

The following histograms show the comparisons of the term test as well as the final exam results for the past three Winter terms (W2012(PSI), W2011 and W2010) as well as one Fall term (F2011). Typically, most students have a stronger math background going into the winter term since many (if not most) have taken Cal 1 in the previous Fall term. This usually translates into better performance in the Winter term NYA physics course. Some of these students are more likely to cover the enriched material and attempt enriched problems on term tests that can be used for bonus marks. The MPSI student grades were comparable to those obtained in the traditional lecture format classes. If anything, the MPSI class overall final average was somewhat higher than the others.


Term Test (Series 1 and 2) and Final Course Grade Results (Series 3) for Fall 2011 and Winters 2010 to 2012(MPSI)
95
90
85
80
75
70
F11
W10
W11
W12(MPSI)
Series1
Series2
Series3

Chapter 5 Conclusion

5.1 Learning from the Past

There is no doubt that the Keller Plan (Keller, 1968) ushered in a teaching-learning paradigm that was truly active learning in nature. Designed to have no formal lecture structure, it was up to the student to work through the course content and learn. There was support by peers and proctors who were available for individual student questions and administered the mastery tests, hence a personalized system of instruction (PSI). The teacher may have also been available but to a very limited extent and was mostly involved in setting up the study guides and mastery tests. With no computer resources available, it was a lot of work for very little reward (Fuller et al., 2005 - 2).

After about a decade or so of enjoying prominence in the educational realm, PSI based courses in Physics significantly declined. Funding for PSI research and support networks all but disappeared. It continued to be used in other disciplines but nowhere to the extent that merited special attention amongst academic circles.

Let's recall the five main points of the Keller Plan (Keller, 1968):

(1) The go-at-your-own-pace feature, which permits a student to move through the course at a speed commensurate with his ability and other demands upon his time.

(2) The unit-perfection requirement for advance, which lets the student go ahead to new material only after demonstrating mastery of that which preceded.

(3) The use of lectures and demonstrations as vehicles of motivation, rather than sources of critical information.

(4) The related stress upon the written word in teacher-student communication.

(5) The use of proctors, which permits repeated testing, immediate scoring, almost unavoidable tutoring, and a marked enhancement of the personal-social aspect of the educational process.

If we want to implement PSI courses within the CEGEP system today, changes would be necessary to ensure that a rebirth would not meet a quick end. Let's reconsider the five points of the Keller Plan, taking into account the resources available in today's educational system that did not exist in the heyday of PSI. Let's also consider that despite these modern day resources, there are certain inherent constraints in the educational system that are the same as those 25 years ago and that may never significantly change to accommodate the original Keller Plan. This is why a modernization is needed.

(1) The go-at-your-own-pace feature… From a student point of view, this would be a desirable feature in a course. Students with different abilities would cover the course over different time periods: some would take more time, some less. The obvious drawback, which existed 25 years ago, and remains the same today, is the time confines of a college term (semester) duration. The quick learner will not have a problem but the slow learner may not finish the course on time. There is no obvious alternative to the time confines of the term (semester) duration.

(2) The unit-perfection requirement for advance… As in point (1), students that move ahead and have successfully mastered the units in their PSI course, have no problem. In fact, it provides a benefit for them as they can in fact end the course earlier than the others allowing them to spend time on other courses or act as peer tutors. However, those that fall behind could get discouraged and opt to drop the course. For this not to happen, there would have to be put in place a course extension/make-up period. This option, although desired, would not be possible within our fixed term length.

(3) The use of lectures and demonstrations as vehicles of motivation (and not for course content delivery)… Removing all lectures in a course would be a monumental feat reaching the pinnacle of the active learning ladder. Some of these techniques are already in place (for example the Flipped class, Bennett et al., 2011). These teaching methods seem to be gathering more and more interest amongst educators. But for the most part CEGEP teachers maintain the traditional chalk-and-talk approach to teaching. Hence, adopting a new teaching approach, such as PSI, would imply major changes be made by educational institutions. Such

changes would have to be supported by government, administration and the teachers themselves. SALTISE, which stands for "Supporting Active Learning and Technological Innovation in Science Education", has organized several meetings at Dawson College and has invited presenters, such as Eric Mazur (Mazur, 1997) to discuss alternate modes to the traditional class and encourage educational research. It is not surprising that, despite the clear benefits derived from active learning, there is significant inertia in most institutions to openly embrace such practices for the students *en masse*. Hence, active learning methods are still mostly experimental in the CEGEPs today.

(4) The related stress upon the written word… This is totally doable in our present system. Student study guides for the individual units (modules) would take a considerable amount of time to set up. However, once they are set up they do not have to be redone (except for textbook references when a new edition comes out). Moreover, our textbooks today are much more student-friendly than those of the past. A textbook such as *Physics for Scientists and Engineers - A Strategic Approach* – by Randall Knight (Knight, 2013) takes into account physics education research, supports the active-learning environment and has a "study-guide" feel to the chapter layouts. A Student Workbook is available as well as an Instructor Guide. What is very important is that the students taking a physics course and using this textbook must be made aware of all these resources and reminded to consult them at appropriate times during the course.

(5) The use of proctors, which permits repeated testing, immediate scoring… Colleges now have in place student-support resources to ensure that students succeed. Student learning centers provide peer tutoring for the weaker students who may be in danger of failing their course(s). At the same time there are resources to address the needs of advanced students such as science fair and robotics clubs. These resources could be tapped to provide in-class peer assistance in a PSI course. These "peer tutors" or "proctors" would help the teacher respond to questions from the students in cooperative group sessions. This help could also extend to work done in computer labs if, for example, the teacher wishes to administer the mastery tests that way.

5.2 MPSI Supports the Reform

Adopting MPSI in the CEGEPs would support the reform goals (MELS, 2005) that are now in place in secondary schools. The CEGEPs are seeing the first cohorts of the reform entering their system. The reform stresses learning outcomes and emphasizes the process leading to learning outcomes. It also promotes integration of learning and the development of more complex intellectual problem-solving skills. In fact, it has been suggested "that when PSI is implemented correctly, it produces higher levels of achievement among students than the lecture-discussion format. Hence, PSI students may be more likely to develop the necessary knowledge base and problem-solving strategies. Research has demonstrated that students enrolled in PSI improved higher order cognitive skills (Reboy et al., 1991).

PSI is an "instructional delivery system" and as such would not dictate course content. A competency-based structure would be easily accommodated by PSI. Also, the integration of several subjects can be easily made (e.g. Physics and Mathematics) through appropriate modules. We would have extensive integration with technology as all of the modules and tests would be computer-based and online (Pear et al., 2002). Computer-based instruction makes for a more active learning experience by allowing students to receive ongoing feedback and evaluation of course content.

MPSI for science instruction would establish a dynamic, student-centered, active learning teaching environment with well-defined learning objectives, activities and assessments. It would move the traditional classroom to one that is student-in-charge. "Numerous teaching methods, based on educational research, have demonstrated that greater student involvement in the classroom enhances learning. This research has demonstrated that students learn more if they are actively engaged with the material they are studying." (Paulson et al., 1998 – 1, 2)

5.3 MPSI Use in other Courses

MPSI can be successfully used in other courses as long as online platforms are available. For example, Pearson's Mastering system exists in Anatomy and Physiology (www.masteringaandp.com), Chemistry (www.masteringchemistry.com) and Biology (www.masteringbiology.com). Hence, Mastery Tests could be prepared and administered online and the Study Guides, once they have been created, could be uploaded to the corresponding Mastering system.

It is now generally agreed that the management of mastery tests can be done best with computer and internet technology (Eyre, 2007) as is the MPSI system. Another successful system that uses an internet-based program is the computer-aided personalized system of instruction CAPSI (Pear, 2002).

Continuing research on PSI using modern internet platforms for different courses in all fields could signal the revival of PSI. Distance education seems to have sparked the most demand for PSI-style courses. Hopefully future generations of instructors at CEGEPs will also discover the merits of PSI and suggest their own MPSI platforms!

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CAPSI. http://www.capsi.org/

FCI and MBT. site http://modeling.asu.edu/R&E/Research.html

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MasteringBiology. www.masteringbiology.com

MasteringChemistry. www.masteringchemistry.com

MasteringPhysics. www.masteringphysics.com

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SALTISE. http://www.saltise.ca/

Skytech. http://www.skytech.com

APPENDIX

1-1-1975

Newton's Laws

NEWTON'S LAWS

INTRODUCTION

When a body is at rest, we know from experience that it will remain at rest unless something is done to change that state. A heavy box on the floor will stay in place unless it is pushed or pulled. We walk without fear beside a massive rock on level ground because we know it won't suddenly move and crush us.

Undoubtedly you have leaned against a chair only to have it move and send you scurrying for your balance. Did you then question the relationship of the interaction between you and the chair to the ensuing motion of the chair?

It was Isaac Newton who first clearly made the connection between the interactions on a body and its motion. In Newton's theory, the acceleration of every object has to be explained in terms of the interactions with other objects. Newton's laws of motion cover an enormous range of experience. At one stroke they convert what in retrospect had previously seemed chaos into a beautifully organized universe. There have been few achievements to rank with this in the history of science.

PREREQUISITES

Before you begin this module, you should be able to:	Location of Prerequisite Content
*Check the units of a given mathematical expression and show that it is dimensionally correct (needed for Objectives 2 and 4 of this module)	Dimensions and Vector Addition Module
*Add or subtract two, three, or four two-dimensional vectors given in unit-vector notation, finding the resultant (needed for Objectives 2 and 4 of this module)	Dimensions and Vector Addition Module
*Describe the position, velocity, and acceleration of an object moving in one dimension with constant acceleration (needed for Objectives 2 and 4 of this module)	Rectilinear Motion Module
*Describe the position, velocity, and acceleration of a single body moving in a plane or moving in projectile motion (needed for Objectives 2 and 4 of this module)	Planar Motion Module

LEARNING OBJECTIVES

After you have mastered the contents of this module you will be able to:

1. Free-body diagram - Draw a diagram of a particle representation of a body isolated from its environment in an inertial reference frame; and
   (a) illustrate, with vectors, all forces that act upon it; and
   (b) identify, by name, the source of each force illustrated.

2. $\vec{F} = m\vec{a}$ - Write Newton's first and second laws in mathematical form; and
   (a) choosing an appropriate coordinate system, apply the second law to a given problem involving a single massive body, solving for either a specified force or the acceleration of the body; and
   (b) use the second law to distinguish between weight and mass.

3. Action-reaction - Apply Newton's third law to a problem to relate the forces exerted and experienced by a body.

4. Motion of a particle - Solve a problem concerning the motion of a body (acceleration, velocity, and displacement) given sufficient information concerning the external forces acting on the body. (These external forces may be gravitational forces or contact forces exerted by another particle, by friction, by nonstretchable ropes, or by rigid rods.)

GENERAL COMMENTS

It should be emphasized that a particle model is used throughout this module, i.e., each body is considered as if it were concentrated at a point and had no extension in space. This should be remembered in your study of examples in the text and in working the Problem Set. All objects (blocks, cars, passengers in elevators, etc.) are to be treated as particles.

Objective 2 is stated as $\vec{F} = m\vec{a}$ because Newton's first law is implicit in the second. That is, if $\vec{F} = 0$, $\vec{a} = 0$: no force acting on the body, no acceleration (change in motion). We should also stress that the $\vec{F}$ in Newton's second law is the resultant force (vector sum) of all the forces acting on a body.

In solving problems in this module, here are some suggested rules to follow, step by step:

1. Identify the particular body to be considered.
2. Identify all interactions (forces) between the body and its environment.
3. Choose a suitable inertial coordinate system (be judicious in your choice, and you will save yourself a lot of effort).
4. Draw a diagram of the object representing it by a point; show all forces acting on the body, and show the coordinate system (free-body diagram).
5. Resolve those forces not lying along a coordinate axis into their rectangular components.
6. Apply Newton's second law.

Following these rules, especially rule 4, will save you much time in mastering Objective 4, where it is easy to confuse the various interactions, forces, and bodies.

Regarding Objective 3 (action-reaction), a more complete treatment will be given in the later module: Applications of Newton's Laws.

TEXT: Frederick J. Bueche, Introduction to Physics for Scientists and Engineers (McGraw-Hill, New York, 1975), second edition

SUGGESTED STUDY PROCEDURE

Read Section 2.3 in Chapter 2 and all of Chapter 5 (excluding Sec. 5.5). Objective 1 is discussed in the initial part of Section 5.3 in relation to the application of Newton's second law. Newton's first and second laws are stated in Section 5.1 (p. 54) in connection with Objective 2, and Newton's second law ($\vec{F} = m\vec{a}$) is further discussed in Section 5.2. The relation between weight and mass is given in Eq. (5.4).

BUECHE

Objective Number	Readings	Problems with Solutions		Assigned Problems		Additional Problems
		Study Guide	Text	Study Guide	Text	
1	Secs. 2.3, 5.3	A, B		I, J	Chap. 2, Prob. 7	Chap. 2, Prob. 4
2	Secs. 5.1, 5.2	C, D		K, L	Chap. 5, Prob. 7	Chap. 5, Prob. 9
3	Sec. 5.1	E, F		M, N	Chap. 5 Ques. 1	
4	Secs. 5.3, 5.4, 5.6, 5.7	G, H	Illus. 5.1, 5.2, 5.3, 5.4	O, P, Q	Chap. 5 Prob. 13, 23	R, S; Chap. 5, Probs. 10, 11, 12

Objective 4 is covered in Sections 5.3, 5.4, 5.6, and 5.7 with several good illustrations.

TEXT: David Halliday and Robert Resnick, Fundamentals of Physics (Wiley, New York, 1970; revised printing, 1974)

SUGGESTED STUDY PROCEDURE

Read Chapter 5 of your text, excluding Section 5-13 and Examples 5 and 6 (which will be covered in the module: Applications of Newton's Laws). Objective 1 is spread over four sections (5-1, 5-3, 5-8, 5-11). Table 5-1 on p. 60 gives a very helpful overview of interactions between a body and its environment that are described by forces; compare this with Table 5-4 on p. 70 for a mathematical description of the forces in each case.

Buried in the first paragraph of Section 5-11 are five rules. These rules are indispensable in working out the problems of Objective 4. Note the explicit and excellent free-body diagrams (and the particle representation) drawn for the examples, i.e., Figures 5-4(b), 5-5(b), 5-6(b), 5-8(b), and 5-11.

Newton's first law is stated and discussed in Section 5-3. Newton's second law is stated mathematically in Eq. (5-1) and discussed at length in Sections 5-2 to 5-5 and 5-8. The relationship between weight and mass is given in Eq. (5-5) and explained in Section 5-9.

Objective 3 is thoroughly explained in an excellent discussion in Section 5-6, and two very good examples are given (Examples 1 and 2). Objective 4 is presented in Sections 5-11 and 5-12 with many excellent examples.

After completing this reading, study the Problem Set and solve the assigned problems. Finally, check your understanding by taking the Practice Test.

HALLIDAY AND RESNICK

Objective Number	Readings	Problems with Solutions: Study Guide	Problems with Solutions: Text	Assigned Problems: Study Guide	Assigned Problems: Text	Additional Problems
1	Secs. 5-1, 5-3, 5-8, 5-11	A, B		I, J		
2	Secs. 5-2 to 5-5, 5-7 to 5-9	C, D	Examples 3, 4(a)	K, L	Chap. 5, Probs. 4, 11	Chap. 5, Probs. 5, 7, 14
3	Sec. 5-6	E, F	Examples 1, 2	M, N	Chap. 5, Prob. 2	
4	Secs. 5-11, 5-12	G, H	Examples 4(b), 7, 8	O, P, Q	Chap. 5 Probs. 25, 50	R, S; Chap. 5, Probs. 8, 9, 12, 13, 16, 18, 21, 35

TEXT: Francis Weston Sears and Mark W. Zemansky, University Physics (Addison-Wesley, Reading, Mass., 1970), fourth edition

SUGGESTED STUDY PROCEDURE

This particular module is spread over Chapters 1, 2, and 5. Interspersed in Chapters 2 and 5 is introductory material on Gravitation and Statics, topics that will be taken up in more depth in the modules Gravitation and Equilibrium of Rigid Bodies. We suggest that you read Sections 1-4 and 1-5 of Chapter 1, Chapters 2 and 5 in order, but skip Sections 2-4 and 5-4.

Objective 1 is discussed quite thoroughly over parts of five sections. In Section 1-5, the concept of force is introduced; however, it is introduced independent of acceleration. When particles interact (do something to each other), one measure of their interaction strength is provided by their acceleration, and this measure leads to the force concept. On p. 14 the technique for determining the resultant force from the individual forces is introduced. On p. 15 an inertial coordinate system is defined, and on p. 18 there appears an excellent discussion of the particle model and rules for constructing a free-body diagram and for solving problems. [Note an example of a free-body diagram in Figure 5-8(b) on p. 66.]

SEARS AND ZEMANSKY

Objective Number	Readings	Problems with Solutions		Assigned Problems		Additional Problems
		Study Guide	Text	Study Guide	Text	
1	Secs. 1-4, 1-5, 2-2, 2-3, 2-6	A, B		I, J		
2	Secs. 2-2, 2-3, 5-2, 5-3, 5-5	C, D	Sec. 2-6, Ex.* 1-4 Sec. 5-3, Ex. 2, 3	K, L	5-1	
3	Sec. 2-5	E, F	Sec. 2-6, Ex. 1, 2 Sec. 5-6, Ex. 4	M, L	5-3	2-1(a)-(g), 2-2
4	Secs. 2-6, 2-7, 5-6	G, H	Sec. 2-7, Ex. 1, 2, 3 Sec. 5-6, Ex. 1, 2, 3, 6, 7	O, P, Q	2-22, 5-24	2-17, 5-13, 5-17, 5-21, 5-22

*Ex. = Example

Objective 2 is spread over five sections. You will find Newton's first law stated on p. 15 with a discussion of it preceding and following this statement. Newton's second law is stated verbally and mathematically [Eq. (5-3)] on p. 58. The relation between mass and weight is given in Eq. (5-6). Disregard Eq. (5-5) since you will take this up in the module Gravitation.

Objective 4 is handled in Sections 2-7 and 5-6 with several examples. Disregard Examples 4 and 5 (Sec. 5-6) for now.

Rule 4 on p. 18 explicitly applies to the case where the resultant force is zero (Newton's first law), but it can be extended to the more general case (Newton's second law) by setting the algebraic sum of all the x components of the forces equal to the mass times the x component of acceleration ($\Sigma F_x = ma_x$) and the algebraic sum of all the y components of the forces equal to the mass times the y component of acceleration ($\Sigma F_y = ma_y$).

Study Problems A through H before working Problems I through Q. When you feel prepared, take the Practice Test.

TEXT: Richard T. Weidner and Robert L. Sells, Elementary Classical Physics (Allyn and Bacon, Boston, 1973), second edition, Vol. 1

SUGGESTED STUDY PROCEDURE

Your text approaches mechanics from a momentum point of view (a concept to be covered in a later module). Momentum is defined and experiments are used to establish the conservation of momentum as the empirical starting point for the development of some of the concepts to be developed in this module.

To make your text compatible with the sequence of ideas as developed in these modules, we suggest the following reading sequence: Sections 5-1 through 5-6 (excluding all the examples in these sections), 7-1 through 7-3, 7-5 through 7-6, and 8-1 through 8-3 (excluding Example 8-6). You may wish to read through Sections 5-5 and 5-6 quickly since the material in these sections is not included in any of the learning objectives of this module but is needed to facilitate the understanding of the material in this module.

WEIDNER AND SELLS

Objective Number	Readings	Problems with Solutions		Assigned Problems		Additional Problems
		Study Guide	Text	Study Guide	Text	
1	Secs. 5-1, 7-1, 7-3, 8-2	A, B		I, J		
2	Secs. 5-1, 5-2, 7-2, 7-3, 7-6, 8-1	C, D	Ex* 7-1, 8-2	K, L		
3	Secs. 7-5, 8-1	E, F		M, N	8-5	
4	Secs. 8-2, 8-3	G, H	Ex. 7-2, 8-3, 8-4, 8-5, 8-7, 8-9, 8-10	O, P, Q, R, S	8-11, 8-12	8-21

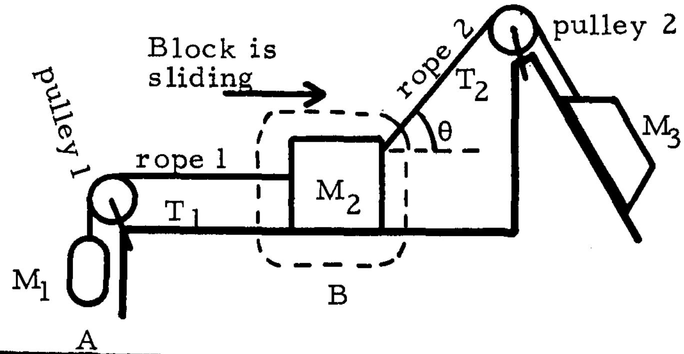
*Ex. = Example(s)

Objective 1 is spread over four sections of reading. An inertial reference frame is defined in Section 5-1. A general discussion is given in Section 7-1 of the concept that interacting particles can manifest this interaction by altering their motion, and this change in motion can be used to measure the strength of the interaction or the force. An explanation of the combination of the forces of interaction to obtain a resultant force is given in Section 7-3. The rules given on the bottom of p. 108 pertain to drawing a free-body diagram and solving problems. Carefully study some of the excellent free-body diagrams in Figures 8-5(b) and 8-6(b) and (c).

Objective 2 is covered in several sections. Newton's first law is stated on pp. 56 and 106. Newton's second law is stated verbally in Section 8-1 and mathematically in Eqs. (7-4) (for this module you will only need the simpler form $\vec{F} = m\vec{a}$) and (8-1). The relationship between mass and weight is given in Eq. (7-10). Objective 3 is developed in Section 7-5.

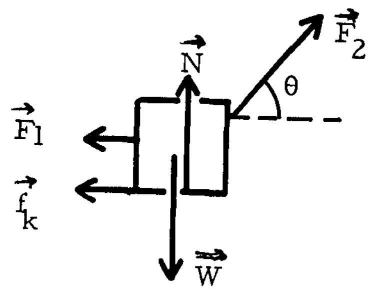
PROBLEM SET WITH SOLUTIONS*

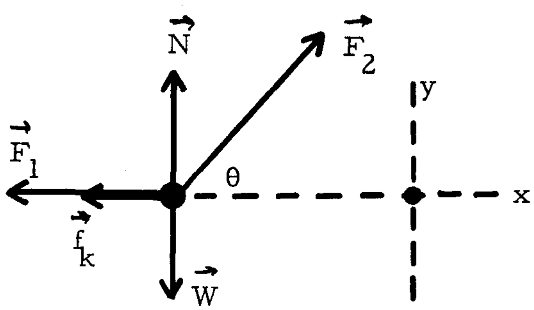
A(1). Given the situation pictured at the right, specify all the forces acting on the body B (mass M_2) and draw a free-body diagram for B.



Solution

We are interested in body B (contained in the dotted lines). $\vec{F}_1$ represents the force that rope 1 exerts on B. $\vec{F}_2$ represents the force that rope 2 exerts on B. $\vec{f}_k$ represents the frictional force on B that opposes the motion. $\vec{W}$ represents the weight or the attraction of the earth for B, $\vec{W} = m\vec{g}$. $\vec{N}$ represents the force that the supporting plane exerts on B.





Free-Body Diagram

*Each of the problems satisfying Objective 4 should also satisfy Objective 1 if worked properly.

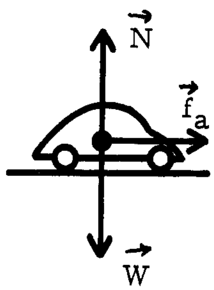
B(1). A small car has a mass of 800 kg. It can accelerate uniformly from rest to 30.0 m/s in 8.0 s, and its brakes slow it down from 30.0 m/s to 15.0 m/s in 5.0 s.

(a) Draw free-body diagrams for the car while it is accelerating and while it is decelerating (brakes applied).

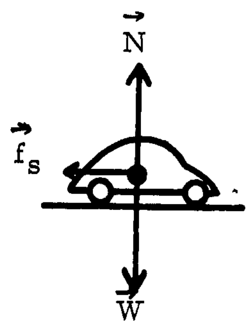
(b) Express the force exerted by the road in terms of the resultant force and the weight.

Solution

(a)



Acceleration



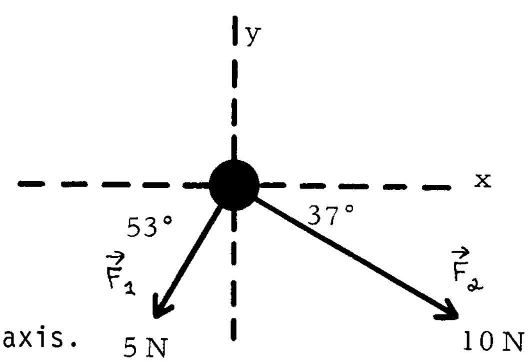
Deceleration - Brakes Applied

(b) The supporting road exerts a normal force $\vec{N}$ perpendicular to the plane of the road, and a frictional force $\vec{f}_a$ or $\vec{f}_s$ parallel to the plane of the road.

$$\vec{F}_c = \vec{F} - \vec{W}$$

where $\vec{F}_c = \vec{N} + (\vec{f}_a \text{ or } \vec{f}_s)$.
$\vec{F}$ is the resultant force which is parallel to the road, and $\vec{F} = \vec{F}_c + \vec{W}$.

C(2). Find the acceleration of the object (weight 5.0 N) under the action of the forces shown in the diagram. The object shown is constrained to move in the x-y plane under the influence of $\vec{F}_1$ and $\vec{F}_2$. The weight of the object acts straight into the paper along the z-axis.



Solution

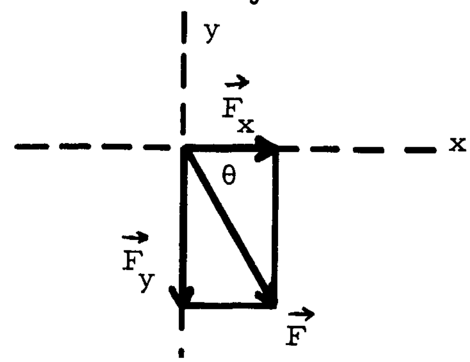
From Newton's second law $\vec{F} = m\vec{a}$, where $\vec{F}$ is the net force. Therefore $\vec{F} = \vec{F}_1 + \vec{F}_2$. Vectorially adding $\vec{F}_1$ and $\vec{F}_2$:

$F_x = F_{1x} + F_{2x} = -F_1 \cos 53° + F_2 \cos 37° = -3.0\text{ N} + 8.0\text{ N},\ F_x = 5.0\text{ N},$

$F_y = F_{1y} + F_{2y} = -F_1 \sin 53° - F_2 \sin 37° = -4.0\text{ N} - 6.0\text{ N},\ F_y = -10.0\text{ N},$

$F = [F_x^2 + F_y^2]^{1/2} = [125\text{ N}^2]^{1/2} = 11.2\text{ N}.$

$\tan\theta = \frac{10\text{ N}}{5\text{ N}} = 2.0,\quad \theta = 63.4°$ below x axis.



$\vec{F} = m\vec{a} = (W/g)\vec{a}$ or $|\vec{a}| = Fg/W.$

$a = \frac{(11.2\text{ N})(9.8\text{ m/s}^2)}{5.0\text{ N}} = 22\text{ m/s}^2$

in the same direction as $\vec{F}$, or 63.4° below the +x axis. Using unit-vector notation:

$\vec{a} = a_x\hat{i} + a_y\hat{j} = \frac{F_x}{m}\hat{i} + \frac{F_y}{m}\hat{j} = \vec{a} = (9.8\hat{i} - 19.6\hat{j})\text{ m/s}^2.$

D(2). A particle of weight 19.6 N is subject to forces of 3.00 N east and 2.00 N north but travels south at a constant acceleration of 1.00 m/s^2. What third force must act on the particle?

Solution

The net force $\vec{F}$ must be south. (You should know why.) From Newton's second law:

$\vec{F} = m\vec{a},$

$\vec{F} = \frac{W}{g}\vec{a} = \left(\frac{19.6\text{ N}}{9.8\text{ m/s}^2}\right) 1.00\text{ m/s}^2 = 2.00\text{ N}$ (net force).

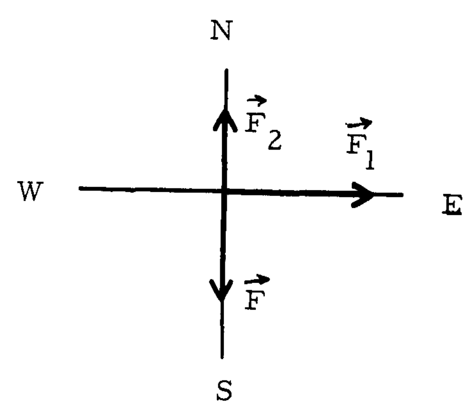
$\vec{F} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3,$

$F_x = F_{1x} + F_{2x} + F_{3x},$

$F_y = F_{1y} + F_{2y} + F_{3y},$

$F_{3x} = -3.00\text{ N},$

$F_{3y} = -4.00\text{ N},$



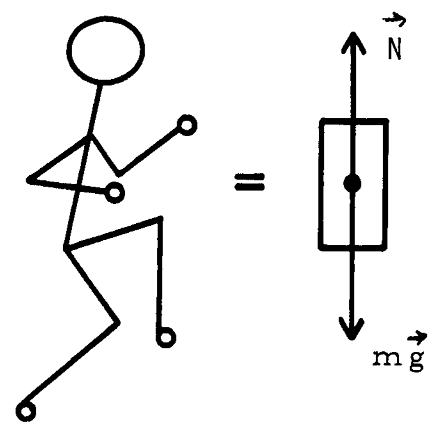
so $\vec{F}_3 = 5.00$ N, 53° south of west, or

$\vec{F}_3 = (-3.0\,\hat{i} - 4.0\,\hat{j})$ N.

E(3). When a high jumper leaves the ground, what object exerts the force that accelerates him upward?

Solution

Let's draw a free-body diagram and see. Considering the man as a unit, we find that the only external forces acting are his weight $m\vec{g}$ and the normal force $\vec{N}$ of the ground. Where does $\vec{N}$ come from? It's the reaction force to the downward force of magnitude N exerted by the man's foot against the ground. As long as $\vec{N} = -m\vec{g}$, the man's center of mass can accelerate neither up nor down.

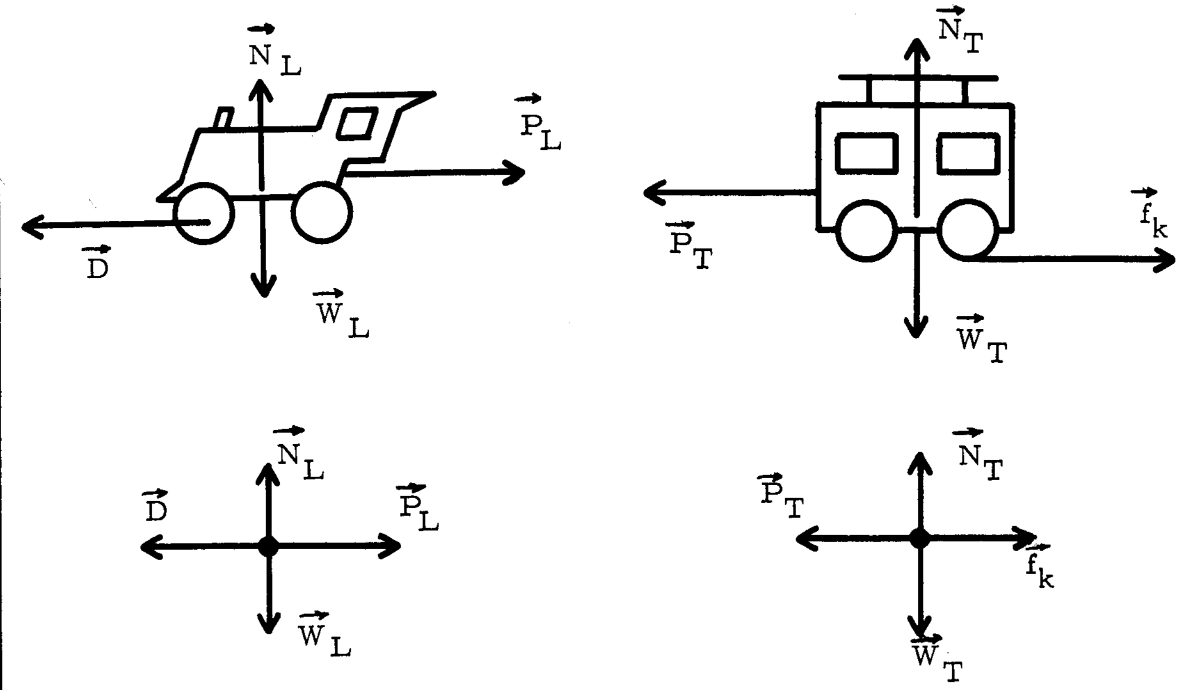


By suddenly straightening his leg, however, the high jumper can increase the force exerted against the ground. $\vec{N}$ will increase correspondingly and his center of mass will accelerate upward. If this acceleration is large enough, he can actually leave the ground. So in one sense, the force that accelerates him (as a unit) upward is exerted by the ground. However, bear in mind that part of $\vec{N}$ is simply a reaction force to forces generated inside his body - forces that allowed him to push his foot down against the ground with a force considerably greater than his own weight.

F(3). A locomotive engineer reads an excerpt from a freshman physics text and then decides to quit his job. His reason is that, according to Newton's third law, the train always pulls backward on the locomotive with a force just as great as that which the locomotive exerts on the train, and therefore the train can never move. As personnel supervisor, you are assigned the task of explaining the situation. Explain it.

Solution

These two forces form an action-reaction pair and <u>must act on different bodies</u>. Let's draw a free-body diagram of the locomotive and the train.



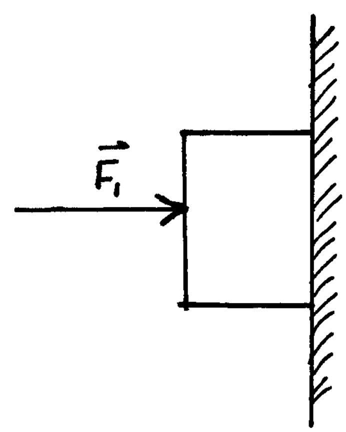
Since $\vec{P}_L$ and $\vec{P}_T$ form the action-reaction pair,

$\vec{P}_L = -\vec{P}_T$,

$\vec{D} + \vec{P}_L = M_L\vec{a}$, Locomotive where $D - P_L > 0$;

$\vec{P}_T + \vec{f}_k = M_T\vec{a}$, Train where $P_T - f_k > 0$.

G(4). A constant horizontal force $\vec{F}_1$ pushes a block of mass 2.00 kg against a vertical wall. The coefficient of static friction between the block and the wall is $\mu_s = 0.60$, and the coefficient of kinetic friction is $\mu_k = 0.40$.



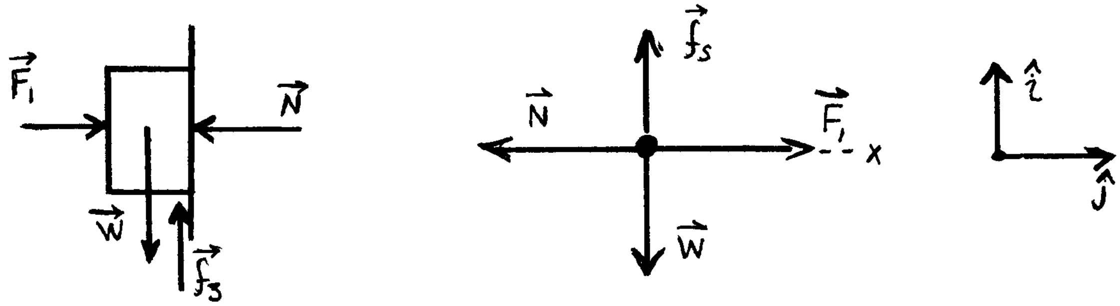
(a) Draw a free-body diagram for the block.

(b) What is the minimum value of $\vec{F}_1$ for which the block will not slip, if it is at rest initially?

(c) Suppose that $\vec{F}_1$ has this minimum value. The block is given a short downward push, just to start it moving. What acceleration will the block have after this push?

Solution

(a)



$\vec{N}$ is the normal force that the wall exerts on the block;

$\vec{f}_s$ is the static frictional force that the wall exerts on the block;

$\vec{W}$ is the weight of the block;

$\vec{F}_1$ is the applied force.

(b) Assume the block is stationary, i.e., zero accelerations in the x and y directions. Apply Newton's second law to the block:

$\Sigma F_x = ma_x, \quad \vec{F}_1 + \vec{N} = 0$ (1)

$\Sigma F_y = ma_y, \quad \vec{f}_s + \vec{W} = 0, \quad \vec{W} = m\vec{g}.$ (2)

The frictional force is given by

$\vec{f}_s \le \mu_s \vec{N}.$

Note: The frictional force depends on the normal, but since $\vec{N} = \vec{F}_1$, the normal depends on the applied force. Therefore the frictional force that "holds" the body up is controlled by the applied force (i.e., we are "pressing" the surfaces in closer contact and making them "bind" more).

From Eq. (2) $\vec{f}_s = \vec{W} = m\vec{g} \le \mu_s \vec{N} = \mu_s \vec{F}_1$, so $\vec{F}_1 \le m\vec{g}/\mu_s$.

The minimum value of $\vec{F}_1$ is $m\vec{g}/\mu_s$:

$$(\vec{F}_1)_{min} = \frac{(2.0\ \text{kg})(9.8\ \text{m/s}^2)}{(0.60)} = 33\ \text{N}.$$

(c) Now $f_k - mg = ma_y$ and $_1 = N$:

$$f_k = \mu_k N = \mu_k F_1,$$

so

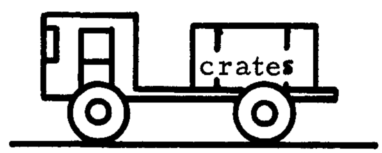
$$a_y = \frac{f_k - mg}{m} = \frac{\mu_k F_1 - mg}{m} = \frac{(\mu_k mg/\mu_s) - mg}{m},$$

$$a_y = g(\mu_k/\mu_s - 1) = (9.8\ \mathrm{m/s^2})\ (0.40/0.60 - 1),$$

$$a_y = -3.3\ \mathrm{m/s^2}.$$

The minus sign designates the acceleration is downward.

H(4). A truck driver has a load of crates on a flat-bed truck and is traveling along a highway at 26 m/s. If the coefficient of friction between crates and truck is 0.80, what is the shortest distance in which he can stop without letting his load slide?



Solution

Assume the deceleration is constant and the final speed is zero. Take the origin of our coordinate system to be a point where the truck begins to decelerate and the x axis along the roadway.

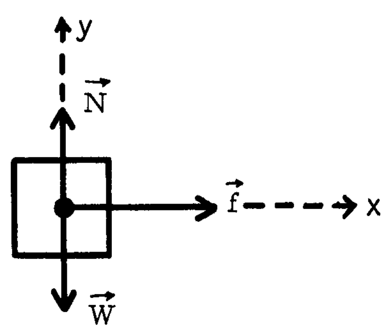
In order for the crate not to slide, what must its speed be relative to the truck bed? Therefore what must be its deceleration relative to our coordinate system?

Free-body diagram of the crate

$\vec{N}$ = normal force,

$\vec{W}$ = weight of crate = $m\vec{g}$,

$\vec{f}$ = frictional force.



Applying Newton's second law:

$$\Sigma F_x = ma_x \quad \text{and} \quad \Sigma F_y = ma_y,$$

$$f = ma_x, \quad N = W = mg,$$

but $f \le \mu_s N$. Assume the maximum frictional force to allow the greatest deceleration before sliding begins: $f = \mu_s N$.

Combining equations leads to $a_x = \mu_s g$ or $a_x = 7.8\ \mathrm{m/s^2}$.

Now we have the initial speed, final speed, and acceleration, which allows us to determine the distance:

$$x = \frac{v_x^2 - v_{x0}^2}{2a_x} = -43 \text{ m.}$$

Problems

I(1). A youngster coasts down a hill of angle θ on his sled.

(a) Identify all forces acting on the youngster.
(b) Draw a free-body diagram of the youngster.

J(1). A tractor climbs a steep grade of angle θ.

(a) Identify all forces acting on the tractor.
(b) Draw a free-body diagram of the tractor.

K(2). A body whose mass is 3.00 kg lies on a smooth horizontal plane. Introduce a coordinate system for answering the following questions:

(a) A horizontal force of 12.0 N is applied in a certain direction. Find the vector acceleration.
(b) A horizontal force of 5.0 N is applied, at right angles (clockwise, looking down) to the force in (a), which is removed. Find the vector acceleration.
(c) Find the vector acceleration when both forces are applied (polar and rectangular descriptions).

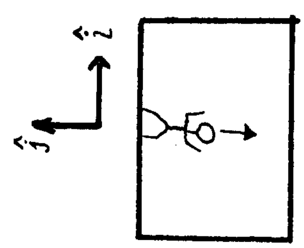
L(2). A skier of mass M gathers speed down a slope (angle θ to the horizontal) even though experiencing a force of friction $\vec{f}$.

(a) Make a free-body diagram for the skier.

(b) Find the acceleration of the skier.

(c) What information about the force $\vec{f}$ is implied by this problem?

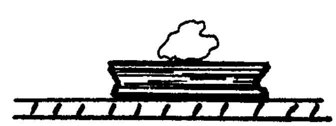
M(3). A 72-kg astronaut pushes away from the side of his 700-kg space capsule with a force of 20.0 N. What happens to the space capsule?



N(3). A book with a rock lying on top of it lies in turn on a table top.

(a) Draw a free-body diagram of the book.

(b) Identify the reaction force to each force acting on the book.



O(4). The coefficient of dynamic friction of a block on an inclined plane may be determined by raising the plane just enough so the block slides with uniform speed, and measuring the angle of inclination of the plane:

(a) Make a free-body diagram for the block.
(b) Derive a relationship between the angle and the coefficient of friction for these conditions.

P(4). A block slides down an inclined plane of angle ϕ with constant velocity. It is then projected up the same plane with an initial speed v_0.

(a) How far up the incline will it move before coming to rest?
(b) Will it slide down again?

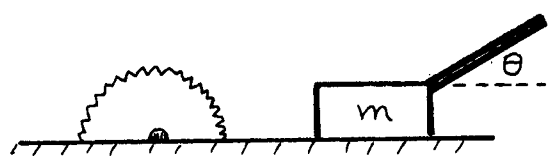
Q(4). A 29.0-kg block is pushed up a 37° inclined plane by a horizontal force of 440 N. The coefficient of friction is 0.250. Find:

(a) the acceleration;
(b) the velocity of the block after it has moved a distance of 6.0 m along the plane, assuming it started at rest; and
(c) the normal force exerted by the plane.

R(4). A hockey puck having a mass of 0.110 kg slides on the ice for 15.2 m before it stops.

(a) Draw a free-body diagram of the puck including friction.
(b) If its initial speed was 6.1 m/s, what is the force of friction between the puck and ice?
(c) What is the coefficient of kinetic friction?

S(4). A man pushes a board of mass m through a circular saw by pushing down on it with a stick as shown:



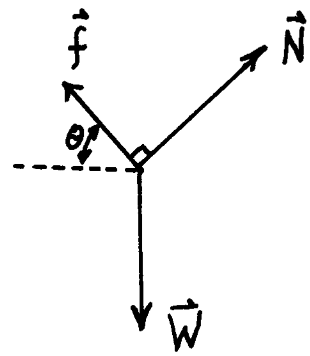
(a) Find the force $\vec{F}$ that must be exerted to make the board slide with constant speed, in terms of the angle θ, the coefficient of friction, and the mass of the board.
(b) Show that if the angle is too steep, the board cannot be made to slide, no matter how great a force is applied. Find this critical angle.

Solutions

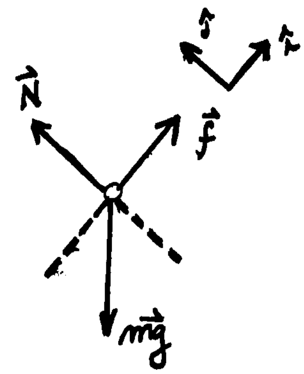
I(1). (a), (b) $\vec{N}$ = normal force that the sled exerts on the youngster (to sled),

$\vec{f}$ = frictional force that the sled exerts on the youngster (to sled),

$\vec{W}$ = weight of the body.

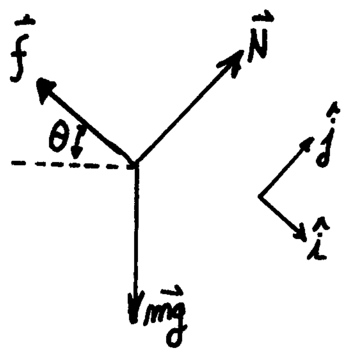


J(1). (a), (b) The surface of the ground exerts both $\vec{N}$ and $\vec{f}$ whereas the earth as a whole exerts $\vec{W}$.



K(2). (a) $4.0\hat{j}$ m/s^2,
(b) $1.70\hat{i}$ m/s^2,
(c) $(1.70\hat{i} + 4.0\hat{j})$ m/s^2, 4.3 m/s^2, θ = 1.2 rad.

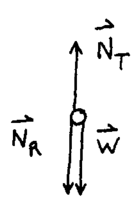
L(2). (a)



(b) $g \sin\theta - f/M$.
(c) $\vec{f} < M\vec{g} \sin\theta$.

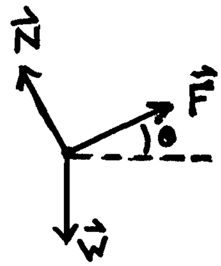
M(3). Accelerates at 0.0300 m/s^2 in j direction until the astronaut hits the other side.

N(3).



Action	Reaction
$\vec{N}_T$	Book exerts downward force on the table $(-\vec{N}_T)$
$\vec{N}_R$	Book exerts upward force on the rock $(-\vec{N}_R)$
$\vec{W}$	Book attracts the earth with a force $-\vec{W}$

O(4). (a)



(b) $\mu = \tan\theta$.

P(4). (a) $v_0^2/4g \sin\phi$.

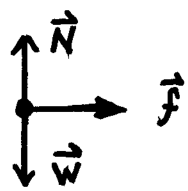
(b) No.

Q(4). (a) 2.00 m/s^2.

(b) 4.9 m/s

(c) 490 N.

R(4). (a)



(b) 0.130 N.

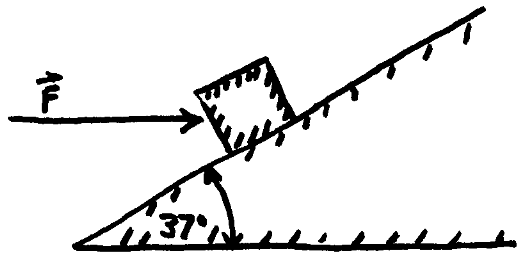
(c) 0.120.

S(4). (a) $\mu mg/[\cos\theta - \mu\sin\theta]$.

(b) $\theta = \text{arc} \cot \mu$.

PRACTICE TEST

1. A 50-kg block on an inclined plane is acted upon by a horizontal force of 50 N. The coefficient of friction between block and plane is 0.300.

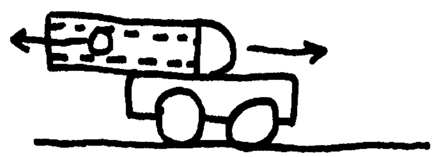


   (a) Draw a free-body diagram of the block, assuming it is moving up the plane.

   (b) What is the reaction force to the force $\vec{F}$ acting on the block?

   (c) What is the acceleration of the block if it is moving up the plane?

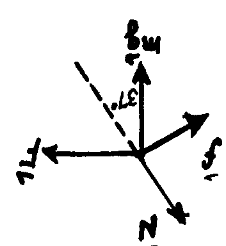
   (d) How far up the plane will the block go if it has an initial upward speed of 4.0 m/s?



2. A 730-kg cannon fires a 4.0-kg cannon ball. While it is in the barrel, the cannon ball has an acceleration of 30 000 m/s^2. What is the acceleration of the cannon?

Practice Test Answers

1. (a)



   (b) The reaction is a force $-\vec{F}$ pushing on the agent.

   (c) $-7.2\ m/s^2$.

   (d) 1.10 m.

2. 164 m/s^2 to the right.

DATE______________________________

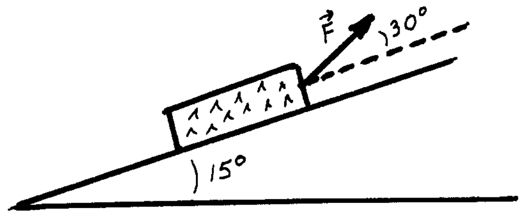
NEWTON'S LAWS

pass   recycle

Mastery Test   Form A   1   2   3   4

Name______________________________ Tutor__________________________________

An elephant is being used to pull a large log up a hill having a slope of 15^o. The log has a mass of 500 kg, and the coefficient of friction between the log and the ground is 0.200. The pulling rope makes an angle of 30^o with respect to the ground as shown in the figure.



1. Draw a free-body diagram of the log.

2. What is the reaction force to each of the forces acting on the log?

3. What force must the elephant exert ($\vec{F}$) for the log to be pulled at a constant speed?

4. If the rope breaks and the log slides down the hill, what is its acceleration?

<u>Note</u>: $\sin 15^o = 0.258$; $\sin 30^o = 0.50$;

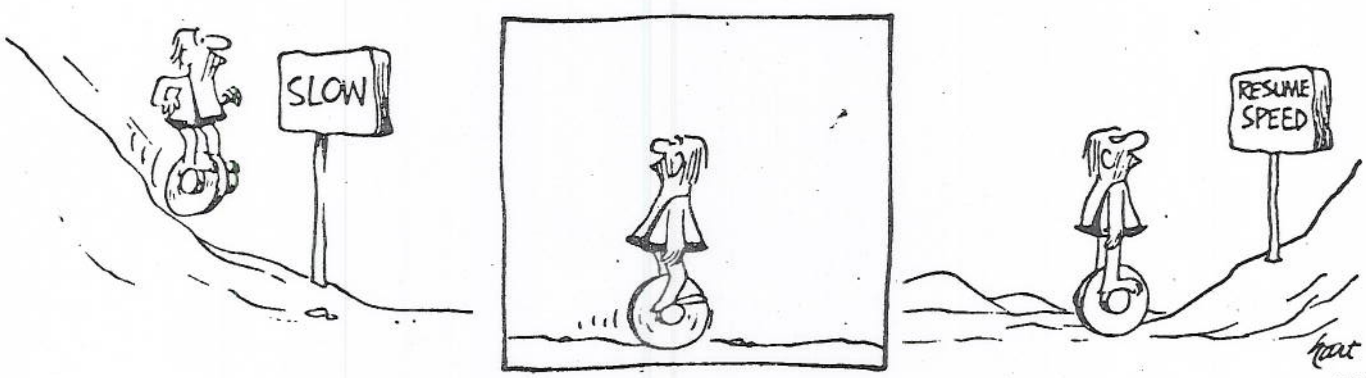
$\cos 15^o = 0.97$; $\cos 30^o = 0.87$.

PHYSICS 101

MODULE 6: Energy

"If you asked a physicist, 'What is the single most fundamental law of physics?' he would probably answer, after some grumbling about stupid unanswerable questions, 'The law of conservation of energy.' If you then asked him what energy *is*, anyhow, he probably would refuse to answer -- and rightly so, as we shall see in this chapter."

(from Physics for Poets by Robert H. March)



Fall, 1981

REPRINTED H 82, A82, A83

Objectives

- recognize forms of energy in the world and describe how they transform from one to the other.
- calculate work done by constant and varying forces in one and two dimensions.
- derive the formulas for the forms of mechanical energy from work.
- recognize that work is a transfer of energy.
- calculate from the definitions the power and efficiency of machines.
- apply conservation of energy to solve problems involving conservative systems.
- apply the concepts of energy and work to systems involving friction.
- solve simple problems involving elastic collisions in one and two dimensions.

Resource Material

Videotape: Energy and Power - an introduction and some sample problems

Film Loops: Conservation of Energy: Pole Vault
Gravitational Potential Energy
Kinetic Energy
A Method of Measuring Energy: Nails Driven into Wood
Conservation of Momentum - Elastic Collisions

Books: *March, Physics for Poets - excellent for this module
*The Project Physics Course, Text and Handbook #3 - highly recommended
Halliday and Resnick, Fundamentals of Physics (2nd edition)
Feynmann, Leighton and Sands, The Feynmann Lectures in Physics vol.1 - good introduction to the idea of energy
Tipler, Physics - equations and problems but not much explanation
Hewitt, Conceptual Physics - basic, easy to understand
Freeman, Physics, Principles and Insights
P.S.S.C., College Physics
Project Physics, Reader #3

Periodical: S.S. Wilson, "Bicycle Technology" from Scientific American, March 1973
- discusses how the human body converts internal biological energy into external work

Lab Experiment: Conservation of Energy

Detailed Outline

6.1 The Nature of Energy

- What is Energy?

Energy is a quantity which we say objects possess. It exists in many forms and is more or less related to the motion of objects or their potential to move or make other objects move. Energy may change from one form to another or be transferred from one object to another, but it is never created or destroyed. This fact is called the Law of Conservation of Energy.

Two of the best references (Project Physics and Physics for Poets) "trace the history of the law of energy conservation from its humble origin as an approximate mechanical law. But the true power of energy conservation comes precisely from the fact that it is not a purely mechanical law. It can only be established as a general law by forming a bridge between mechanics and other fields of physics."

Appendix 1, in the inimitable style of Richard Feynmann, gives a simple analogy to the historic quest for the all-inclusive concept of energy. Read it.

- Energy Transfers in Everday Phenomena

Energy is a concept that pervades everyday life as well as being useful in physics. In these days of "energy crisis" it is useful to be able to recognize the forms of energy we use and see what their ultimate origins are. With a few exceptions (such as nuclear and geothermal energy) all energy on earth comes ultimately from the sun. Read Appendix II: "Energy Conservation on Earth" and some of the following references.

References: *Feynmann, section 4-1
*March, page 67-79(middle of page)
*Project Physics Text #3, page 20-23,31-43, and sections 10.8,10.10 & 10.11
Project Physics Reader #3, chapt.3
Hewitt,page 52 to 62 and exercises 11-18 on p.66
Tipler, pp.186-188

Film loop: Conservation of Energy: Pole Vault

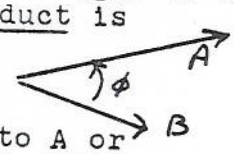
6.2 Work

Many of the formulas for energy can be derived from Newton's laws by first defining a quantity called "work". Work is <u>not</u> a form of energy, but the work done in a particular interaction is a measure of <u>how much energy</u> has been transferred either from one form to another or from one object to another.

- Scalar Product of Two Vectors

<u>definition:</u> for any two vectors $\vec{A}$ and $\vec{B}$ with an angle of ϕ between them, the <u>dot product</u> or <u>scalar product</u> is

$$\boxed{\vec{A}\cdot\vec{B} = A\,B\cos\phi}$$



that is, A times the component of B parallel to A or
B " " " " A " " B.

- Work

<u>definition</u>: for a <u>constant</u> force , the work done by the force F on the object <u>in question</u> is

$$\boxed{W = \vec{F}\cdot\vec{\Delta s}}$$

where: $\vec{F}$ = the force in question - <u>not necessarily the resultant force</u>
$\vec{\Delta s}$ = the displacement of the object

N.B. W is a scalar and is measured in joules (J)
1 joule = 1 kg m^2/s^2

- for a <u>changing</u> force <u>in one dimension</u> where F is a function of x ($\overline{F(x)}$):

$$W = \int_{x_1}^{x_2} F(x)\,dx$$

= area under the F vs x curve

- for the definition of work done by a changing force in two or three dimensions, see H & R section 7-4.

References: Tipler sec. 7-1,7-3,7-5,7-7
Hewitt pp 46-47
Feynmann p 14-2
H & R sec 7-1, 7-2, 7-3, 7-4

EXERCISES: H & R p 103 Questions #2,3,4,5
H & R p 104 Problems 1, 5 (omit f), 6,7(a),9

Exercises (cont'd)

1. If A = 3 and B = 6, and $\vec{A}.\vec{B} = 4$, find the angle between $\vec{A}$ and $\vec{B}$
2. If $\hat{i}$, $\hat{j}$, and $\hat{k}$ are mutually perpendicular unit vectors, what is the value of each of the possible dot products ? ($\hat{i}\cdot\hat{i}$, $\hat{i}\cdot\hat{j}$, $\hat{i}\cdot\hat{k}$, etc) Can you formulate a simple rule to describe the pattern in your results ?
3. If $\vec{A} = A_x\,\hat{i} + A_y\,\hat{j} + A_z\,\hat{k}$ and $\vec{B} = B_x\,\hat{i} + B_y\,\hat{j} + B_z\,\hat{k}$, find A . B
4. A force of $5\,\hat{i} + 6\,\hat{j}$ Newtons acts on a mass during a displacement of $2\,\hat{i} - 3\,\hat{j}$ metres; find the work done by the force.
5. Same as 4. above but the force is $6\,\hat{i} - 4\,\hat{j}$ Nt and the displacement is $2\,\hat{i} + 3\,\hat{j}$ m.
6. For each of 4. and 5. above, find the magnitude of $\vec{F}$ and of $\vec{\Delta s}$, and find the angle between them.
7. Calculate the work done in moving a 1 kg book
   (a) from the floor under a desk to the top of the desk 0.7 m high.
   (b) from the floor under one desk to the top of another desk which is 5 m away.
   (c) from the top of that desk back to the top of the first desk.
   (d) from the top of a desk to the floor under that same desk.
   (e) from the top of one desk to the floor under another desk 5 m away.
8. How much work is done by the sun on the earth in the course of one year?

6.3 <u>Forms of Energy</u>

Kinetic Energy

<u>Work done by the resultant force</u> on an object is equal to the <u>change in kinetic energy</u> of that object. This statement is known as the "Work-Energy Theorem" and is the basis of the relationship between work and energy.

$$\boxed{KE = \tfrac{1}{2}\,mv^2}$$

$$\boxed{WD_{F_{Res}} = (\tfrac{1}{2}\,mv^2)_f - (\tfrac{1}{2}\,mv^2)_i}$$

Gravitational Potential Energy

Work done against gravity in raising on object to a higher position is called the change in gravitational potential energy of that object. For a constant gravitational force, we can declare an arbitrary position to correspond to zero potential energy. Then

$\boxed{GPE = mgh}$ where: h = vertical height above the arbitrary zero level

Note: - To avoid the problem of what to call "zero height" it is usually useful to calculate only the change in GPE.

- Strictly speaking, the GPE belongs to the earth-object system and not just to the object itself. However, when the motion of the earth is negligible we usually attribute the energy to the object alone.

Elastic Potential Energy

Work done in stretching or compressing a spring is stored in the spring as elastic potential energy.

$$\boxed{EPE = \frac{1}{2} kx^2}$$

where: k = the spring constant (recall F = kx) in N/m
x = the amount the spring has been stretched or compressed from its normal length.

Note: The term "potential"energy means that if the force responsible for the potential energy (eg. the gravitational or elastic force) is allowed to do work on the object, the energy originally expended in increasing the potential energy can be recovered as kinetic energy.

Heat

The kinetic energy of the molecules in a substance. Whenever friction does work on an object, it changes other forms of energy into heat. This is because the two surfaces rubbing together cause the molecules near the surface to move around or vibrate faster. Heat is often measured in calories. 1 calorie = 4.2 J

Other Forms of Energy

chemical, electrical, nuclear, radiant (light), sound, mass (!?!), etc.

References: H & R sec 7-3 (middle of page 97 to end), 7-5,6
*Project Physics Text #3, p.31-43 & sec.10.10
*Tipler, sec.7-2,7-4
*March, pp.69-79
PSSC, sec.17-1 to 17-4,17-10,18-1 to 18-4,18-6
Freeman, sec.9.1 to 9.10
Hewitt, pp48-51

film loops: Grav. Pot. Energy
Kinetic Energy
A Method of Measuring Energy

Exercises H&R p 103 Questions 7,8,9 (neglect air resistance)
p 105 Problems 12,13,16,14,17,22

9) Estimate the kinetic energy of each of the following:
(a) a pitched baseball (b) a jet plane
(c) a sprinter in a 100 m race
(d) the earth in its motion around the sun.

10) Hang a known weight from a rubber band and measure the elongation of the band. Calculate the energy stored in the band.

11) Fill two mixing bowls with cold water and measure their temperatures. Then run an egg beater in one bowl for a few minutes. Compare the temperatures of water in the two bowls. Describe the energy transfers which have taken place.

12 What becomes of the original kinetic energy when
(a) an egg drops on the floor?
(b) a spectator at a show claps his hands?
(c) a hammer hits a nail?
(d) What happens to the potential energy when a skydiver falls at terminal velocity?

13) J.P.Joule tried to measure the difference in temperature between the top and the bottom of a waterfall in Switzerland. If you assume that the amount of heat produced is roughly equal to the loss of GPE, calculate the temperature difference you would expect to observe between the top and bottom of a waterfall about 50 m high (like the one at Niagara).

14) when one pound of stored animal fat is "burned" it provides about 4300 kcal (kilocalories) of energy. Suppose that on your present diet of 4000 kcal/day you keep a constant weight. If you cut your diet to 3000 kcal and maintained the same physical activity, how much weight would you lose in a month?

6.4 Power and Efficiency

Definitions:

power: the rate at which energy is transferred (work is done)

$$\text{average power} = \frac{\text{work done (energy transferred)}}{\text{time taken to do it}}$$

machine: any device that changes one form of energy to another.

efficiency: the efficiency of a machine =

$$\frac{\text{the amount of energy converted to the desired form}}{\text{the amount of energy used}} \times 100\%$$

From conservation of energy it can be seen that no machine can be more than 100% efficient. In fact the presence of friction means that all real machines are less than 100% efficient.

The unit of power is the watt (W). 1 W = 1 J/s

When a force $\vec{F}$ acts on an object with instantaneous velocity $\vec{v}$, the instantaneous power developed is $\boxed{P = \vec{F} \cdot \vec{v}}$

References: Hewitt, p.47-48 and 51-55
Tipler, sec. 7-6
H & R sec 7-7

Exercises H & R p103 Questions 10,11,12
H & R p105 Problem 24

15. A 500 kg elevator is accelerating upward from rest at 2 m/s^2
    a) Find the tension in the cable.
    b) Find the work done by the cable in rising 4 m.
    c) Find the average power developed by the cable.
    d) Find the instantaneous power developed at t = 0 sec; at t = 1 sec; at t = 2 sec.

16. An elevator weighing 10000 N is moving upward at a constant velocity of 3 m/s.
    (a) How much energy per second is used to keep it moving if you neglect friction?
    (b) What power is needed to keep it going at that rate with no friction?
    (c) Suppose that due to friction, etc, the efficiency of the elevator is 60%. If it is an electric elevator how much electric power does it use?

17) An electric kettle holds a kilogram of water (about 1 quart). It is rated at 600 watts. Estimate how long it will take the water to reach boiling point, starting from room temperature (20°C). What assumptions have you made?

18) One of the base camps for hikers in the White Mountains is at 500 m altitude near a mountain of 1800 m altitude. Suppose that you (weight = 600 N) take your pack (weight = 100 N) and set out to conquer the mountain.
(a) How much work do you do in climbing the vertical distance between the base camp and the mountain top?
(b) If you can only develop 40 watts during the climb, how many hours does it take you?
(c) Your friend (wt = 780 N, pack wt = 120 N) develops the same power as you. Does his hike take the same time, less or more than yours? Why?

19) Is it possible to design an electrical system so that the generator, once started, would produce enough electricity to operate a motor, which in turn could power the generator so that the system would run itself? Explain.
Note: A generator is a device that converts other forms of energy into electrical energy. A motor is a device which changes electrical energy into mechanical work.

6-5 Conservative vs Non-conservative Forces: Problem-Solving Using Energy

For mechanical systems, the law of conservation of energy can be derived from Newton's laws; so theoretically any problem that can be solved using the concept of energy can be solved using Newton's laws and vice versa. In practice, energy methods are often much simpler and more useful, especially when dealing with forces that are not constant or when we only want the final result of a process and not the details of the process itself.

a) When work is done on a system against some kinds of forces, the energy gained by the system can directly be recovered as kinetic energy e.g. when we lift a book upward against gravity, then release it e.g. when we compress a spring against its elastic restoring force, then release it.

Such forces, each of which has a potential energy associated with it, are called conservative forces. When dealing with such forces, it is useful to define a new quantity, the mechanical energy (ME) = KE + Sum of all forms of potential energy.
For a system in which the only external forces are conservative ones, the total mechanical energy is conserved: $\boxed{KE + EPE + GPE + \ldots = \text{const}}$

As time goes on and the system evolves, the way the energy is partitioned among the various forms KE, EPE, GPE, etc may change; the total ME however remains constant.

b) On the other hand, some forces cannot be associated with any form of potential energy; when work is done against such <u>non-conservative forces</u>, the energy gained is <u>not</u> recoverable as KE e.g. when we push an object against <u>friction</u>, the work we do increases the <u>heat</u> energy of the system, but cannot be recovered as macroscopic KE when we stop pushing. The work done <u>by</u> friction <u>on</u> the system is always negative (Why ?) and is equal to the <u>change</u> in mechanical energy or <u>minus</u> the <u>change</u> in heat energy

$$WD_{\text{by friction}} = \Delta ME = -\Delta(\text{Heat energy})$$

Thus for a system where friction is the only non-conservative force acting, $\Delta ME + \Delta(\text{Heat energy}) = 0$

or

$$\boxed{KE + \text{Sum of all forms of PE} + \text{Heat energy} = \text{constant}}$$

c) If non-conservative forces <u>other</u> than friction act on the system , the work done by these forces $= \Delta ME + \Delta(\text{Heat energy})$

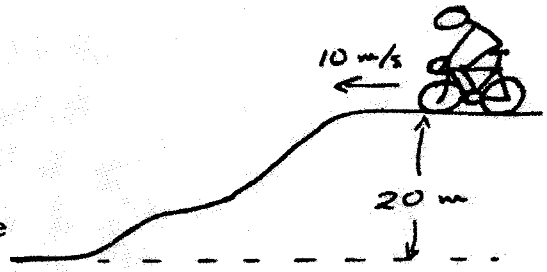
In such cases it is found that the work done by the non-conservative force is accompanied by an energy change in some <u>other</u> system (the object <u>applying</u> the force, for instance) ; this energy change is equal and opposite to the energy change in the original system $(\text{Total energy})_{\text{system 1}} = -(\text{Total energy})_{\text{system 2}}$

By including both <u>systems</u>, we find once again $\boxed{E_{tot} = \text{constant}}$

So far as we know, it is <u>always</u> possible to find, for <u>any</u> event, a system in which the total energy is conserved. (Recall the similar discussion for the law of conservation of linear momentum)

To solve a problem using energy, you must first decide what sorts of forces act on the system. If only conservative forces do work, then the mechanical energy is conserved. If friction is the only non-conservative force which does work, then the sum of the ME and the Heat energy is conserved. If other non-conservative forces do work, the WD by them is equal to the change in the total energy of the system. In all cases, the work done by the <u>resultant</u> force (no matter what sort of forces make up the resultant) is equal to the change in the kinetic energy.

Example: A cyclist approaches a bumpy hill at 10 m/s. He decides to coast down the hill. Assuming he makes it, what is his speed at the bottom of the hill 20 m below?



Solution: The normal force on him does no work in this case (Why not?) We will neglect friction and air resistance. Thus only gravity (a conservative force) does work on him $\therefore$ $KE + GPE = \text{const}$

or $\Delta KE = -\Delta GPE$ or KE gained = GPE lost

$$GPE \text{ lost} = mg\Delta h = m \times 10 \times 20 = 200m \text{ Joules}$$

$$\therefore KE \text{ gained} = KE_f - KE_i = 200m \text{ Joules}$$

$$\frac{1}{2}\cancel{m}v^2 - \frac{1}{2}\cancel{m}(10)^2 = 200\cancel{m}.$$

$$\therefore v^2 = 10^2 + 2 \times 200 = 500$$

$$\therefore v = \sqrt{500} = \boxed{22.4 \text{ m/s}}$$

If all the forces which do work are conservative but there are more than two forms of energy, a more formal approach is needed. The following steps are strongly recommended- omit one at your peril!

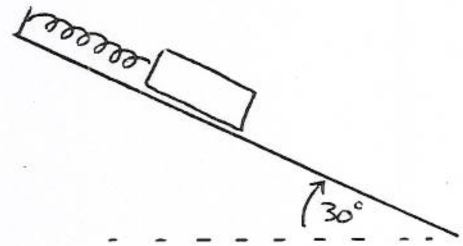
1) Check that all the forces which do work are conservative
2) For each conservative force, find the appropriate potential energy. Choose a level for zero GPE. This does not have to be ground level. "h" is then measured from this level and it may be either positive or negative depending on whether it is above or below h = 0. (Note that the position x = 0 for a spring is <u>not</u> arbitrary. This is because the spring force is not constant. You must find from the information given where x = 0.)
3) Set up an expression for the total initial energy of the system.
4) Set up an expression for the total final energy of the system.
5) Equate (3) and (4) and solve for the unknown quantities.

Example:

A 0.5 kg glider is attached by a spring ($k = 5.0$ N/m) to the upper end of an air track tilted at 30° to the horizontal. The glider is released from rest at the position where the spring is unstretched.

(a) Calculate its speed after it has moved 30 cm along the track.

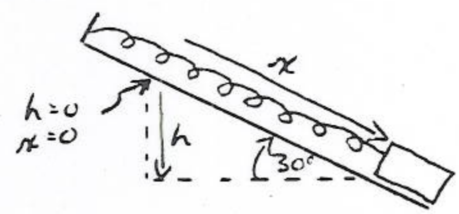
(b) How far down the track does the glider go before it stops?



Solution: Only gravitational and elastic forces do work, therefore the KE + GPE + EPE = constant

(a) Let $h = 0$ at the same position as $x = 0$.

initial position: $h = 0$, $x = 0$, $v = 0$



$\therefore$ total energy $= 0$

final position: $x = 0.3$ m

$h = -0.3 \sin 30 = -0.15$ m

below $h = 0$

$v = ?$

$\therefore$ total energy $= \frac{1}{2} m v^2 + m g h + \frac{1}{2} k x^2$

$= \frac{1}{2} \times 0.5 \times v^2 - 0.5 \times 10 \times 0.15 + \frac{1}{2} \times 5.0 \times (0.3)^2$

$= 0.25 v^2 - 0.525$

equate initial and final total energy

$$0 = 0.25 v^2 - 0.525$$

$$v^2 = \frac{0.525}{0.25} \longrightarrow v = \boxed{1.45 \text{ m/s}}$$

(b) where it stops: $v = 0$

$h = -x \sin 30$

$x = ?$

final total energy $= \frac{1}{2}mv^2 + mgh + \frac{1}{2}kx^2$
$= 0 - 0.5 \times 10 \times 0.5x + \frac{1}{2} \times 5.0 \times x^2$
$= -2.5x + 2.5x^2$

equate initial and final total energy

$$0 = -2.5x + 2.5x^2$$

$\therefore\ x = \boxed{1.0\ m}$ The glider stops 1.0 m down the track.

References: H.&.R. sec.8-1,8-2,8-3,8-4,8-7,8-8

SEE ALSO PAGES 17—19 OF THIS MODULE.

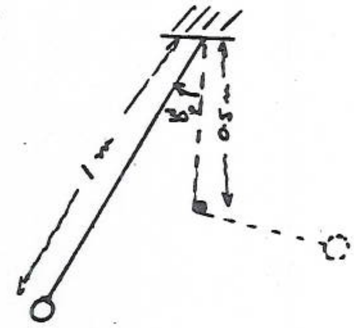
Exercises: H.&.R. questions #1,2,3,5,6 (page 126)

20. You (m = 60 kg) and your bicycle (m = 15 kg) are stopped at the top of a long hill. The height of the hill is 400 m and the length 5000 m. You coast down the hill keeping perfect control of the bicycle.
(a) How much gravitational potential energy has been lost when you are 3/4 of the way down?
(b) What happens to this potential energy? (Igno all forms of friction.)
(c) What is your velocity when 3/4 of the way down?
(d) Is this reasonable? What have we neglected that we shouldn't have?

21. An 800N hockey player cruising at 5 m/s trips over the blue line and falls. If the coefficient of friction between his pants and the ice is 0.1, how far will he slide? Solve the problem by energy methods.

22. A certain toy gun fires a 5 g bullet by means of a spring. The spring has a force constant of 100 N/m and is compressed 5 cm when the gun is loaded. Use "energy" to solve the following:
(a) If the gun is pointed straight up and fired, how high will the bullet go?
(b) What will be the bullet's velocity when it is 2/3 of the way back down?
(c) If the gun is mounted at the edge of a table 1.0 m high, what is the velocity when the bullet hits the floor?
(d) If the gun is aimed at an angle of 60° to the horizontal, how high above the table does the bullet go?

23. A mass m is suspended from a string 1 m long. It is then pulled to one side so that the string makes an angle of 30° with the vertical.
(a) Calculate the speed at the lowest point of its path after release.
(b) A peg is located 0.5 m below the point of suspension as shown so that when the pendulum swings past, the string hits the peg. How far up on the other side will the pendulum rise?
(c) As the pendulum falls and rises, is the string doing work on it? If not what is?



6.6 Elastic Collisions

Definitions:

totally inelastic collision: one in which the objects stick together after the collision. (Most of the collisions in Module 3 were of this type.)

perfectly elastic collision: one in which the total kinetic energy of the system is conserved.

Solving problems:

In any elastic collision, both the total momentum and the total kinetic energy of the system is the same before and after the collision. This means that in a two dimensional problem, you will have three equations relating the masses and velocities, two for momentum (a vector) and one for kinetic energy (a scalar).

References: H&R sec 10-4, 10-6

Example:

A neutron (mass = 1.7×10^{-27} kg) of energy 1.7×10^{-12} J runs head on into a stationary deuteron (mass = 3.4×10^{-27} kg) and bounces straight back.
(a) Assuming an elastic collision, calculate the velocity of the neutron and the deuteron after the collision.
(b) what fraction of the energy of the neutron is transferred to the deuteron?

<u>Solution:</u>

find initial velocity of neutron: $\frac{1}{2} m v_0^2 = 1.7 \times 10^{-12}$ J

$$v_0 = \sqrt{\frac{2 \times 1.7 \times 10^{-12}}{1.7 \times 10^{-12}}} = 4.47 \times 10^{7} \text{ m/s}$$

Before: After

momentum: $m_N v_0 = m_N v_N + m_D v_D$ ①

energy: $\frac{1}{2} m_N v_0^2 = \frac{1}{2} m_N v_N^2 + \frac{1}{2} m_D v_D^2$

Note that $m_D = 2 m_N$ ∴ the equations reduce to:

$$v_0 = v_N + 2 v_D \quad ①$$

$$v_0^2 = v_N^2 + 2 v_D^2 \quad ②$$

Since v_0 is known, we want to eliminate either v_N or v_D from the equations. ∴ substitute $v_N = v_0 - 2 v_D$ into ②

$$v_0^2 = v_0^2 - 4 v_0 v_D + 4 v_D^2 + 2 v_D^2$$

$$0 = -\cancel{4}^{2} v_0 \cancel{v_D} + \cancel{6}^{3} v_D^{\cancel{2}}$$

$$v_D = \frac{2}{3} v_0$$

from ①: $v_N = v_0 - 2\left(\frac{2}{3} v_0\right) = -\frac{1}{3} v_0$

Substituting for v_0: $\boxed{\begin{array}{l} v_D = 2.98 \times 10^{7} \text{ m/s} \\ v_N = -1.49 \times 10^{7} \text{ m/s} \end{array}}$

The − sign means that the neutron is moving backwards (←) after the collision.

Exercises H&R Questions p.164 #4,8,7

24. A 5kg mass moving at +6 m/s strikes a 4kg mass moving at - 7.5 m/s After the collision, the 5kg mass has velocity -4 m/s while the other has velocity + 5 m/s. Was the collision elastic ?

25. Same as 24. above but m_1 = 10 kg, v_{1i} = + 26 m/s, v_{1f} = 14 m/s and m_2 = 3 kg, v_{2i} = 0, v_{2f} = + 40 m/s .

26. A 15 gm mass is moving to the right with speed of 3 m/s toward a 6 gm mass moving to the left with speed of 7.5 m/s. Find the final velocities, assuming a perfectly elastic collision.

27. As in 26. above, but assume a perfectly inelastic collision. What fraction of the kinetic energy has been 'lost' ? Where did it go ?

28. H & R p.167 Problem #36

29. A 200 g glider with an initial velocity of 1.0 m/s collides on a level air track with a stationary glider of mass 500 g and sticks to it. Calculate the kinetic energy lost in the collision.

30. A 500 g glider with an initial velocity of 1.0 m/s collides elastically with a stationary glider of mass 200 g.
(a) Calculate the velocities of the two gliders after the collision.
(b) what fraction of the 500 g glider's original energy was given to the 200 g glider?

FURTHER HINTS FOR PROBLEM-SOLVING USING ENERGY

Almost all problems involving mechanical energy are solved using the general relationship:

Work done by non-conservative forces on a system	=	change in total mechanical energy of the system
$\vec{F} \cdot \vec{\Delta x}$		$= \Delta(KE + GPE + EPE)$

Problems tend to fall into one of three catagories:

Type 1: - No non-conservative forces do work.
- There are only two forms of mechanical energy in the system.

In this case, the left side of the general equation is zero, so the total mechanical energy is constant. Since there are only two forms of energy, the loss in one form of energy equals the gain in the other and vece versa. See the example on p.6-11 in the module.

Type 2: - No non-conservative forces do work.
- There are three (or more) forms of mechanical energy in the system.

In this case, the total mechanical energy is also constant, but a change in one form must be shared by two other forms of energy. For this reason, a more formal approach is required. This is outlined on p.6-11 on the module and illustrated on p.6-12.

Type 3: - Work is done by non-conservative forces which changes the total mechanical energy.

In this case, the full work-energy equation must be used.

If the work done is positive, the total mechanical energy of the system increases. e.g. you raise a block with your hand, or stretch a spring.

If the work done is negative, then the total mechanical energy decreases. e.g. sliding friction is acting on an object or you lower a block with your hand.

To solve problems of the third type, follow these steps:

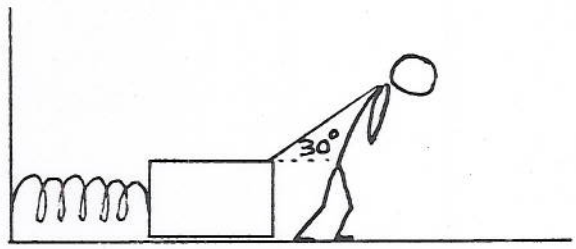
1) Choose an appropriate zero level for h and find where x = 0 (if a spring is involved).

2) Set up expressions for total initial mechanical energy and total final mechanical energy.

3) Substitute these into the equation

$$\boxed{\text{work done} = \text{total final mechanical energy} - \text{total initial mechanical energy}}$$

Example: A man pulls a crate (m = 20 kg) across a floor. The crate is attached to the wall by a spring (k = 200 N/m). He starts with the crate stationary and the spring stretched 0.5 m more than its normal length. After he has pulled with a constant force of 400 N for a distance of 1.0 m, the crate is moving 2.0 m/s. Calculate the force of friction on the crate.



Solution: total initial energy: $E_i = EPE = \frac{1}{2}kx^2$
$= \frac{1}{2} \times 200\,(0.5)^2 = 25\ \text{J}$

total final energy: $E_f = KE + EPE = \frac{1}{2}mv^2 + \frac{1}{2}kx^2$
$= \frac{1}{2} \times 20 \times 2^2 + \frac{1}{2} \times 200 \times (1.5)^2$
$= 40 + 225 = 265\ \text{J}$

work done by man + work done by friction $= \Delta E$
$\vec{F}_M \cdot \vec{\Delta x} + \vec{F}_f \cdot \vec{\Delta x} = E_f - E_i$

$400 \times 1.0 \times \cos 30 - F_f \times 1.0 = 265 - 25$
(N.B. $\vec{F}_f$ is opposite to $\vec{\Delta x}$)

$\therefore F_f = 346 - 265 + 25 = \boxed{106\ \text{N}}$

Notes:

- In general, think of energy as money in a bank where you have three accounts. Positive work done is like a deposit. Negative work done is like a withdrawal. If there are no deposits or withdrawals, the total amount of money stays constant, but there may be transfers from one account to the others.

- The energy that a system gains (or loses) through work done does not materialize from nowhere (or disappear altogether). It must come from another system or go to another system to satisfy the larger conservation of energy law. Thus work done is just a transfer of energy from one system to another or from one form of energy to another.

Problems

1) What would become of the energy that powers a hydro-electric plant if the plant and dam were never built in the first place?

2) A cardboard tube 1 meter long and closed at both ends contains some lead pellets. Suppose that you stand the tube on end, let the lead fall down the tube and come to rest, turn the tube upside down and repeat 300 times. If you neglect the amount of heat lost to the tube and surroundings, what is the increase in temperature?
N.B. Lead has a heat capacity of 0.04 cal/gram ^{o}C. ie. it requires 0.04 calories to warm up 1 gram of lead by $1^{o}C$.

3) Trace the chain of energy transformations in each of the following:
(a) an automobile accelerates from rest on a level road, climbs a hill at constant speed, and comes to a stop at a red light.
(b) A windmill in Holland pumps water out of a flooded field.
(c) You cut the grass with an electric lawn mower.
(d) A firecracker explodes andthe pieces finally fall to earth.
(e) Battery powered electric lights are used to grow potato plants in a basement.

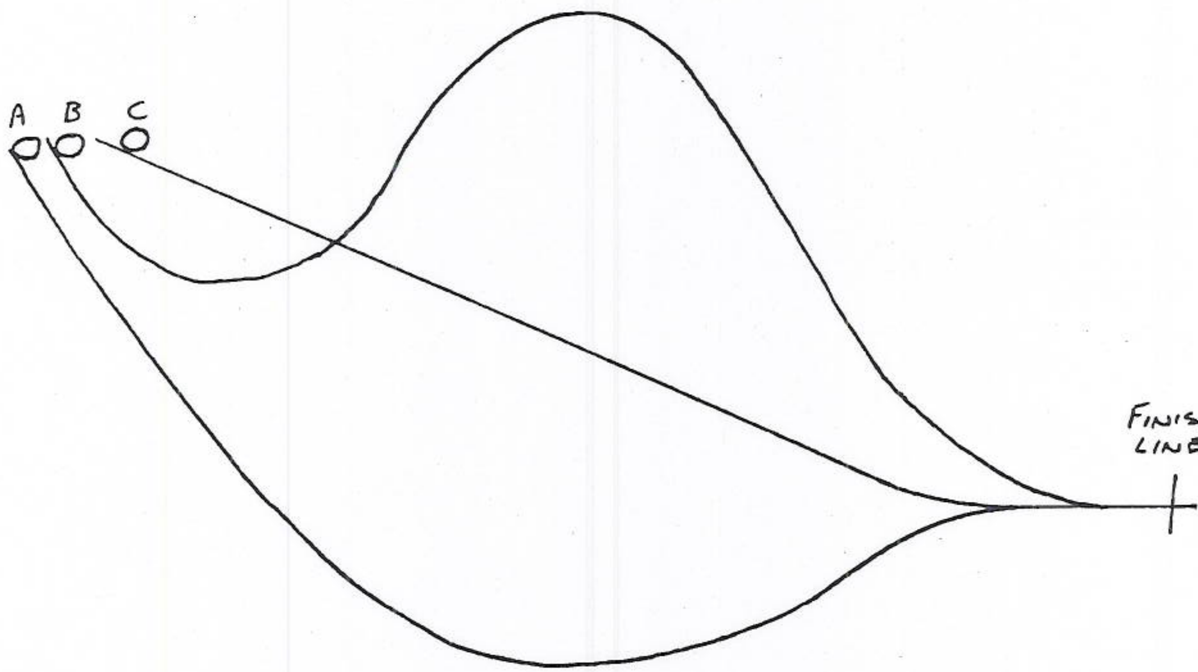
4) Discuss the statement "All of the gasoline you burn in a car is used to heat up the tires, the road and the air."

5) (a) Estimate the work done against gravity in climbing the stairs from the 100 floor to the physics lab.
(b) Suppose you made a mistake and went to the top floor first and then went down again to the physics lab. How would that affect the work done?
(c) Estimate the power you are capable of producing while getting up the stairs at your average pace.
(d) The human body is about 20% efficient. If you spent 1/2 hour climbing stairs at the same rate, how much would you have to eat (in kcal) to make up for the exercise?

6) We just said that the human body has an efficiency of about 20%. Does this mean that:
(a) only 1/5 of the food you eat is digested?
(b) 4/5 of the energy you obtain from food is destroyed?
(c) 1/5 of the energy you obtain from food is used to run the "machinery" of the body?
(d) you should spend 80% of every day lying quietly without working?
(e) 1/5 of the energy you obtain from food is used to enable your body to do work on external objects?

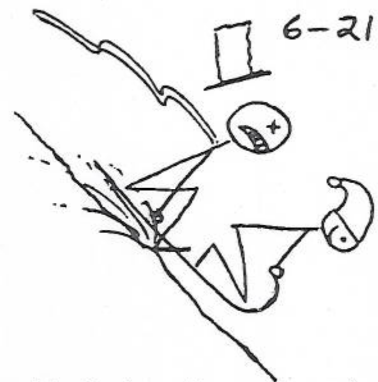
7) (a) A river flows at the rate of 1000 m^3/s. It goes over a waterfall 100 m high. Theoretically what is the maximum power you could extract from the river at the base of the waterfall?
(b) What is the ultimate source of the energy produced by a hydro-electric generator?

8) Three steel balls are set at the top of three frictionless tracks as shown, and released with zero velocity. Which one(s) will have the highest speed at the finish line and which the lowest?



9) A certain nefarious villain aims his slingshot at a window on the upper floor of Vanier College 15 m above the ground. The sling-shot is stretched 40 cm from its unstretched position and held there with a force of 100 N. Wishing to do a great deal of damage, he has chosen a large rock of mass 1.0 kg.
   (a) Can the stone reach the window?
   (b) What is the largest stone that could just reach the window with the slingshot used as above?
   (c) Explain why even with the stone in part (b), NFV would still not break the window.

10) Meanwhile the nefarious villain, unable to control his anger, is chasing the student, intending to steal the magic calculator which he thinks is responsible for the student's success. They end up in the sports complex in the large gymnasium, the villain on a ledge and the student trapped on another ledge on the other side 10 m higher than the villain. Villain grabs a handy trapeze intending to swing across the room and up to the other ledge.
   (a) Will he succeed? Why? Under what conditions might he?
   (b) Is the student's success really due to his magic calculator?

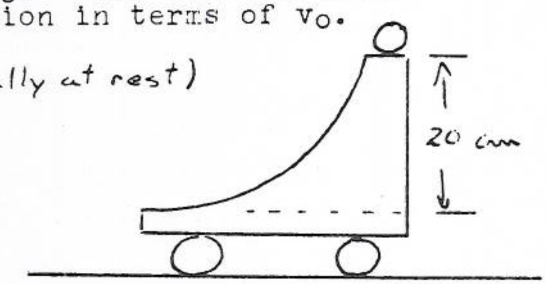


11) NFV & VVPS having temporarily resolved their differences are seen tobogganing together in the Laurentians. They are clocked at 25 m/s going down an expert hill which slopes at 45° to the horizontal. With the heels of both of Villain's boots dug into the snow, the effective coefficient of friction is 0.4.
   (a) How fast will they be going 100 m (parallel to the slope) farther down the hill? (Solve using energy.)
   (b) At this point the ground becomes level. Will they stop safely before they reach the chalet 50 m away? (or is Villain planning to bail out at the last minute?!)

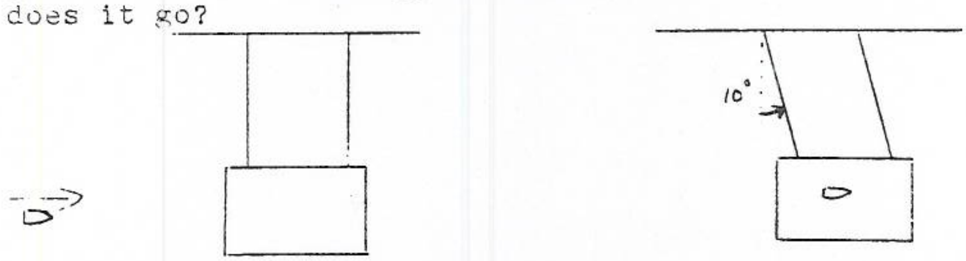
12) A ball is dropped from a height of 2.0 m and rebounds off the floor to a height of 1.5 m.
   (a) Is the collision with the floor elastic?
   (b) If not, how much energy is lost in the collision? (mass of ball = 0.5 kg)

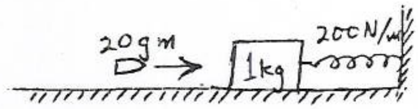
13) Two gliders of equal mass collide elastically on a level air track. One glider is initially stationary and the other moving to the right with velocity v_o. Find the velocities of the two gliders after the collision in terms of v_o.

14) The cart shown in the diagram (initially at rest) is equipped with frictionless wheels and has a mass of 0.50 kg. The ball rolls down the ramp and off the end of the cart. It has a mass of 0.10 kg. Calculate the final velocity of the cart.



15) A ballistic pendulum is a device for measuring the velocity of a bullet. It consists of a a box of sand suspended by wires of known length. When the bullet hits the box it becomes embedded in it and the box swings back and up on the wires. The mass of the box is 20 kg , the length of the wires is 2.0 m and the maximum angle to which the box swings is 10° when struck by a certain bullet. If the mass of the bullet is 10 g, what was its velocity before striking the box? How much kinetic energy is lost in the collision? Where does it go?



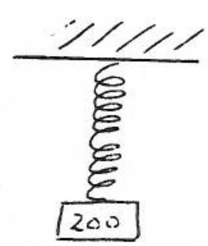


16. H & R p.166 Problems #26,31

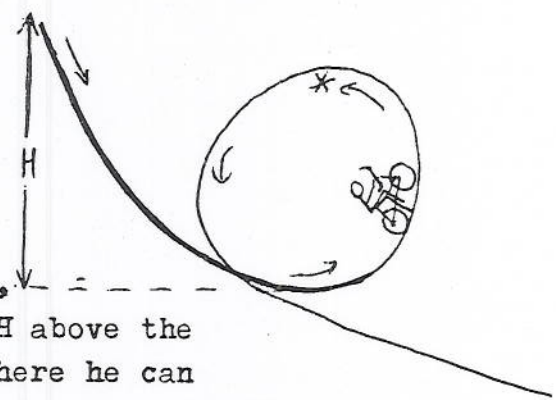
17. A 1 kg block of wood is attached to a spring of force constant 200 N/m and rests on a smooth surface as shown. A 20 gm bullet is fired into the block and the spring compresses 13.3 cm.
a) Find the original velocity of the bullet before the collision.
b) What fraction of the original mechanical energy is 'lost' ?

18. A 5 kg mass slides down a frictionless hill. At the bottom, 2 m below its initial height, it strikes a 10 kg mass and the two stick together as they slide up a second hill . What vertical height do they reach on the second hill ?

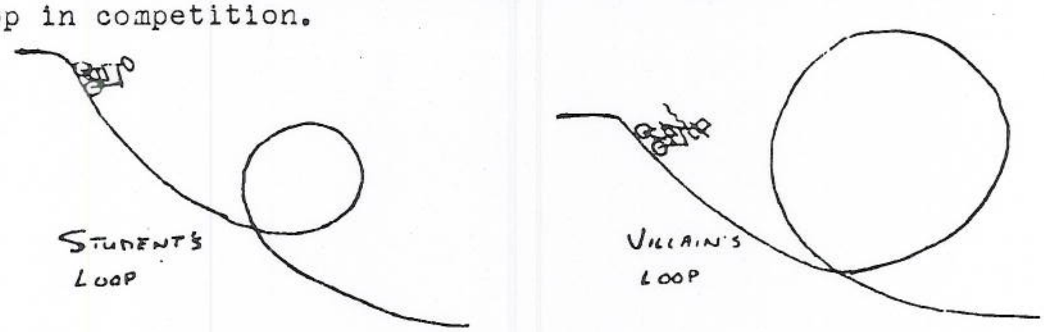
19. A mass of 200 g is suspended from a spring. When the spring is unstretched, the mass is 10 cm below the support. When the mass is held at equilibrium by the spring, it is 50 cm below the support. The mass is then raised 20 cm above its equilibrium position.
(a) How much work is done to raise it?
(b) The mass is then released. What is its speed as it passes the equilibrium point?
(c) How far down does it go before it stops?



20. [A difficult problem]
Consider the circus stunt cyclist doing a loop-the-loop. If he starts from rest and simply coasts down the frictionless track, what is the minimum height H above the lowest point on the track where he can start his death - defying run and not fall off the track at the top*? Take the circle as having radius R.

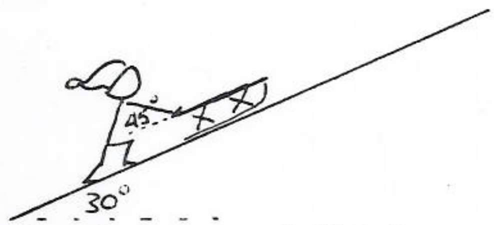


21) A certain physics student works for a circus during the summer months. He coasts on a bicycle down a ramp and through a loop-the-loop to the astonishment and pleasure of all the spectators. N. Farious Villain, not wishing to be outdone, sets up his own loop in competition.



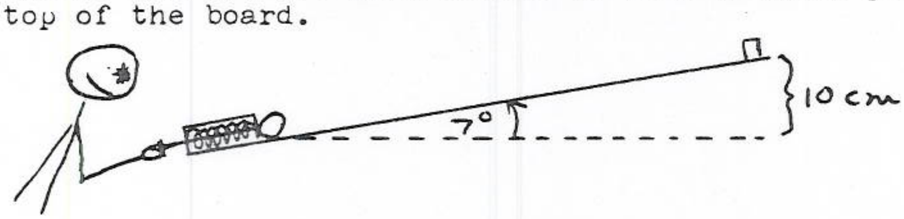
Do I need to ask? Would you hire N.F.V. on a long-term contract for your circus?

22) A child moves a 5 kg sled up a 30° slope by pushing on it at an angle of 45° to the slope with a force of 50 N.



(a) Calculate the work done by the child in going 10 m along the slope.
(b) After 10 m of pushing, the sled has slowed from an initial velocity of 4 m/s to 2 m/s. Calculate the work done by friction.
(c) Calculate the coefficient of friction.

23) A pinball machine is a game consisting of a sloping board about 1 meter long with various targets on it. To start the game you let a small ball (m = 0.2 kg) rest against a compressible spring; you compress (load) the spring and then release it quickly, and the ball shoots up the board. A certain pinball machine has a spring which is compressed by 2.0 cm when it is "loaded". The top of the board is 10 cm above the end of the spring and is inclined at 7° to the horizontal. The ball's speed is 2.0 m/s when it leaves the spring and 1.0 m/s just before it hits a small post at the top of the board.



(a) What is the force constant (k) of the spring? Assume that the spring is frictionless and perfectly elastic.
(b) Is the board frictionless? How do you know? Describe briefly the forms of energy that are exchanged from the time the spring is loaded until the ball reaches the top post.

(OVER)

23) (c) The ball bounces elastically off the peg and rolls back down the slope miraculously missing all obstructions. How fast is it going when it is back down at the level of the spring?

24) Halliday & Resnick: p.105 #27,28,32,36
p.127 #5,10,14,20,21,34,35,36,37,39,43
p.165 #15,19

<u>Additional Problems</u> (for those who want (or need) extra practice)

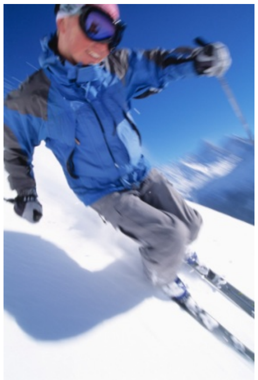
Halliday & Resnick: p.105 #21,25,29,30,31,35
p.127 #4,5,6,8,17
p.165 #13,18,21,23

MODULE 1 Study Guide

APPENDIX III

Concepts of Motion

pp. 110 - 160

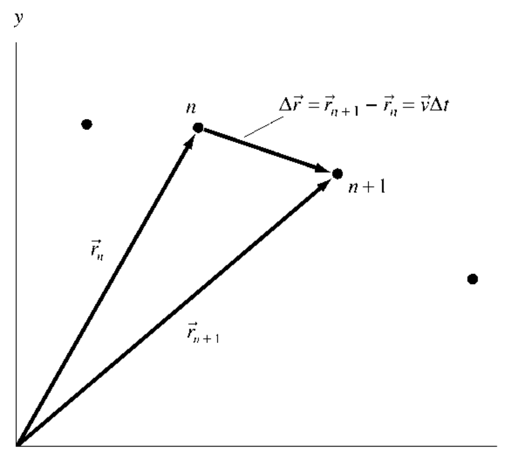


Introduction

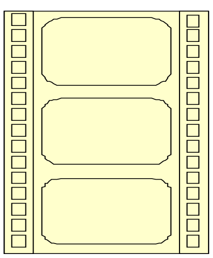
If you are asked to describe "in a nutshell" what classical mechanics is about, what would your answer be? A good answer is that it is the study of the *motion* of objects (including live ones!). It is important, therefore, to understand the quantities that we use to analyze motion. The basic quantities that are used to describe motion are position, velocity, and acceleration. It is from these quantities that you will later connect to the concepts of force, energy and momentum.

To better understand these concepts, *motion diagrams* are introduced. The motion diagram is an important tool to *visualize* motion. Imagine taking a movie of a moving object and then cutting apart the frames, stacking them, and projecting them onto a screen. Through these motion diagrams you explore the concepts of position, velocity (average velocity is treated as instantaneous velocity in this module and in Chapter 1 of the textbook) and acceleration.

Since the quantities of motion are vector quantities, it is important to have a basic understanding of their properties. Vector properties of addition and subtraction are shown graphically for now by sliding vectors in a plane and applying the tip-to-tail technique. Do you remember how to do this?



In the diagram on the right the dots represent a moving object.



The vectors $\vec{r}_{n+1}$ and $\vec{r}_n$ represent the final and initial positions (over a time interval Δt) giving a displacement $\Delta\vec{r}$ such that (use tip to tail method)

$\Delta\vec{r} = \vec{r}_{n+1} - \vec{r}_n$

What is $\vec{v}_{\text{avg}} = \Delta\vec{r}/\Delta t$, ? In what direction does it point? Note that there is no distinction made in this module between instantaneous and average velocity.

What would $\vec{a}_{\text{avg}} = \Delta\vec{v}/\Delta t$ represent?

Much of this module (and Chapter 1) is focused on developing and practicing specific *procedures* for determining velocity and acceleration vectors. Note that the "problems" in the examples and in the homework are for the purpose of learning to *describe* a problem statement with a pictorial or graphical representation and not to *solve* the problems with memorized equations that you may have learnt previously.

Problem Solving Techniques

Another important aspect of this chapter is the development of good problem-solving skills. When you encounter a word problem, after reading it, what do you do? Perhaps you think about it for a while and then come up with a *plan*. The first part of that plan is to build a *model* – what assumptions do you make? What I feel really helps in the solution of the problem is *describing* the problem situation through sketches (stick figures are ok!), coordinate systems, and the identification of known and unknown quantities. *A picture is worth a thousand words* really applies here!

Try to keep in mind that motion can be described using several representations:

- Verbal, as presented in typical end-of-chapter (EOC) problems.
- Pictorial, as shown in motion diagrams, and pictures that establish coordinate systems and define symbols.
- Graphical, in position-, velocity-, and acceleration-versus-time graphs.
- Mathematical, through the relevant equations of kinematics and dynamics.

The general guideline for using significant figures is to use 2 or 3 (a *rule of thumb*), depending on the context. Only 1 is too few (except for rough estimates) and 5 or more is too many.

An interesting but many times difficult thing to do is to ask for an order of magnitude estimate of a certain quantity. Estimate the height of a particular tall building? A rough idea of the height of each floor times the number of floors would give you that estimate.

Pre-Lecture Exercises

1. If car B overtakes and passes car A on the highway, both traveling in the same direction, do the cars have the same *velocity* at the instant when B is alongside A? Do they have the same *position*?

2. Is it true that speeding up always means positive values of the acceleration and slowing down negative values of the acceleration?

3. Consider the following motion diagram of an object. 
   Is the object moving to the right, to the left, or is there not enough information to tell?

4. Draw a motion diagram of an object that is thrown into the air, reaches the maximum height and then comes back down to the starting point. Where is the *turning point* for this motion?

   Draw a few velocity and acceleration vectors on the way up and on the way down. What can you say about the velocity and acceleration at the turning point? Is there an acceleration at the turning point. Would the object get away from the turning point if both $\vec{v}$ and $\vec{a}$ were zero?

Pre-Lecture Multiple Choice Conceptual Questions

1. What is a “particle”?

2. What quantities are shown on a complete motion diagram?

3. An acceleration vector
   a. tells you how fast an object is going.
   b. is constructed from two velocity vectors.
   c. is the second derivative of the position. (*not* correct for the reading of Chap. 1)
   d. is parallel or opposite to the velocity vector.

4. The pictorial representation of a physics problem consists of
   a. a sketch.
   b. a coordinate system.
   c. symbols.
   d. a table of values.
   e. Both a and b.
   f. All of a, b, c, and d.

Learning Objectives & Competencies

Learning Objectives *In this chapter you will*:		**Competencies**	***Section in Textbook***
OBJ1	understand and use the basic ideas of the *particle model*.	*Comprehend*	1.2
OBJ2	analyze the motion of an object by using *motion diagrams* as a tool.	*Apply*	1.1, 1.5
OBJ3	differentiate between the concepts of position, velocity, and acceleration.	*Comprehend*	1.3
OBJ4	recognize the relationship between $\vec{v}$ and $\vec{a}$ when an object is speeding up, slowing down, or at a turning point.	*Comprehend*	1.4, 1.5, 1.6
OBJ5	gain initial experience with graphical addition and subtraction of vectors.	*Apply*	1.3
OBJ6	begin the process of learning to analyze problem statements and to translate the information into other representations.	*Apply*	1.7
OBJ7	learn about position-versus-time graphs and the sign conventions for one-dimensional motion.	*Apply*	1.6

Course Content (Course Outline)

Chapter/Module 1 - Concepts of Motion – ***Module Completion Date (MCD) Jan. 27***	
- *comprehend* the notions of a motion diagram and the particle model	1.1, 1.2
- *comprehend* the notions of position, velocity and acceleration vectors	1.3-1.5
- *comprehend* the graphical representations of *x vs t, v vs t, a vs t*	1.6

Study Procedures and Problem Solving – Reminders

* PSI supports individual student learning. You can work at your own pace! However, keep in mind that there are certain deadlines that must be met (Term Tests & Final Exam). A rough estimate at this point is that you must have *mastered* Modules 1 to 4 inclusive for the 1st Term Test. This means that the mastery tests for these modules have been done successfully.

* To encourage you to do your best, here are some suggested study procedures. Start by reading the Study Guide for Chapter 1. The Objectives & Competencies table tells you which chapter sections must be studied in order to master the module.

* In the textbook chapters you will find solved problems. Try to do these problems on your own without looking at the solution. Once you have given it your best shot, correct your work by looking at the solutions.

* In the table below you will find a summary of worked out textbook problems as well as MP online suggestions. Note the objective number (OBJx). Consult your study guide to see what the objective is.

* These and other problems could be used in cooperative sessions for group work as well as for hand-in homework assignments.

Learning Resources

Objectives (OBJ)	Textbook Examples	Stop to Think (STT) (Answers p. 33)	Tactics Box (TB) & Problem Solving Strategy (PSS)	MP EOC Practice Problems
OBJ1	All examples	1.2		4
OBJ2	Most of the examples	1.1	PSS 1.1	44,46
OBJ3	1.4 to 1.6			9
OBJ4	1.4 to 1.6	1.4	TB 1.3	11
OBJ5	Most of the examples	1.3	TB 1.1, 1.2	
OBJ6	1.8, 1.9		TB 1.5	21
OBJ7	1.7			19, 56

MODULE 2 Study Guide

Kinematics in One Dimension

Introduction

In Module 1, the concepts of position, velocity and acceleration were presented. Motion diagrams were used extensively to show, in pictorial form, the vector nature of these quantities. In this module we want to focus on motion in one dimension only. Later, when you have studied how vectors can be analyzed using components (Module 3), two dimensional motion will be investigated (Module 4).

Textbook Terminology

Although the basic kinematic quantities x, v_x, and a_x (or y, v_y, and a_y) are components of vectors, a full discussion of vectors is not needed for one-dimensional motion. The text (and modules) uses a generic symbol *s* to represent position if not along *x* (for horizontal motion) and *y* (for vertical motion). Also, $v = |\vec{v}|$ is the magnitude of the velocity vector, or speed, and $a = |\vec{a}|$ is the magnitude of the acceleration. Components of vectors, such as v_x or a_y, always use explicit *x*- and *y*-subscripts. It is important to recognize that vertical motion (along y), horizontal motion (along x), and motion on an incline (along s) as just variations of "one-dimensional motion."

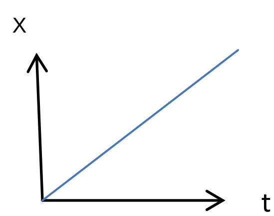
It is worth repeating that there are *multiple representations of knowledge*. In particular, motion has the following descriptions:

- Verbal, as presented in typical EOC problems.
- Pictorial, including (1) motion diagrams and (2) a sketch showing beginning and ending points as well as coordinates and symbols.
- Graphical, as shown in position-, velocity-, and acceleration-versus-time graphs.
- Mathematical, through the relevant equations of kinematics.

It is important to keep these descriptions in mind since you want to build up a strong conceptual foundation of kinematics and a systematic approach to analyzing problems. You will be required to move back and forth between these different representations.

Interpreting x-t, v_x-t and a_x-t graphs

If a person is moving with constant velocity (the magnitude of the velocity is called the speed) along the horizontal (x-axis) and you plot x versus t the resulting graph is linear.



What does the *slope of the x-t graph* represent? The mathematical representation of the slope is $\Delta x/\Delta t$ and since the curve is linear it gives you the constant velocity of the person. What type of curve would give a *non-constant velocity*?

The area under the v-t curve

You have seen that the slope of the position-time graph gives you the velocity of a moving object. How can you go from velocity to position? It turns out that the displacement Δx is exactly the same as the area under the velocity-time curve. The constant-velocity equation $s = s_0 \square + v_s \Delta t$ is the algebraic expression that supports

$$\Delta s = s - s_0 = v_s \Delta t = \text{the area under the velocity-versus-time curve.}$$

Hence, the position is obtained by the expression

$$s = s_0 + \text{ the area under the velocity-versus-time curve.}$$

This is true whether the velocity is constant or not. Whether you can in fact determine the area under the curve is another question. It is easy to do so for straight lines. When you encounter more complex curves, calculus (Cal II !) can be used if the functions are known.

Instantaneous velocity and acceleration

The expression for the average velocity is given by $v_{s\ avg} = \Delta s/\Delta t$. This expression tells you that the displacement is taken over a finite time interval Δt (hence average). If you wanted to obtain a *better* value you would reduce the time interval Δt . How much can you *reduce* this time interval Δt? As much as you want! For a curved section on an x-t graph the slope would approach that of a straight line and the average velocity reaches a constant or *limiting* value. Hence, in the *limit* as Δt approaches 0 ($\Delta t \rightarrow 0$) the average velocity becomes an *instantaneous* velocity at time t. In calculus this is called the derivative of s with respect to t.

$$v_s = \lim_{\Delta t \to 0}(\Delta s/\Delta t) = ds/dt$$

In a similar fashion, we can use the above arguments to apply to acceleration which is obtained from the v_s – t graph. Hence the instantaneous

$$a_s = \lim_{\Delta t \to 0}(\Delta v/\Delta t) = dv_s/dt$$

Equations of motion with constant acceleration

In each chapter there are equation derivations. You are strongly urged to go over these derivations as they will not be presented in class unless there is a good reason to do so. You need to understand the underlining principles and assumptions taken. If need be further discussions could take place in a group or lecture session. For constant acceleration the equations are derived in section 2.4 of the textbook.

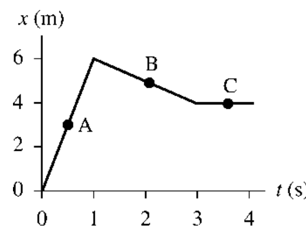
Free Fall Motion

When objects are thrown upward or dropped from a certain height, their motions are dictated by the pull of gravity. Neglecting air resistance, this is referred to as *free fall*. Close to the surface of the earth the acceleration due to gravity doesn't change significantly and is assumed constant. All objects, neglecting air resistance, will have the same acceleration due to gravity.

What is important here is to differentiate between the *magnitude of the acceleration* due to gravity, commonly referred to as g = 9.80 m/s^2, and its *direction* since acceleration is a vector quantity. Hence, the *acceleration can be positive or negative depending on the choice of coordinate system used*.

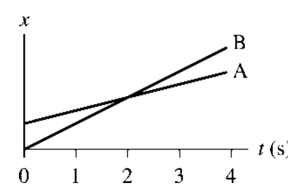
Pre-Lecture Exercises

1. Give a *verbal* description of the motion represented by the graph on the right.
   Rank in order the *speeds* (magnitude of the velocity) at points A, B, and C, from fastest to slowest.
   Draw a *velocity*-versus-time graph—*with a proper numerical scale*.

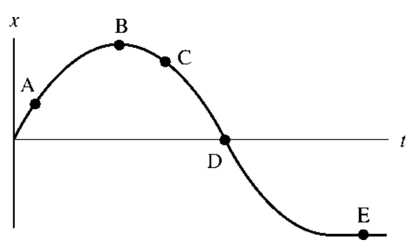


Rank in order the speeds at points A, B, and C, from the fastest to the slowest.

2. This graph shows the motion of two objects A and B.
   Do A and B ever have the same speed? If so, at what time?

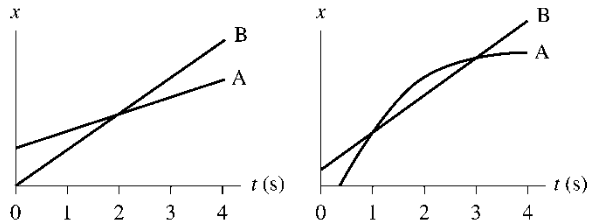


3. Consider the following position-versus-time graph of an object moving along the x-axis.



   At which lettered point or points is the object (a) moving fastest, (b) at rest, and (c) slowing down?

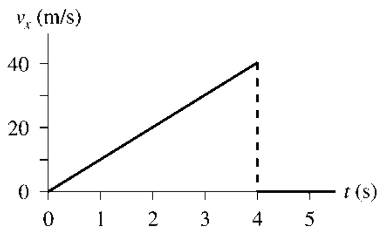
4. Consider the following graphs below showing two objects moving along the x-axis.



Do A and B ever have the same speed? If so, at what time or times?

Do A and B ever have the same speed? If so, at what time or times?

Answer the questions posed under each graph and then draw the respective v_x curves.



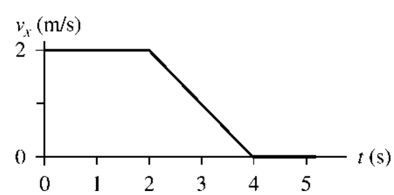
Find the position at times t = 1, 2, 3, 4, and 5 seconds. Assume x_0 = 0 m.

5. Consider the graph on the left. Find graphically i.e. using the graph, not a kinematics equation, the position at t = 1, 2, 3, 4, and 5 s.

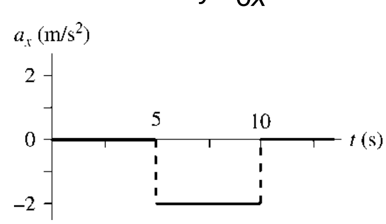
   Draw a position-versus-time graph.

   Draw the acceleration-time graph.

6. Draw the position graph and the acceleration graph that go with the velocity graph shown below. The initial position is x_0 = 2.0 m.



7. An object moving horizontally has the acceleration-versus-time graph shown below. At t = 0 s, the object has x_0 = 0 m and velocity v_{0x} = 10 m/s.



   a. Draw a velocity-versus-time graph for the object. Include a numerical scale on the vertical axis.
   b. Draw a motion diagram of the object's motion.
   c. Write a description of a real object for which this is a realistic motion.

Pre-Lecture Multiple Choice Conceptual Questions

1. The slope at a point on a position-versus-time graph of an object is

   a. the object's speed at that point.
   b. the object's average velocity at that point.
   c. the object's instantaneous velocity at that point.
   d. the object's acceleration at that point.
   e. the distance traveled by the object to that point.

2. The area under a velocity-versus-time graph of an object is

   a. the object's speed at that point.
   b. the object's acceleration at that point.
   c. the distance traveled by the object.
   d. the displacement of the object.

3. At the turning point of an object,

   a. the instantaneous velocity is zero.
   b. the acceleration is zero.
   c. Both a and b.
   d. Neither a nor b.

4. A 1-kg block and a 100-kg block are placed side-by-side at the top of a frictionless hill. Each is given a very light tap to begin their race to the bottom of the hill. In the absence of air resistance

   a. the 1 kg block wins the race.
   b. the 100 kg block wins the race.
   c. the two blocks end in a tie.

Prerequisites

Prerequisites	Location in Textbook	Module
Velocity and Acceleration	1.4 – 1.5	1
Motion in 1 – D	1.6	1
Problem Solving	1.7	1
Derivatives	Calculus I	

Learning Objectives & Competencies

Learning Objectives *In this chapter you will:*		**Competencies**	***Section in Textbook***
OBJ1	differentiate clearly between the concepts of position, velocity, and acceleration.	*Comprehend*	2.1 to 2.4
OBJ2	interpret kinematic graphs.	*Recall*	All sections
OBJ3	translate kinematic information between verbal, pictorial, graphical, and algebraic representations.	*Comprehend*	2.6
OBJ4	learn the basic ideas of calculus (differentiation and integration) and utilize these ideas both symbolically and graphically.	*Apply*	2.2
OBJ5	understand free-fall motion.	*Apply*	2.5
OBJ6	begin the development of a robust problem-solving strategy.	*Apply*	Most sections
OBJ7	solve quantitative kinematics problems and interpret the results.	*Apply*	Most sections

Course Content (Course Outline)

Chapter/Module 2 - Kinematics in One Dimension – ***MCD Feb. 3***	
- *comprehend* the relationship between these graphical representations (slope of the tangent and signed area under the graph)	2.1-2.4, 2.7
- *apply* graphical analysis to translate from one sketch to another	2.1-2.4, 2.7
- *comprehend* the functional dependence of *x, v* and *a* on *t*	2.1-2.4, 2.7
- *apply* the above graphical and functional techniques to solve problems in one-dimensional kinematics	2.4
- *comprehend* the notion of motion under constant acceleration	2.4
- *comprehend* the graphical interpretation of motion under constant acceleration	2.4-2.6
- *apply* graphical analysis to obtain the equations of motion under constant acceleration	2.3, 2.4
- *recall* the kinematics equations for motion under constant acceleration	2.4
- *apply* the above equations to solve kinematics problems with single and two simultaneous motions	
- *apply* the kinematics equations to problems in 1-D motion under constant acceleration	2.4
- *apply* the above concepts to free-fall	2.5

Objectives (OBJ)	Textbook Examples	Stop to Think (STT) (Answers p. 71)	Tactics Box (TB) & Problem Solving Strategy (PSS)	MP EOC Practice Problems
OBJ1	2.1, 2.3 – 2.5	2.1	TB 2.1	2.11
OBJ2	2.3, 2.4, 2.6, 2.8, 2.9	2.2 2.3, 2.4, 2.5	TB 2.2	2.26
OBJ3	2.19, 2.20	2.6		2.35
OBJ4	2.6, 2.7, 2.8, 2.9			2.31
OBJ5	2.15, 2.16, 2.22			2.49
OBJ6	All examples above			
OBJ7	2.17, 2.18			2.77

MODULE 3 Study Guide

Vectors and Coordinate Systems

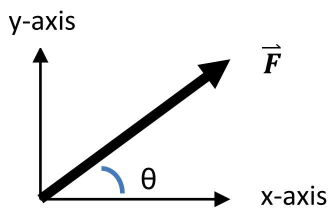
Introduction

Many quantities in physics require only one number to describe. The distance travelled is simply given in meters. The mass of an object is obtained in kilograms. However, there are other quantities that require both a magnitude and a direction to describe. These are *vector* quantities. For example *force* is a vector quantity. Hence, it is important to be able to analyze vectors in a systematic way. In high school you probably used the “tip-to-tail” approach to handle the addition and subtraction of vectors.

The notation used to describe a vector quantity is very important. When components are not required, vectors can be written as (magnitude, direction)—for example, $\vec{F}$ = (50 N, 30° north of east).

However, the use of a coordinate system in many problems involving vectors makes the solutions much easier to obtain. In this case, you work with the *vector components* for addition and subtraction of vectors. In this module we only worry about multiplication of a vector by a scalar. Later you will also learn that a vector can be multiplied to give a scalar or a vector.

A vector is decomposed into components parallel to the coordinate axes. For this reason it is important to show a clear diagram of the coordinate system and the angles involved.



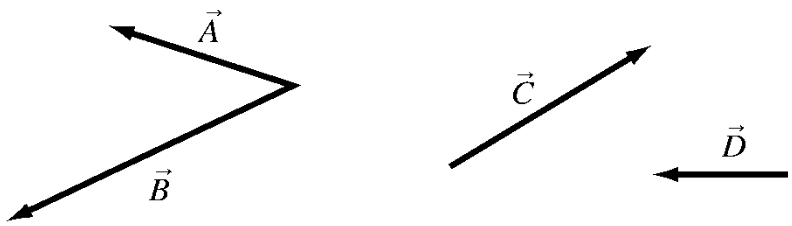
Thus $F_x = F\cos\theta$ and $F_y = F\sin\theta$. In the different quadrants these components can be positive or negative. In these modules you will use angles less than 90 degrees in whichever quadrant you are in, making sure to describe where you are. For example the force is applied at angle of 40^o above the positive x-axis.

When many vectors are involved it is convenient to use unit vector notation. We introduce unit vectors ($\hat{\imath}$, $\hat{\jmath}$, $\hat{k}$) corresponding to the (x, y, z) axes respectively. For example, $\vec{F} = 2\hat{\imath} - 5\hat{\jmath}$ N, is a force whose x-component is 2 N in the positive x direction and 5 N in the negative y direction.

When writing vector components, explicitly use subscripts, such as v_x and a_y, even for one-dimensional motion. Thus the quantities v, a, and F are unambiguously the magnitudes of vectors.

Pre-Lecture Exercises

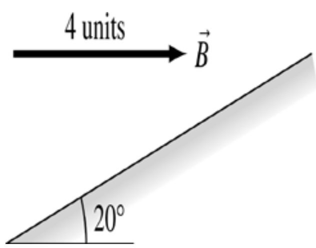
1.



Draw the vectors:
a. $\vec{A} + \vec{B}$
b. $\vec{A} - \vec{B}$
c. $2\vec{A} - \vec{B}$

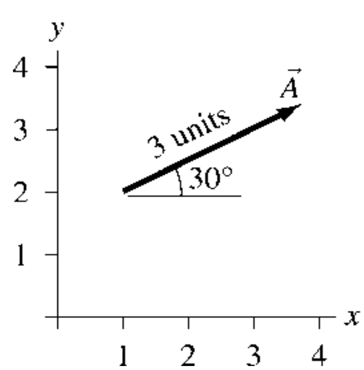
Draw the vector $\vec{C} + \vec{D}$.

2. Determine the components of the vector $\vec{B}$ along the incline and perpendicular to the incline.



3.

Find the x- and y-components of vector $\vec{A}$.



4. What angle does the force $\vec{F} = 2\hat{\imath} - 5\hat{\jmath}$ N make with the negative y-axis?

Pre-Lecture Multiple Choice Conceptual Questions

1. What is a vector?

2. What is the name of the quantity represented as $\hat{\imath}$?

3. This chapter shows how vectors can be added using
   a. graphical addition.
   b. algebraic addition.
   c. numerical addition.
   d. Both a and b.
   e. Both a and c.
   f. Each of a, b, and c.

4. To *decompose* a vector means
   a. to break it into several smaller vectors.
   b. to break it apart into scalars.
   c. to break it into pieces parallel to the axes.
   d. to place it at the origin.

Prerequisites

Prerequisites	Location in Textbook	Module
Vector addition and subtraction	1.3	1
Trigonometry	Appendix A	

Learning Objectives & Competencies

Learning Objectives *In this chapter you will:*		Competencies	*Section in Textbook*
OBJ1	understand the basic properties of vectors.	*comprehend*	3.1, 3.2
OBJ2	add and subtract vectors graphically	*comprehend*	3.2
OBJ3	be able to decompose a vector into its components and to reassemble vector components into a magnitude and a direction using a coordinate system.	*apply*	3.3
OBJ4	recognize and use the basic unit vectors.	*comprehend*	3.4
OBJ5	work with tilted coordinate systems.	*apply*	3.4

Course Content (Course Outline)

Chapter/Module 3 – Vectors – ***MCD Feb. 10***	
- *comprehend* the Cartesian $(\hat{i}, \hat{j}, \hat{k})$ vector coordinate system	3.3, 3.4
- *comprehend* the relationship between the magnitude and direction of a vector and its Cartesian components	3.3
- *comprehend* the graphical and algebraic representations of vector addition, subtraction and multiplication by a scalar	3.2
- *comprehend* the decomposition of a vector into mutually-perpendicular components	3.3
- *comprehend* the notion of a unit vector	3.4

Learning Resources

Objectives (OBJ)	**Textbook Examples**	**Stop to Think (STT) (Answers p. xxx)**	**Tactics Box (TB) & Problem Solving Strategy (PSS)**	**MP EOC Practice Problems**
OBJ1				Q4, Q6, Q7
OBJ2	3.1, 3.2	3.1, 3.2		3.1
OBJ3	3.3, 3.4	3.3	TB 3.1	3.26
OBJ4	3.5, 3.6			3.29
OBJ5	3.7			3.36, 3.45

MODULE 4 Study Guide

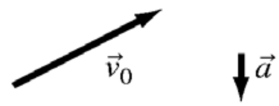
Kinematics in 2-D

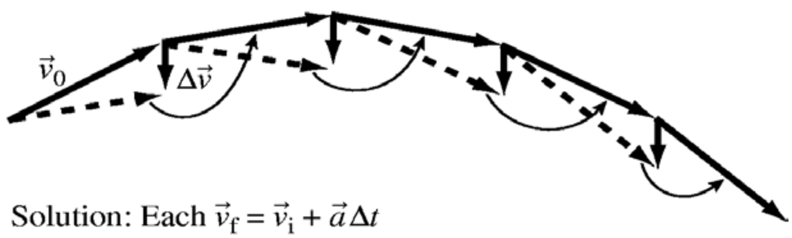
Introduction

The stunt driver flying through the air is moving in a 2 dimensional plane, going up, down and forward. You can say that the motion can be broken up as one being along the horizontal axis and another along the vertical axis. This means that the quantities of the motion can be described as 2-D vectors in a plane. In general, 2-D motion is composed of two 1-D motions. If there is motion in the x-y plane, then you decompose the vectors along the x-axis and the y-axis. Hence, the position, velocity and acceleration vectors can be written as

$\vec{\mathbf{r}} = x\,\hat{\boldsymbol{i}} + y\,\hat{\boldsymbol{j}}$ m $\qquad \vec{\mathbf{v}} = v_x\,\hat{\boldsymbol{i}} + v_y\,\hat{\boldsymbol{j}}$ m/s $\qquad \vec{\mathbf{a}} = a_x\,\hat{\boldsymbol{i}} + a_y\,\hat{\boldsymbol{j}}$ m/s^2

Construct a motion diagram of the trajectory of a particle with the initial velocity and constant acceleration shown here.





Solution: Each $\vec{v}_f = \vec{v}_i + \vec{a}\,\Delta t$

Circular motion, seen all around us, can be difficult to understand from the point of view of the vector nature of the quantities of motion, namely, position, velocity and acceleration. For *uniform circular motion*, the speed of the object moving in a circular path is constant and can be determined from $v = 2\pi r / T$.

The magnitude of the centripetal (or radial) acceleration, $a = v^2/r$, is also constant. However, the vector quantities are not since they constantly change direction. The kinematic equations you have leaned for constant-acceleration motion do not apply.

Non-uniform circular motion involves an acceleration that has two components: the *centripetal acceleration* component that causes the change in the direction of the velocity vector and the *tangential acceleration* component that causes the change in the speed of the object. Hence, $a^2 = a_c^2 + a_t^2$

Pre-Lecture Exercises

1. How is the acceleration determined from the velocity?

2. For constant acceleration (in 2-D) what do you expect the equations of x, y, v_x , v_y to be as functions of time? These will be the equations to use for projectile motion (which assumes constant acceleration due to gravity).

3. Show that $v_{xf}^2 = v_{xi}^2 + 2a_x\Delta x$ and similarly for v_{yf}^2. Hint: Refer to Chapter 2.

Pre-Lecture Multiple Choice Conceptual Questions

1. A ball is thrown upward at a 45° angle. In the absence of air resistance, the ball follows a

   a. tangential curve.
   b. sine curve.
   c. parabolic curve.
   d. linear curve.

2. A hunter points his rifle directly at a coconut that he wishes to shoot off a tree. It so happens that the coconut falls from the tree at the exact instant the hunter pulls the trigger. Consequently,

   a. the bullet passes above the coconut.
   b. the bullet hits the coconut.
   c. the bullet passes beneath the coconut.
   d. This wasn't discussed in Chapter 4.

3. What is the name of a reference frame that moves at constant speed in a straight line?

4. For uniform circular motion, the acceleration
   a. points toward the center of the circle.
   b. points away from the circle.
   c. is tangent to the circle.
   d. is zero.

Prerequisites

Prerequisites	Location in Textbook	Module
Acceleration vectors on a motion diagram	1.5	1
Constant acceleration kinematics and free fall	2.5, 2.6	2
Decomposing vectors into components	3.3, 3.4	3

Learning Objectives & Competencies (Textbook)

Learning Objectives *In this chapter you will:*		**Competencies**	***Section in Textbook***
OBJ1	identify the acceleration vector for curvilinear motion.	*comprehend*	4.1
OBJ2	compute two-dimensional trajectories.	*apply*	4.2
OBJ3	understand projectile motion.	*apply*	4.3
OBJ4	understand the kinematics of uniform circular motion.	*apply*	4.5
OBJ5	understand the kinematics of non-uniform circular motion.	*comprehend*	4.7

Course Content (Course Outline)

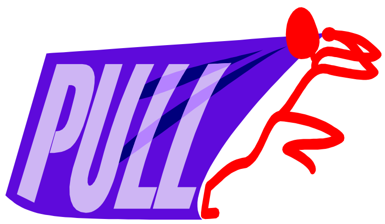
Chapter/Module 4 - Motion in Two Dimensions – ***MCD Feb. 17***	
- *comprehend* 2-D motion as two simultaneous, independent 1-D motions	4.2
- *comprehend* the notions of the position, velocity and acceleration vectors	4.1, 4.2
- *apply* vector algebra to extend the kinematics equations to two-dimensional motion	4.2
- *apply* the above concepts to projectile motion	4.3
- *comprehend* the notions of uniform and non-uniform circular motion and angular quantities	4.5, 4.6
- *comprehend* the connections between angular and linear quantities	4.7

Learning Resources

Objectives (OBJ)	Textbook Examples	Stop to Think (STT) (Answers p.125)	Tactics Box (TB) & Problem Solving Strategy (PSS)	MP EOC Practice Problems
OBJ1	4.1	4.1	TB 4.1	4.4, 4.7
OBJ2	4.2, 4.3	4.2		4.9, 4.39
OBJ3	4.4, 4.5, 4.6	4.3	PSS 4.1	4.13, 4.46, 4.81, 4.83
OBJ4	4.11	4.6		4.62
OBJ5	4.15			4.63

MODULE 5 Study Guide

Force & Motion



Introduction

From what you see around you and from your own experiences, you may feel that the motion of an object requires a *force* and that it will stop if no force acts on it any longer. However, nothing can be further from the truth according to the Laws of Physics!

You know that when a body is at rest, it will remain at rest unless something acts on it to change that state. A chair, on the floor under the kitchen table, will stay in place unless it is *pulled* away. Why did the chair stay in place? Why did it move?

Pull on your friend's arm (gently!) and he will agree that he feels a *pulling force*. If you now hand him one end of a rope, pull on the other end, and ask what he experiences, more than likely he'll reply, "You're pulling on me." You'll soon find out that actually the rope is pulling on your friend with a tension force!

It was Sir Isaac Newton who first clearly made the connection between the interactions on a body and its motion. In Newton's theory, the acceleration of every object has to be explained in terms of the interactions with other objects.

Newton's First Law (the Law of Inertia) states that an object will stay at rest or in motion unless there is a *resultant (net) force* that acts on it.

If you decide to sit on the chair you just pulled away from the table, can you identify which forces act on you? However, you stay sitting so that means that the sum of all those forces must add to zero (and you remain at rest).

In chapter 5, you are introduced to the idea of dividing a problem into the *system*, which is the object or objects of interest, and the *environment*, which is everything else. At this time, the system is a single object — called the *object of interest*—and all forces originate in the environment.

http://www.youtube.com/watch?v=54fAE2iN2II

http://www.youtube.com/watch?v=lZ2kQzt6xOs&feature=related

Newton's second law in the, *operational form,* is written as $\vec{a} = \vec{F}_{\text{net}}/m$. Although $\vec{F} = m\vec{a}$ looks more elegant, it conveys the wrong impression that "$m\vec{a}$ is a force." The operational form conveys a better sense of cause and effect. Note, however, that "motion does not need a *cause*." The question is not "Why does an object move?" but "Why does it *change* its motion?"

Pre-Lecture Exercises

1. An elevator is going up at a *steady* speed. Note that tension and gravity are the only two forces acting on the elevator.

   Is T greater than, equal to, or less than F_G? Or is there not enough information to tell?

2. Suppose you push a block across the table at *steady* (constant) speed. Since you're exerting a force on it, why isn't it accelerating?

   Identify all the forces and draw a free body diagram. Compare the size of the pushing force and the size of the friction force.

3. A ball is tossed straight up into the air. Neglect air resistance. How does it move up without an upward force?

   Is a *cause* needed for the ball to move upwards? Or does inertia take care of that?

   The proper question to ask is not "Why does it move upward?" but "Why does it slow down and eventually fall?"

Pre-Lecture Conceptual Questions

1. What is a "net force?"

2. List at least two of the steps used to identify the forces acting on an object.

3. Which of these is *not* a force discussed in this chapter?

   a. The tension force.
   b. The normal force.
   c. The orthogonal force.
   d. The thrust force.

4. What is the name of a diagram used to show all forces acting on an object?

Prerequisites

Prerequisites	Location in Textbook	Module
Understand what acceleration is	1.5	1
Review properties of vectors	3.2	3

Learning Objectives & Competencies

Learning Objectives *In this chapter you will:1*		Competencies	Section in Textbook
OBJ1	recognize what does and does not constitute a force.	*recall*	5.1, 5.3
OBJ2	identify the specific forces acting on an object.	*comprehend*	5.2, 5.3
OBJ3	draw an accurate free-body diagram of an object.	*apply*	5.7
OBJ4	begin the process of understanding the connection between force and motion.	*comprehend*	5.4, 5.5
OBJ5	begin learning how to *explain* an observation on the basis of physical principles.	*comprehend*	5.6

Course Content (Course Outline)

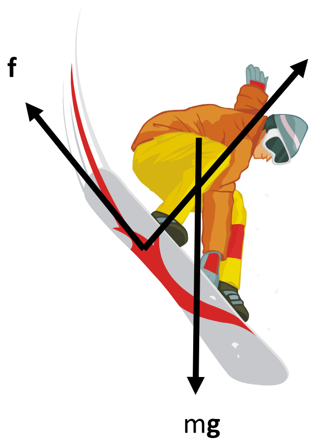
Chapter/Module 5 – Force and Motion – ***MCD Feb. 24***	
- *comprehend* the notion of force as causing a change in velocity	5.4
- *comprehend* the vector properties of gravitational force, normal force, tension, and the classification of these forces as field or contact forces	5.3
- *apply* vector algebra to the decomposition of forces into components	5.1
- *apply* superposition to determine the net force	5.1
- *recall* Newton's 1st and 2nd Laws	5.5, 5.6
- *comprehend* the notion of inertia (Newton's First Law)	5.4, 5.6
- *comprehend* the notion of mass as the measure of inertia	5.4
- *comprehend* the relationship between net force and acceleration (Newton's Second Law)	5.5
- *comprehend* the notion of the free-body diagram	5.7

Learning Resources

Objectives (OBJ)	Textbook Examples	Stop to Think (STT) (Answers p. 150)	Tactics Box (TB) & Problem Solving Strategy (PSS)	MP EOC Practice Problems
OBJ1	5.1, 5.2, 5.3	5.1	TB 5.2	
OBJ2		5.2		5.5
OBJ3	5.4, 5.5. 5.6		TB 5.3	
OBJ4		5.3, 5.4		5.15, 5.35
OBJ5				5.43, 47

MODULE 6 Study Guide

Dynamics of Motion in 1D



Introduction

Learning to recognize and identify forces carefully and accurately is one of the largest hurdles you will face. If you have begun to get a good handle on this from Module/Chapter 5, then the present chapter becomes more a matter of consolidating and using that information.

Free-body diagrams have been introduced, but likely you didn't get enough opportunity to practice drawing free-body diagrams. This is an important focus of the present chapter. Some of the major difficulties with free-body diagrams include:

- Identifying a force correctly, but not knowing which way it points.
- Including forces exerted *by* the object, not just forces exerted *on* the object.
- Placing the tips, rather than the tails, of the vectors at the origin, which makes it hard to determine the *x*- and *y*-components of the forces.
- Including "$m\vec{a}$" as a separate force. After all, Newton's second law says $\vec{F} = m\vec{a}$. This error is likely a continued belief in the need for some kind of "force of motion."
- Not using a coordinate system, or using an inappropriate one.
- Making errors in determining the component of the force vectors.

A few words must be said about the concepts of weight and the gravitational force. The gravitational force doesn't always correspond to what a scale reads or to your sensation of heaviness. Hence, "weight is the force of gravity" and "*w* = *mg"*, with *g* the free-fall value" are inconsistent statements. A more satisfactory approach is to define weight as what a scale reads. (To be more precise, the reading of a calibrated spring scale on which the object is stationary.) This is an operational definition (in keeping with the use of operational definitions elsewhere in the textbook), it agrees with your sensation of heaviness, and it works with (rather than fights against) the inevitable fact that the word "weight" is going to be associated with the common and well known practice of weighing. Weight really does increase in an elevator as it accelerates upward, and astronauts in free-fall really are weightless!

Hence, the force that shows up on a free-body diagram and that is used in Newton's second law is the "gravitational force" (or "force of gravity") $\vec{F}_{\mathrm{G}} = (mg,\ \text{straight down})$. We say that "gravity acts on an object" rather than "weight acts on an object." The symbol *g* needs to be called the "free-fall acceleration" rather than the "acceleration due to gravity," and, indeed, this terminology has been used since Module/Chapter 2.

An important goal in this chapter is that you recognize that you can “read” the necessary information about forces off the free-body diagrams. Thus it is very important to identify forces and to draw free-body diagrams properly. This part of the analysis is the *physics*, and the subsequent solution for the acceleration and the motion is “merely” mathematics. Memorizing every equation in the book will be of little use to you if you can’t identify forces and draw a correct free-body diagram.

You may still be having difficulty using vector components or recognizing that $\vec{F} = m\vec{a}$ is a shorthand way to write three simultaneous equations involving the components.

Friction is introduced as a *model* (it is not a physical law, such as Newton’s second law). Kinetic friction is rather straight forward but you may have a harder time with static friction. It may be difficult to understand how there can be a force without a well-specified value, and you may have difficulty knowing which way the static friction force points. What would happen to the object if there were *no* friction? Note that the static friction force responds *as needed*—both size and direction—to prevent slipping. Because there’s an upper limit to the size of the static friction force, the object *will* slip if the limit is exceeded. Beware that you don’t apply $f_{\text{s max}} = \mu_{\text{s}} mg$ indiscriminately to any situation. In many cases $n \neq mg.$!

The “big picture” you want to see in Chapter 6 is:

$$\underline{\textit{individual forces} \Rightarrow \textit{net force} \Rightarrow \textit{acceleration} \Rightarrow \textit{kinematics}}$$

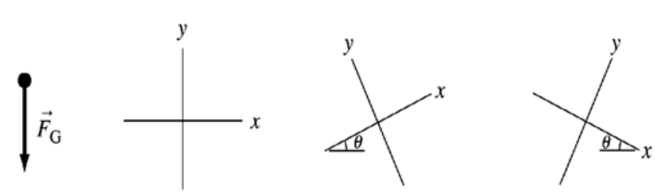
To encourage this awareness it is important to insist that you

- use *all* the steps in the problem-solving strategy.
- begin the mathematical representation of each problem with a full statement of Newton’s first or second law.
- *use* the free-body diagram to obtain the force components for Newton’s laws.

<u>Pre-Lecture Exercises</u>

1. A 100 kg block on which the gravitational force is 980 N hangs on a rope. Find the tension in the rope if the block is stationary, then if it’s moving upward at a steady speed of 5 m/s, and finally if it’s accelerating upward at 5 m/s^2. Make sure you draw a motion diagram, identify the forces, draw a free-body diagram and then explicitly use Newton’s first or second law.

2. A mass *m* is shown as a point with a downward gravitational force vector $\vec{F}_{\text{G}}$. Find the components $(F_{\text{G}})_x$ and $(F_{\text{G}})_y$ in each of the three coordinate systems shown below. Can you prove that the angle θ between the force vector and the negative *y*-axis is the same as the “tilt angle” of the coordinate system?



Find the *x*- and *y*-components of $\vec{F}_{\text{G}}$ in each of these three coordinate systems.

3. A 75 kg skier starts down a 50-m-high, 10° slope on frictionless skis. What is his speed at the bottom? In this problem you will go all the way from the pictorial representation through to the use of kinematics equations.

   Show that the acceleration on a frictionless incline is $a = g\sin\theta$ a fact that was asserted in Chapter 2 but not really proved.

   In this problem you are using a "model" and making approximations. Is it reasonable to treat the skis as frictionless? Is it reasonable to ignore air resistance? Is the answer exactly the speed of a real skier, approximately the speed of a real skier, or not even close to the speed of a real skier?

Pre-Lecture Conceptual Multiple Choice Questions

1. What is the difference, or is there a difference, between *mass* and *weight*?

2. Newton's first law can be applied to

   a. static equilibrium.
   b. inertial equilibrium.
   c. dynamic equilibrium.
   d. both a and b.
   e. both a and c.
   f. all of a, b, and c.

3. The coefficient of static friction is

   a. smaller than the coefficient of kinetic friction.
   b. equal to the coefficient of kinetic friction.
   c. larger than the coefficient of kinetic friction.
   d. not discussed in this chapter.

4. The force of friction is described by

   a. the law of friction.
   b. the theory of friction.
   c. a model of friction.
   d. the friction hypothesis.

Prerequisites

Prerequisites	Location in Textbook	Module
Constant a kinematics	2.4-2.6	2
Vectors and components	3.3-3.4	3
Identify forces and free body diagrams	5.2,5.3 and 5.7	5

Learning Objectives & Competencies

Learning Objectives *In this chapter you will:*		**Competencies**	***Section in Textbook***
OBJ1	draw and make effective use of free-body diagrams	*Comprehend*	All sections
OBJ2	recognize and solve simple equilibrium problems	*Apply*	6.1
OBJ3	distinguish mass, weight, and gravity	*Comprehend*	6.3
OBJ4	learn and use simple models of friction	Apply	6.4
OBJ5	apply the full strategy for force and motion problems to problems in single-particle dynamics	*Apply*	All sections & 6.6

Course Content (Course Outline)

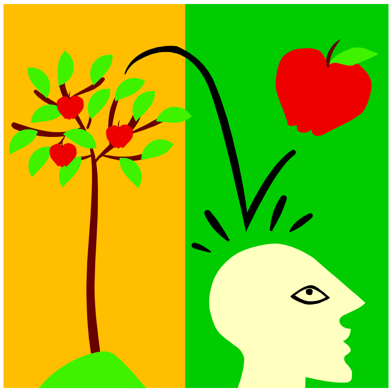
Chapter/Module 6 – Dynamics of Motion in One Dimension – *MCD Mar. 2*	
- *apply* Newton's 2^{nd} Law for the special case a = 0, v = 0 (static equilibrium)	6.1
- *apply* Newton's 2^{nd} Law using the component method to obtain the force components	6.2
- *comprehend* the notions of weight and apparent weight	6.3
- *comprehend* the properties of static and kinetic friction	6.4
- *comprehend* the notions of the coefficients of static and kinetic friction, and the limits of static friction	6.4
- *apply* the above concepts to solve dynamics problems	6.6
Optional Topic	
- *apply* the above concepts to problems involving drag	6.5

Learning Resources

Objectives (OBJ)	**Textbook Examples**	**Stop to Think (STT) (Answers p. 182)**	**Tactics Box (TB) & Problem Solving Strategy (PSS)**	**MP EOC Practice Problems**
OBJ1	Most examples	6.1		
OBJ2	6.1		PSS 6.1	6.35
OBJ3		6.2		
OBJ4	6.6, 6.7	6.3		6.52, 6.46
OBJ5	Most Examples and 6.9, 6.10, 6.11,		OSS 6.2	6.58, 6.70

MODULE 7 Study Guide

Newton's Third Law



Introduction

An apple falls off a tree and hits you on your head. The apple exerts a force (an action) on your head. The apple bounces off your head. What pushed the apple off your head? Was a force (reaction) exerted on the apple by your head? Since your head is more massive than the apple, was the force exerted on the apple greater than the force the apple exerted on your head?

These two forces are an example of an "*action-reaction pair*" – equal and opposite forces and acting on different objects. Your head and the apple have interacted according to Newton's Third Law.

Suppose a large truck and a compact car have a head-on collision. *During the collision*, is the force of the truck on the car larger, smaller, or equal to the force of the car on the truck?

Some of the more specific difficulties you may have with Newton's third law and with interacting objects are:

- You don't believe Newton's third law. It's too contrary to common sense.
- You have difficulty identifying action/reaction force pairs:
  - You match two forces on the same object.
  - You place forces on the wrong objects.
  - You don't believe that long-range forces (e.g., gravity) have reaction forces.
- You may confuse equal force with equal acceleration.
- You may not understand tension:
  - You think that tension is the *sum* of the forces exerted at the two ends of a string.
  - You think that tension exerts a force only in the direction of motion.
  - You think that tension can pass through an object to another string on the other side.
- You may not recognize that objects connected by an inextensible string must have accelerations of equal magnitude.

Chapter 5 began the process of dividing a problem into the *object of interest* and the *environment*. That process now becomes even more important with the need to identify several *interacting objects*, some of which form the *system*. The interaction diagram, described in steps 1–3 of Tactics Box 7.1, asks you to:

- Represent *every* object with a circle.
- Identify the interactions between objects.
- Represent each interaction as a line between the two interacting objects.
- Recognize that every interaction consists of two forces, $\vec{F}_{\text{A on B}}$ and $\vec{F}_{\text{B on A}}$.
- Group the objects of interest into "the system" by drawing a box around them, leaving all other objects in the environment. Forces from objects in the environment are external forces.

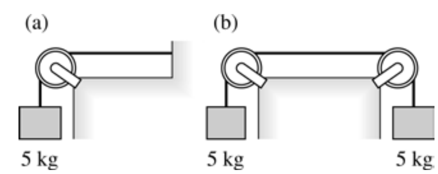
Moving from the interaction diagram to free-body diagrams is described in step 4 of Tactics Box 7.1:

- Draw a *separate* free-body diagram for each object within the system.
- Use dotted lines to connect the two members of an action/reaction pair. Verify that the two forces connected by dotted lines (1) are on two *different* free-body diagrams and (2) point in opposite directions.

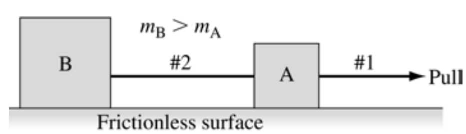
This strategy for analyzing interacting objects is illustrated in textbook Examples 7.1 and 7.2, and then in many of the later worked examples. The emphasis on *separate* and *different* is important. You may have a tendency to identify the gravitational force $\vec{F}_G$ and the normal force $\vec{n}$ on an object as an action/reaction pair. You will avoid this error if first you verbalize these as $\vec{F}_{\text{earth on A}}$ and $\vec{F}_{\text{table on A}}$, and verify that the forces of a pair appear on two different free-body diagrams. This confirms that the forces between two colliding carts are *always* equal in magnitude, regardless of the masses or the initial velocities of the carts. Another demonstration has two students of different size push against each other with bathroom scales, each calling out the reading on "their" scale as they move forward or backward.

<u>Pre – Lecture Exercises</u>

1. Compare the tension at the point at which the string in (a) is attached to the wall to the tension in the middle of the string in (b).

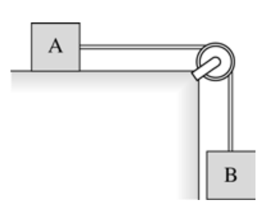


2. Shown below, is a person pulling on a string and accelerates blocks A and B, connected by massless strings, across a frictionless surface. Note that m_B is greater than $m_{A.}$ Compare the force exerted by string 1 on block A with the force exerted by string 2 on block B.



How does the force string 1 exerts on A compare to the force string 2 exerts on B?

3. Block A can slide across a frictionless table when pulled by a falling block B and a massless string. Initially, block A was held in place by someone's hand. What happens to the tension in the string when the hand is removed (increase, decrease or stays the same)?



4. A 200 kg horse is hooked up to a 400 kg wagon, and you signal the horse to pull forward.

   The (talking!) horse turns to you and says, "Why bother? However hard I pull, the wagon is just going to exert an equal but opposite force on me. The wagon won't move."

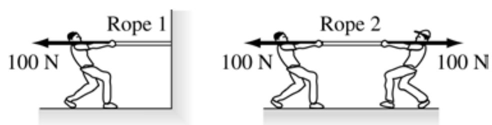
   Will the wagon move? If not, explain why not. If so, what kind of explanation would you give the horse to convince him to pull? You might want to use pictures as part of your explanation.

Pre – Lecture multiple choice questions

1. The propulsion force on a car is due to

   a. static friction.
   b. kinetic friction.
   c. the car engine.
   d. elastic energy.

2. Is the tension in rope 2 greater than, less than, or equal to the tension in rope 1?



3. An *acceleration constraint* says that in some circumstances

   a. the acceleration of an object has to be positive.
   b. two objects have to accelerate in the same direction.
   c. the magnitude of the accelerations of two objects have to be equal.
   d. an object is prevented from accelerating.
   e. Acceleration constraints were not discussed in this chapter.

Prerequisites

Prerequisites	Location in Textbook	Module
Concepts of force and tension	5.1-5.3	5
Problem-solving strategy	6.2	6

Learning Objectives & Competencies

Learning Objectives *In this chapter you will:*		**Competencies**	**Section in Textbook**
OBJ1	learn how two objects interact	*comprehend*	7.1
OBJ2	identify action/reaction pairs of forces	*comprehend*	7.2
OBJ3	understand and use Newton's third law	*apply*	7.3
OBJ4	understand how to use *propulsion* forces and tension forces	*apply*	7.2, 7.4, 7.5

Course Content (Course Outline)

Chapter/Module 7 – Newton's Third Law – *MCD Mar. 16*	
- *comprehend* the notion of equal and opposite forces for two objects acting on each other (Newton's Third Law), with emphasis on identifying the body on which each force is applied	7.1-7.3
- *apply* Newton's 2nd law to multiple mass systems connected by massless ropes going over pulleys	7.4, 7.5

Learning Resources

Objectives (OBJ)	**Textbook Examples**	**Stop to Think (STT) (Answers p. 209)**	**Tactics Box (TB) & Problem Solving Strategy (PSS)**	**MP EOC Practice Problems**
OBJ1				Q7.7, Q7.12, PSS 7.1
OBJ2	7.1, 7.2	7.1	TB 7.1	EX 7.1, EX. 7.6
OBJ3	7.3, 7.4	7.2, 7.3	PSS 7.1	7.33
OBJ4	7.5, 7.6, 7.7, 7.8, 7.9, 7.10	7.4, 7.5, 7.6		Q7.14, Q7.15, 7.34, 7.39, 7.44

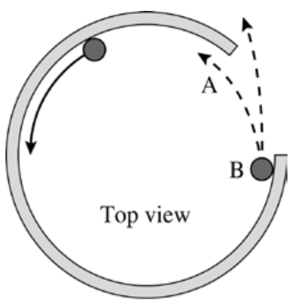
MODULE 8 Study Guide

Dynamics II: Motion in a Plane – Circular Motion Dynamics

Introduction

As the roller coaster moves on the track, most of the time it may not be moving in a straight line but in a circular path. The roller coaster has an acceleration toward the center of the circular path that dictates the change in its direction of motion.

Circular motion requires a shift in your thinking from the emphasis until now on linear motion and motion that can be decomposed into independent linear motions along two axes.



Common incorrect responses

A marble is rolled around the inside of an incomplete circular hoop lying flat on a table. Predict the marble's trajectory after passing point B.

a) Do you predict it will continue with perfect circular motion, reentering the hoop at A?
b) Do you predict a circular tendency that "runs down," so the marble curves to the left but gradually straightens out?
c) Is your prediction different from the two above?
d) Could the particle have *a linear trajectory* from B?

Be careful when you see (or use) the *term* "centripetal force" ! It is NOT a new *kind* of force, like the gravitational force or the normal force, and so there is no force vector labeled "centripetal force" to free-body diagrams. You should understand that circular motion is due to a center-directed force. Hence, in this text, you will see the term *centripetal acceleration* as the acceleration of an object moving in a circle, but it does not use the term *centripetal force*. In a problem involving circular motion, start by analyzing the forces present, then conclude *from the situation* that the net force points to the center. In other words, you want to understand the chain of reasoning:

- The circumstances make $\vec{F}_{\text{net}}$ point toward a fixed point.
- Therefore, $\vec{a} = \vec{F}_{\text{net}}/m$ also points toward a fixed point (a centripetal acceleration).
- Therefore the motion is uniform circular motion.

Because circular motion analysis requires looking at forces both in the plane of motion (the *xy*-plane) and perpendicular to the plane of motion, the text introduces a new "*rtz*-coordinate system." The origin is placed on the particle (for free-body diagram purposes) and the *r*-axis is chosen to point toward the center of the circle. This choice makes the radial component of acceleration always positive $(a_r = v^2/r > 0)$ and the perpendicular component zero $(a_z = 0)$. The tangential component a_t is zero for uniform circular motion but non-zero for non-uniform circular motion.

Orbital motion is introduced in this chapter as an important application of circular motion. However, this topic will be expanded in Chapter 13, where Newton's law of gravitation is presented. The goal for now is that you begin to understand that orbital motion is nothing other than free fall—that a satellite is "falling" around the earth but never getting any closer to the ground because the earth's surface curves away at the same rate.

NOTE: Part I Summary

Chapter 8 is followed by the first of seven part summaries. Each summary consists of a "knowledge structure" plus a short diversion relevant to the part just completed. Each knowledge structure summarizes the essential information of the preceding chapters in an expert-like hierarchical arrangement. Students should note that, thus far, there are only three physical principles: Newton's laws. We've considered three general types of motion, each of which uses the second law in a slightly different way. Each form of motion then branches into more specialized kinematic results. At an even finer scale, not shown here, is information about specific types of forces.

You can photocopy this page and keep it in front of you as you study for the term test that includes Part I. You could look up specific details as needed, but this table describes the basic approach that you should apply to *any* problem in single-particle dynamics.

Pre – Lecture Exercise

A car drives at steady speed *v* over the top of a circular-shaped hill of radius 50 m. What's the maximum speed the car can have without "flying off" the hill at the top? You refer to this speed as the *critical* speed.

Pre – Lecture Multiple choice questions

1. Circular motion is best analyzed in a coordinate system with

   a. *x*- and *y*-axes.
   b. *x*-, *y*-, and *z*-axes.
   c. *x*- and *z*-axes.
   d. *r*-, *t*-, and *z*-axes.

2. This chapter studies

   a. uniform circular motion.
   b. nonuniform circular motion.
   c. orbital motion.
   d. Both a and b.
   e. Both a and c.
   f. All of a, b, and c.

3. For uniform circular motion, the net force

   a. points toward the center of the circle.
   b. points toward the outside of the circle.
   c. is tangent to the circle.
   d. is zero.

Prerequisites

Prerequisites	Location in Textbook	Module
Kinematics of 2D motion	Chapter 4, 4.5 - 4.7	4
Newton's 1st and 2nd laws	6.1 and 6.2	6
Gravity and Weight	6.3	6

Learning Objectives & Competencies

Learning Objectives *In this chapter you will:*		**Competencies**	***Section in Textbook***
OBJ1	compute two-dimensional trajectories	*Apply*	8.1, 8.2
OBJ2	understand the dynamics of uniform and non-uniform circular motion	*Apply*	8.3, 8.7
OBJ3	learn the basic ideas of orbital motion	*Comprehend*	8.4
OBJ4	answer "How does the water stay in the bucket?" and related questions	*Comprehend*	8.6

Course Content (Course Outline)

Chapter/Module 8 - Dynamics of Motion in Two Dimensions – *MCD Mar. 23*	
- *comprehend* the notion of centripetal and tangential acceleration	4.5 - 4.7
- *recall* the relationship between centripetal acceleration and tangential speed	4.6, 8.2
- *comprehend* the notion of net force as it contributes to uniform and non-uniform circular motion	8.3, 8.7
- *apply* the above concepts to problems involving uniform and non-uniform circular motion.	8.4, 8.6, 8.7

Learning Resources

Objectives (OBJ)	Textbook Examples	Stop to Think (STT) (Answers p. 235)	Tactics Box (TB) & Problem Solving Strategy (PSS)	MP EOC Practice Problems
OBJ1	8.1, 8.2	8.1, 8.2, 8.3		8.25
OBJ2	8.3, 8.4, 8.5, 8.6, 8.7		8.1	8.6, 8.8, 8.10, 8.46, 8.47, 8.59, 8.61
OBJ3				8.11
OBJ4				8.13 – 8.16

MODULE 9 Study Guide

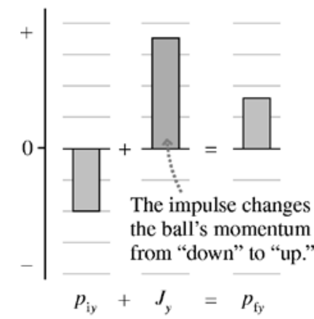
Impulse and Momentum

Introduction

In a collision process or an explosion it is very difficult (most of the time) to know the precise nature of the force or forces acting to change the motion of the objects involved. Sometimes these forces act for a short period of time or they may act for a long time period. In this chapter we introduce a *new perspective* for looking at problems of force and motion, namely, impulse and momentum.

Essentially, we now focus on what happens to the motion of an object (it's momentum) when we consider the action of force(s) over time (the impulse delivered to the object).

Suppose you drop a ball from a certain height above the floor. The dropped ball has a "long" impulse due to gravity as it falls and changes momentum. Then as it strikes the floor it has a "short" impulse due to both the normal force *and* gravity. The normal force that acts on the ball due to the floor grows from zero to a magnitude that far exceeds the weight of the ball. Why? Then it shrinks back to zero as the ball rises above the floor. So the action of the force of the floor on the ball over a relatively short period of time (impulse) has gone to change the momentum of the ball from "down" to "up".



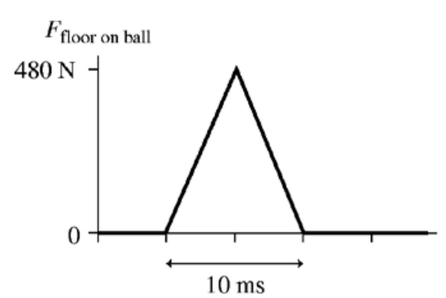
Momentum bar chart of a bouncing ball.

Suppose you have the choice of a rubber ball or a sticky clay ball (of equal mass) that you could throw against an upright wood block in order to knock it over. Which would you choose? Is sticking to the block more effective at applying a force than bouncing off the block? Which is the elastic collision and which is the inelastic collision? Which is more effective to knock over the wood block?

When it comes to analyzing collisions and explosions, conservation of momentum is extremely important. Suppose you consider two gliders on an air track (zero friction) moving toward each other and allowed to collide. *Each* glider experiences an impulse during the collision process. Hence, *each* glider will also experience a change of momentum. What do you think is the *total* change of momentum of the two-glider system?

Pre – Lecture Exercise

A 200 g rubber ball is released from a height of 2.0 m. It falls to the floor, bounces, and rebounds. The force of the floor on the ball is shown in the figure. How high does the ball rebound? (Answer: 1.62 m. Don't forget the 10 ms impulse due to the weight force $\vec{w}$, which is small but not entirely negligible.)



Pre – Lecture Multiple Choice Questions

1. What is an *isolated system*?

2. *Impulse* is
   a. a force that is applied at a random time.
   b. a force that is applied very suddenly.
   c. the area under the force curve in a force-versus-time graph.
   d. the time interval that a force lasts.

3. The total momentum of a system is conserved
   a. always.
   b. if the system is isolated.
   c. if the forces are conservative.
   d. never; it's just an approximation.

4. In an *inelastic collision*,
   a. impulse is conserved.
   b. momentum is conserved.
   c. force is conserved.
   d. energy is conserved.
   e. elasticity is conserved.

Prerequisites

Prerequisites	Location in Textbook	Module
Action reaction force pairs and Newton's third law	7.2 - 7.3	7

Learning Objectives & Competencies

Learning Objectives *In this chapter you will:*		Competencies	*Section in Textbook*
OBJ1	understand interactions from the new perspective of *impulse* and *momentum*	*Comprehend*	9.1, 9.2
OBJ2	learn what is meant by an *isolated system*	*Recall*	9.3
OBJ3	apply conservation of momentum	*Apply*	9.3, 9.4
OBJ4	understand the basic ideas of inelastic collisions, explosions, and recoil in 1D and 2D	*Apply*	9.4, 9.5

Course Content (Course Outline)

Chapter/Module 9 – Impulse, Momentum, Inelastic Collisions – *MCD Mar 30*	
- *comprehend* the notions of impulse and momentum as vector quantities	9.1
- *apply* the impulse-momentum theorem to solving impulse and momentum problems	9.2
- *apply* Newton's 3rd Law to show that linear momentum is conserved for two objects in collision	9.3
- *comprehend* and *apply* the conservation of linear momentum	9.3
- *recall* the relationship between change in momentum of a colliding body and average force of collision on that body	9.3
- *apply* the above concepts to problems involving inelastic collisions & explosions in one and two dimensions	9.4, 9.5

Learning Resources

Objectives (OBJ)	**Textbook Examples**	**Stop to Think (STT) (Answers p. 266)**	**Tactics Box (TB) & Problem Solving Strategy (PSS)**	**MP EOC Practice Problems**
OBJ1	9.1	9.1	TB 9.1	9.3, 9.8, 9.12, 9.25, 9.32
OBJ2	9.2	9.2		
OBJ3	9.3	9.3	PSS 9.1	9.19, 9.23
OBJ4	9.4 to 9.10	9.4, 9.5		9.39, 9.41, 9.51, 9.58

MODULE 10 Study Guide

Conservation of Energy

Introduction

Energy is a very abstract concept unlike the well-defined idea of momentum that we saw in the previous module. We have several forms of energy: kinetic energy, potential energy, thermal energy, chemical energy, nuclear energy, and so on. There is an interesting comparison of energy with money that you can read about in section 10.1.

What we will be concerned with in this module are the first two forms mentioned in the paragraph above, namely, kinetic energy and potential energy. The sum of these two energy forms gives us the total mechanical energy.

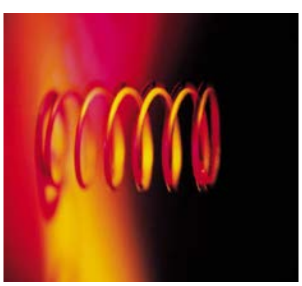
We will be using kinetic and potential energy in familiar contexts and develop the *before-and-after* perspective of the conservation law of total mechanical energy when we are dealing with frictionless settings.

So the two key ideas essential for getting started with energy are:

- There are two basic types of energy—kinetic energy (energy of motion) and potential energy (energy of position).
- These two kinds of energy—at least under some circumstances—can be *transformed* back and forth without loss.

The derivation connecting these two energy forms is done in section 10.2. Some calculus is used, so you can ask your teacher about the details if you have not done integration before. Keep in mind that we only consider motions of objects close to the surface of the earth where the acceleration due to gravity is a constant ($g = 9.81\ m/s^2$).

An example would be throwing a ball straight up into the air (neglecting air resistance). During the throwing process you would impart to the ball kinetic energy. Remember that in Module 2 you said that it has an initial upward speed. Now the motion is being looked at in terms of kinetic energy ($\frac{1}{2}mv^2$). When the ball gets to the highest point it stops momentarily (the speed at the maximum height is zero). Hence, we say that at the maximum height the ball only has potential energy and the kinetic energy has been transformed into gravitational potential energy.



What would be different if you threw the ball at an angle (projectile motion). Starting with only kinetic energy when the ball is thrown, what can you say about its energy at the highest point? Explain. Hint: recall what you learned in Module 4.

The restoring force of a spring depends on the *displacement* of the end of the spring. Hence if we use the symbol "x" it must represent

the amount of stretch (+) or compression (-) from the *equilibrium position (un-stretched, un-compressed spring length where x = 0)*, not a displacement from the origin of the x-axis. Then we can write Hooke's law as $F = -kx$. This leads to the spring potential energy $U_s = \frac{1}{2}kx^2$.

However, the textbook also writes Hooke's law as $F_s = -k\Delta s = -k(s - s_e)$, where F_s is explicitly a vector component, Δs is a generalized displacement, and s_e is the *equilibrium position* of the end of the spring. This leads to $U_s = \frac{1}{2}k(\Delta s)^2$ for the elastic potential energy of a spring.

In some collisions, the molecular bonds get compressed and then expand to push the objects back apart. That is to say that during the collision process kinetic energy transforms to potential energy and then transforms back to kinetic energy. Since we analyze the collision process just before and just after the collision, it suffices to say that in such a collision kinetic energy is conserved. This is called an *elastic collision*. Since momentum and kinetic energy must both be conserved, the collision must satisfy two simultaneous equations in 1-D. It gets a bit more complicated in 2-D where conservation of momentum must be applied using the x and y axis, since momentum is a vector quantity.

In the "Newton's cradle" demo if one metal ball is raised and then let go, what happens after it collides with the hanging stationary balls?
Hint: What happens when you shoot a pool ball at another ball at rest on the pool table.

Pre – Lecture Exercises

1. Two balls, one twice as heavy as the other, are dropped from the roof of a building. Just before hitting the ground, the heavier ball has

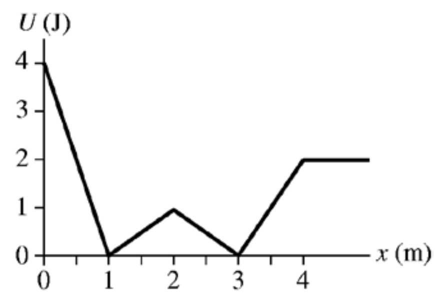
   a) one-half b) the same amount as c) twice d) four times the kinetic energy of the lighter ball.

2. A block sliding along a frictionless horizontal surface with velocity *v* collides with and compresses a spring. The maximum compression is 1.4 cm. If the block then collides with the spring while having velocity 2*v*, the spring's maximum compression will be

   a) 0.35 cm b) 0.7 cm c) 1.0 cm d) 1.4 cm e) 2.0 cm f) 2.8 cm g) 5.6 cm

3. Consider the potential-energy graph shown that describes the motion of a particle with a total energy of 1.5 J.

   a) Where does it speed up, where does it slow down?
   b) Where are the turning points in the motion?
   c) What energy transformations are taking place?
   d) Make a graph of kinetic energy versus position.



Pre – Lecture Conceptual Questions

1. Energy is a physical quantity with properties somewhat similar to
   a) money.
   b) a liquid.
   c) momentum.
   d) heat.
   e) work.

2. Hooke's law describes the force of
   a) gravity.
   b) a spring.
   c) collisions.
   d) tension.
   e) none of the above.

3. A *perfectly elastic collision* is a collision that conserves
   a) kinetic energy and linear momentum.
   b) only thermal energy.
   c) only kinetic energy.
   d) only potential energy.

Prerequisites

Prerequisites	Location in Textbook	Module
Free fall Kinematics	2.6	2
Free body diagram and dynamics	5.7	5
Derivatives, differentials, chain rule, integrals	2.2, 2.3, Appendix A	2

Learning Objectives & Competencies

Learning Objectives ***In this chapter you will:***		Competencies	***Section in Textbook***
OBJ1	begin developing a concept of kinetic and potential energy —what it is, how it is transformed, and how it is transferred (conservation of total mechanical energy) and the basic energy model (using gravitational potential energy) and solve problems	*Comprehend*	10.1, 10.2, 10.3
OBJ2	learn Hooke's law for springs and the new idea of a *restoring force*	*Recall*	10.4
OBJ3	define and apply elastic potential energy of a spring to motion and solve problems	*Apply*	10.5
OBJ4	learn and to interpret energy diagrams – omit equilibrium positions	*Apply*	10.7

Course Content (Course Outline)

Chapter/Module 10 – Conservation of Energy & Elastic Collisions – *MCD Apr. 6*	
- *comprehend* the notion of kinetic energy and its relationship to mass and speed	10.1, 10.2
- *recall* the formulae for gravitational and elastic potential energy	10.2, 10.3, 10.5
- *recall* Hooke's Law	10.4
- *comprehend* the concept of elastic potential energy	10.5
- *apply* the above concepts to solve problems using the methods of conservation of TME	10.3 -10.5
- *comprehend* the concept of an elastic collision and conservation of kinetic energy	10.6
- *apply* the above concepts to problems involving conservation of momentum and energy	10.6

Learning Resources

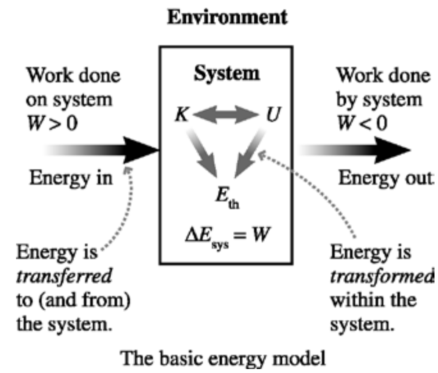
Objectives (OBJ)	Textbook Solved Problems	Stop to Think (STT) (Answers p. 301)	Tactics Box (TB) & Problem Solving Strategy (PSS)	MP EOC Practice Problems
OBJ1	10.1, 10.2, 10.3, 10.4	10.1, 10.2, 10.3	PSS -10.1	10.1, 10.5, 10.69, 10.76
OBJ2	10.5	10.4		
OBJ3	10.6, 10.7, 10.8	10.5		10.20, 10.21, 10.22, 10.41, 10.45
OBJ4		10.6	TB -10.2	10.29

MODULE 11 Study Guide

Work (and Energy)

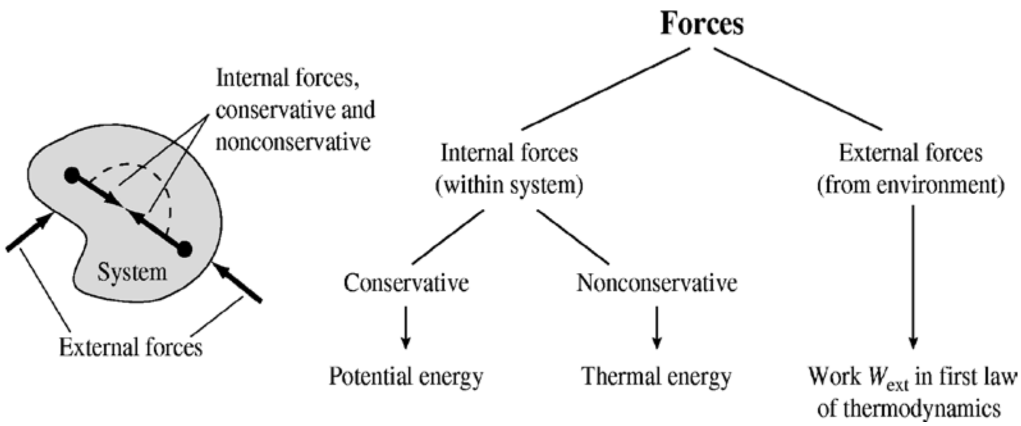
Introduction

In Module 10 you found that energy conservation was a useful idea, but its use was restricted to situations without friction or other dissipative forces. The goal of this Module is to expand those initial ideas into a more complete understanding of work and energy. The *basic energy model* is shown in the figure. Energy can be *transformed* within the system without changing the value of E_{sys}. However, energy can also be *transferred* between the system and the environment. For now, we're only concerned with the mechanical transfer of energy due to forces acting on the system. The mechanical transfer of energy is defined as *work*.



The basic energy model

It is important to distinguish between a *system* and the *environment*. Action/reaction forces within the system may be either conservative (gravitational forces, spring forces) or non-conservative (friction forces). Equally important, the environment may exert external forces on the system.



The work-kinetic energy theorem (or simply the work-energy theorem – *W.E.T.)* summed over all the particles in the system gives

$$\Delta K = W_c + W_{diss} + W_{EXT} \quad = W_T$$

where W_c is the work done by conservative forces, W_{diss} is the work done by dissipative non-conservative forces within the system, and W_{ext} is the work done by external forces acting on the system. But conservative forces can be associated with a potential energy U via

$$\Delta U = -W_c$$

and dissipative forces increase the thermal energy by $\Delta E_{th} = -W_{diss}$. Thus the work-kinetic energy theorem can be written as

$$\Delta K + \Delta U + \Delta E_{th} = \Delta E_{mech} + \Delta E_{th} = W_{ext}$$

We can make this expression more concise if we lump together $\Delta E_{\text{th}} = -W_{\text{diss}}$ and W_{ext} on the right hand side and call it W_{nc} . Then the work-energy method equation (*W.E.M.E.*) becomes

$$\Delta K + \Delta U = W_{nc}$$

The work done by conservative forces is taken care of by the change in potential energy (hence there could be several terms here)

How do you actually calculate work? Fortunately, the technique introduced in Chapter 10 for finding gravitational and elastic potential energy is easily generalized, on p. 307, to

$$\Delta K = \int_{s_i}^{s_f} F_s \; ds$$

Thus we discover the work-kinetic energy theorem $\Delta K = W_T$ if we define the work done by the net force $\vec{F}$ as

$$W = \int_{s_i}^{s_f} F_s \; ds$$

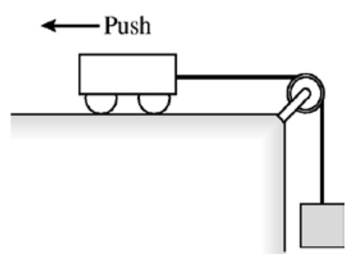
If you are not comfortable with calculus, the above definition is equivalent to saying that the work done by a force is the area under the *force vs position* curve where it is understood that we consider the component of force along the displacement. This way we can consider both constant and non-constant forces.

The vector dot (scalar) product is useful when considering the work done by constant forces. Some practice doing dot products is useful before you are comfortable using $\vec{F} \cdot \Delta\vec{r}$ to calculate work. In particular, it is useful to see that $A_x B_x + A_y B_y$ and $AB\cos\theta$ are the same thing when calculating the dot product.

Power, “the rate of doing work”, will be quickly discussed in mechanics.

Pre-Lecture Exercises

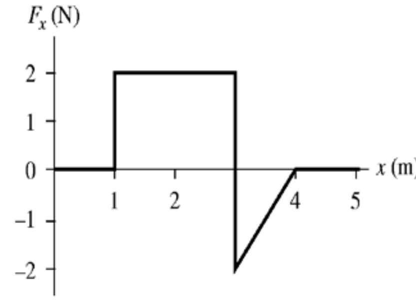
1. Consider a low-friction cart attached by a string to a hanging mass. First release the cart from rest.



   - Does ΔK increase or decrease?
   - What is the *sign* of ΔK?
   - What forces act on the cart?
   - For each of the forces, is the work positive, negative, or zero?
   - Is W_{net} positive, negative, or zero? Does this agree with ΔK?

   Next, push the cart *away* from the pulley so that it slows as the hanging mass is lifted. Answer the same questions above after you release the cart and before it reverses direction.

2. A 1.0 kg block moves along the *x*-axis. It passes *x* = 0 m with velocity v_x = 2.0 m/s. It is then subjected to the force shown in the graph.



   a. Which of the following is true: The block gets to *x* = 5 m with a speed greater than 2.0 m/s, the block gets to *x* = 5 m with a speed of exactly 2.0 m/s, the block gets to *x* = 5 m with a speed of less than 2.0 m/s, or the block never gets to *x* = 5 m?
   b. Calculate the block's speed at *x* = 5 m.

3. A 200 g block on a rough surface with μ_k = 0.8 is pushed against a spring with spring constant 500 N/m, compressing the spring 2.0 cm. If the block is released, with what speed is it shot away from the spring? (This is a variation on Example 9 from Chapter 10. Now you have to include the W_{diss} term.)

4. A rope with a tension of 30 N pulls a 2.0 kg box up a rough ($\mu_k = 0.3$), 2.0-m-long, 30° incline. What is the speed of the box at the top (using W.E.M.E.)?

<u>Pre-Lecture Conceptual Questions</u>

1. What new mathematical idea about vectors was introduced in this chapter?

2. The statement $\Delta K = W$ is called the
   a. law of conservation of energy.
   b. kinetic energy equation.
   c. work-kinetic energy theorem.
   d. weight-kinetic energy theorem.

3. The transfer of energy to a system by the application of a force is called __________.

<u>Prerequisites</u>

Prerequisites	Location in Textbook	Module
Gravitational Potential Energy	10.2 – 10.3	10
Hooke's Law & Elastic Potential Energy	10.4 -10.5	10

<u>Learning Objectives & Competencies</u>

Learning Objectives ***In this chapter you will:***		**Competencies**	***Section in Textbook***
OBJ1	understand the basic energy model	*Comprehend*	11.1
OBJ2	recognize transformations between kinetic, potential, and thermal energy	*Comprehend*	11.1, 11.5
OBJ3	define work and use the work-kinetic energy theorem	*Apply*	11.2, 11.3
OBJ4	use vector algebra (scalar or dot product) to solve for work done in one, two and three dimensions and work done by a variable force	*Apply*	11.3, 11.4
OBJ5	develop and apply a complete method of the law of conservation of energy to problems	*Apply*	11.5, 11.7, 11.8
OBJ6	introduce and use the idea of power	*Comprehend*	11.9

Course Content (Course Outline)

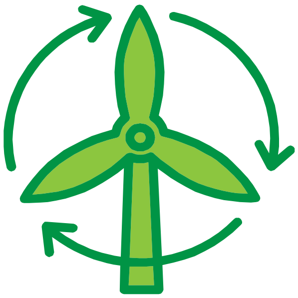
Chapter/Module 11 - Work and Energy – *MCD Apr. 13*	
- *comprehend* the notion of work	11.1
- *recall* the definition of work done by a constant force	11.2, 11.3
- *apply* vector algebra (scalar or dot product) to solve for work done in one, two and three dimensions	11.3
- *comprehend* the work done by a spring	11.4
- *comprehend* the work done by gravity	11.5
- *comprehend* the notion of potential energy as the work done by a conservative force	11.5
- *comprehend* the distinction between conservative and non-conservative forces	11.5
- *comprehend* conservation of energy in an isolated system	11.8
- *comprehend* the Work Kinetic Energy Theorem	11.8
- *comprehend* the work done by kinetic friction and other non-conservative forces as it contributes to the Work Energy Method Equation	11.7, 11.8
- *comprehend* the notions of instantaneous and average power	11.9
- *apply* the above concepts to solve problems using energy techniques and dynamics	11.8

Learning Resources

Objectives (OBJ)	Textbook Examples	Stop to Think (STT) (Answers p. 335)	Tactics Box (TB) & Problem Solving Strategy (PSS)	MP EOC Practice Problems
OBJ1		11.1		
OBJ2	11.9			
OBJ3	11.1, 11.2, 11.3	11.2, 11.3		11.17
OBJ4	11.5, 11.6, 11.7, 11.8	11.4		11.8, 11.12, 11.14
OBJ5	11.10, 11.14, 11.15, 11.16, 11.17	11.6	PSS 11.1	11.50, 11.54, 11.57, 11.74
OBJ6		11.7		

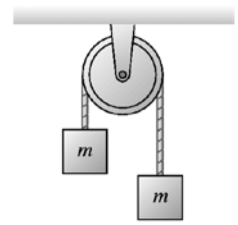
MODULE 12 Study Guide

Rotation of a Rigid Body



Introduction

Consider an Atwood's machine in which two identical blocks are held *at different heights* with the rope connecting the blocks going over a massive pulley. The rope cannot slip relative to the pulley but the axle of the pulley is frictionless.



Can you predict what would happen when the blocks are released from rest from the different heights? In other words, do the blocks stay where they are initially, does the left block move down and the right block moves up or does the right block move down as the let block moves up? Explain.

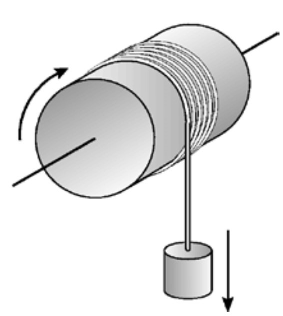
Rotational kinematics are an exact analog of linear kinematics. Also, it is important to review the section on circular motion in Chapter 4 that addresses the angular quantities and their relationship to linear quantities (4.5 – 4.7). Table 12.1 summarizes the equations for rotational motion with constant angular acceleration.

Here is an important note on sign convention. The textbook uses the convention that counterclockwise is positive and clockwise is negative. However, just as we found it convenient to choose coordinate systems with the direction of the acceleration a being positive (Chapters 5 to 8), we can do the same for rotational dynamics. Hence, rather than sticking to an absolute sign convention for the angular quantities, it may be more convenient to give the sense of the angular acceleration a positive sign when doing rotational dynamics problems.

However, it is important not to interpret positive and negative values of the angular acceleration α as speeding up and slowing down. 12.4 shows the four combinations of ω and α, illustrating that a positive value of α can cause the rotation either to speed up or to slow down.

It is important to recall the graphical interpretations of the kinematical quantities. In other words, it is important to realize that α is the slope of an ω-versus-t graph and so on.

The most important aspect of this chapter is the study of rotational *dynamics* and angular momentum (not the kinematics of rotation even though we will need to know this to some extent). To do so we will have to understand the concepts of torque and moment of inertia. Then we will be able to write down Newton's second law for rotation.



What does a torque do? Consider a pulley or cylinder that you can wrap a cord around several times and attach to a falling weight. Assume also that the axle is frictionless. The first and most important idea is that a torque creates an angular acceleration. In the diagram on the right you can see that a larger hanging weight causes a larger angular acceleration. It's also important to see what happens when you change the moment of inertia (the mass and/or mass distribution of the rotating object) while the torque remains the same (or at least approximately the same).

Note that a wheel on low-friction bearings will spin perfectly well with *no* torque. Torque *changes* the angular velocity but isn't needed to *have* an angular velocity.

Another thing that you notice in the diagram is that the falling mass will have a linear acceleration while the rotating cylinder, of say radius R, has an angular acceleration. To solve this type of problem, one must be able to relate the two as we saw in Chapter 4. This is called a *constraint equation* and is written as

$$a_t = \alpha R$$

Also, this problem can involve conservation of energy. The rotating cylinder will gain rotational kinetic energy, while the falling mass will lose gravitational potential energy and gain translational kinetic energy. Here the constraint equation is

$$v = \omega R$$

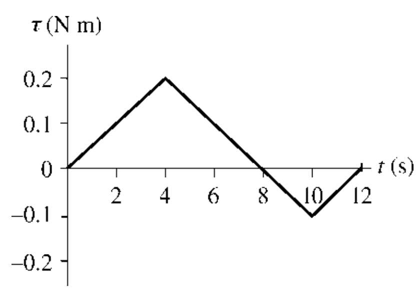
To study angular momentum you will have to understand another type of vector product referred to as the *cross (vector)* product. Some of you who have studied some magnetism in high school will be aware of *the right-hand rule*. The table on p. 368 shows three versions of the right-hand rule.

The other thing that you will have to learn is how to solve the cross product of two vectors (to get the third vector) using the unit vectors $\hat{i}, \hat{j},$ and $\hat{k}$. The primary goal of the vector description of rotational motion is to show that $d\vec{L}/dt = \vec{\tau}_{\text{net}}$. This follows easily when using vectors, where $\vec{v} \times \vec{p} = \vec{0}$ because the vectors are parallel. Hence, you will see that the vector angular momentum is conserved for an isolated system with $\vec{\tau}_{\text{net}} = \vec{0}$.

You will see several demonstrations either in class or in the lab. A rotating platform with a chair on it (hence a rotating chair!) and a spinning bicycle will offer a great demonstration of the law of conservation of angular momentum.

Pre-Lecture Exercises

1. A 12-cm-diameter, 2.0 kg disk, which is initially at rest, experiences the net torque shown in the figure below. What is the disk's angular velocity at *t* = 12 s?

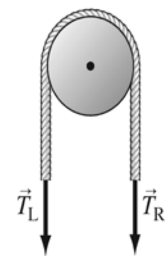


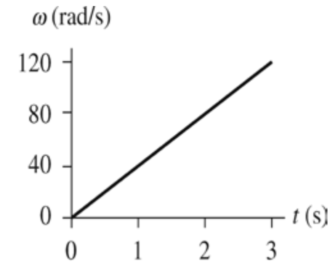
2. A rope passes over a 10-cm-diameter, 2.0 kg pulley that rotates on frictionless bearings. The graph below shows the pulley's angular velocity as a function of time. (This problem assumes the sign convention in the textbook).

   a. Is the tension T_L in the left rope larger, smaller, or equal to the tension T_R in the right rope? Explain.

   b. If you answered "equal" in part a, what is the magnitude of tension T_L ?

   c. If you answered "larger" or "smaller" in part a, what is the difference $|T_L - T_R|$ between the two tensions?





Pre-Lecture Conceptual Questions

1. A new way of multiplying two vectors is introduced in this chapter. What is it called?

2. *Moment of inertia* is

   a. the rotational equivalent of mass.
   b. the time at which inertia occurs.
   c. the point at which all forces appear to act.
   d. an alternative term for *moment arm*.

3. A rigid body is in equilibrium if

   a. $\vec{F}_{net} = \vec{0}$.
   b. $\tau_{net} = 0$.
   c. either a or b.
   d. both a and b.

Prerequisites

Prerequisites	Location in Textbook	Module
The Mathematics of Circular Motion	4.5 – 4.7	4
Equilibrium	6.1	6
Newton's Second Law	6.2	6
Kinetic and Gravitational Potential Energy	10.2	10

Learning Objectives & Competencies

Learning Objectives ***In this chapter you will:***		**Competencies**	***Section in Textbook***
OBJ1	extend the particle model to the rigid-body model and understand the moment of inertia	*Apply*	12.1, 12.3
OBJ2	understand the equilibrium of an extended object	*Comprehend*	12.8
OBJ3	understand rotation about a fixed axis	*Apply*	12.7
OBJ4	understand the concept of torque, rotational kinetic energy and rotational dynamics	*Apply*	12.3, 12.5 - 12.7
OBJ5	introduce the vector description of rotational motion and conservation of angular momentum	*Apply*	12.10, 12.11

Course Content (Course Outline)

Chapter/Module 12 - Rotation of a Rigid Body & Angular Momentum – *MCD Apr. 20*	
- *comprehend* the motion of center of mass for a rigid object	12.2
- *comprehend* angular position, velocity and acceleration	4.5 - 4.7, 12.1
- *apply* the kinematics equation to rotational motion at constant angular acceleration	4.7
- *recall* the relationship between angular and linear kinematics properties	4.5 - 4.7
- *comprehend* the concept of moment of inertia	12.3
- *recall* the formulae for the moment of inertia of a system of particles	12.4
- *apply* superposition to solve for moment of inertia of systems of particles and composite bodies	12.4
- *recall* the formula of rotational kinetic energy of a body	12.3
- *comprehend* the notion of torque	12.5
- *recall* the formula for torque in terms of applied force	12.5
- *apply* vector algebra (vector or cross product) to solve for the torque in three dimensions	12.10
- *apply* the above concepts to solving problems in rotational dynamics about a fixed axis, including problems with massive pulleys	12.6, 12.7
- *comprehend* the notion of angular momentum	12.10
- *apply* vector algebra (vector product) to solve for angular momentum in three dimensions	12.10
- *recall* the formulae for the angular momentum of a particle and of a rigid body	12.11
- *comprehend* the application of Newton’s Laws to rotational motion (namely the conservation of angular momentum, the relationship between torque and change of angular momentum)	12.11
- *comprehend* the conservation of angular momentum in closed systems	12.11
- *apply* the conservation of angular momentum in problems in rotational motion about a fixed axis	12.11
Optional Topic	
- *apply* the above concepts to solve problems involving static equilibrium of rigid bodies	12.8

Learning Resources

Objectives (OBJ)	Textbook Examples	Stop to Think (STT) (Answers p. xxx)	Tactics Box (TB) & Problem Solving Strategy (PSS)	MP EOC Practice Problems
OBJ1	12.1	12.1		12.56
OBJ2	12.16	12.5	PSS 12.2	**12.31, 12.32, 12.34**
OBJ3	12.12 – 12.14		PSS 12.1	
OBJ4	12.9, 12.10	12.2, 12.3, 12.4,		12.11, 12.19, 12.22, 12.67, 12.70, 12.71,
OBJ5	12.19,12.20, 12.21, 12.22, 12.23	12.6		12.38 - 12.46, 12.49, 12.87, 12.88

PHYSICS NYA MPSI

Course Content

TEXT:

Physics for Scientists and Engineers: A Strategic Approach by Randall D. Knight, 2 Ed. Vols. 1, 3, 4, 5. Pearson Addison-Wesley, 2008.

**** The textbook comes with an access code for the Mastering Physics online system. You will need this access code for this course. It can also be used for later physics courses. ****

LIBRARY REFERENCES:

- *Fundamentals of Physics* by D. Halliday, R. Resnick and J. Walker, John Wiley & Sons Inc.
- *Physics* (*Extended Version)* by P. Tipler, *3*rd Edition, Worth Publisher.
- *Physics for Scientists and Engineers* by Serway and Jewett, *7*th Edition, Thomson/Brooks Cole Publishing, 2008.
- *University Physics with Modern Physics* by Young and Freedman, 13th Edition, Pearson Addison Wesley, 2012. There are also the *Study Guide and Student Solutions* manuals Volume: 1.

*** This course will be using the Personalized System of Instruction (PSI) that relies on Study Modules found in your MP online class MPIAFIGLIOLA51498 as well as on Omnivox, handouts, my office door mailbox and the library!**

Hence, in this course content you will see references to Module numbers in addition to Chapter numbers. There is a one to one correspondence.

DESCRIPTION: (key words are *italicized*)

Some of the science program goals that are encountered in Mechanics are problem-solving skills, lab skills, the use of mathematical tools and logical reasoning. Mechanics is the branch of physics dealing with *motion* and the *forces* which affect motion.

The course begins with a mathematical review involving Trigonometry and Calculus (mostly Calculus I). This is not a Module as such and does not correspond to a particular chapter in the text book. However, you can find these reviews in most textbooks in the Appendix section.

Kinematics, the science of movement (Chapters/Modules 1, 2 and 4), where the motion of point - like objects (*the particle model*) is analyzed using the concepts of motion diagrams and connections between position - , velocity-, and acceleration - time in 1 and 2 dimensions are made.

At this point in the course it is traditional to make a brief foray into *Vector Analysis* (Chapter/Module 3).

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Dynamics examines the concept of *force*, bringing us to a discussion of *Newton's Laws of Motion.* Newton's laws are applied to objects in *rectilinear* and *circular motion* (Chapters/Modules) 5, 6, 7 and 8).

Impulse and Momentum and the *Law of Conservation of Linear Momentum* are studied and applied to *inelastic collision problems* (Chapter/Module 9).

The concepts of *kinetic energy* and *potential energy* are introduced. The *Law of Conservation of Total Mechanical Energy* provides alternative methods for describing motion (Chapter/Module 10). Here we also take a look at *elastic collision problems* where both conservation of momentum and kinetic energy apply.

The concept of *work* and the mathematics of the *dot (scalar) product* are introduced. The concept of work is connected to energy using the *Work-Kinetic Energy Theorem*. The concepts of *conservative* and *non-conservative forces* lead to the more general statement of the *Work-Energy-Method-Expression* that connects work and total mechanical energy (Chapter/Module 11).

We study the kinematics and dynamics of rotations about a fixed axis, introducing the concepts of *torque* and *angular momentum* (Chapter/Module 12). The vector (cross) product is also introduced.

Finally, we touch on some aspects of *Newton's Theory of Gravity* (Chapter/Module 13).

GENERAL OBJECTIVE:

Analyze various physical situations and phenomena by applying the fundamental principles of classical mechanics.

METHODOLOGY: ***Ponderation*** is 3-2-3 i.e. 3 hours of lectures, 2 hours of labs and 3 hours of home-work per week. The laboratory periods will help the student to investigate and verify the laws of physics. Tutorial periods (when a lab is not scheduled) may be used as problem-solving/collaborative sessions.

However, in a PSI course the students are encouraged to work on their own and at their own pace. Hence only part of the time assigned to weekly lectures will be used by the teacher standing in front of the classroom and presenting material. A system of student feedback (Pre-Lecture Exercises and Conceptual Questions) will be set up to help structure the lectures. The rest of the time will be used for collaborative sessions, demonstrating problem-solving techniques, tutorials or doing mastery tests (these may also take place in the computer lab). Where applicable, some of the theory will be illustrated with in-class demonstrations.

Online ***Mastery Tests***, designed to determine when students have mastered a given module, will be counted toward the assignment grade. Some hand-in assignments will also be given to ensure that writing skills are maintained. These "assignments" will give the students problem-solving practice as well as provide weekly progress reports.

The two mid-term class tests will further provide feedback to the students as to their understanding of the subject. The comprehensive final exam will allow the students to show that they have acquired an overview of Classical Mechanics.

Office hours (posted on Omnivox) offered by the teachers are meant to open a two-way dialogue between the teacher and the student, to allow for a more personal interaction and offer an opportunity for questions to be asked and answered.

DEADLINES:

It is most important that no one falls behind too much as you will all have to write the term tests and final exam on their scheduled dates. Hence, a ***Module Completion Date (††MCD)*** is indicated as a *guideline*. It is highly recommended that you attempt the first Mastery Test for the module by the MCD deadline.

These deadlines reflect the number of Modules that have to be covered in the term. However, the Modules are not the same length so this gives you some slack time if you fall behind. There is no problem if you get ahead and certainly to your credit in a PSI course. The fast-paced students may be asked to help the slower ones.
A minimum Module coverage will be announced for the Term Tests that will take place in the classroom for the whole group at the specified dates. A review session will take place before each term test.

MARIANOPOLIS COLLEGE
EVALUATION QUESTIONNAIRE

DO NOT WRITE ON THE QUESTIONNAIRE

Instructions

All teachers at Marianopolis are evaluated regularly. Please think about how this course has been going. Think about the strengths of your teacher and what aspects of your teacher's performance need improvement. About one month after the course is over and the grades have been submitted, your instructor, the Dean, and the Department Chairperson will receive a statistical summary of the evaluations from each class. It is very important that you think about each question carefully and answer as honestly as possible so that your instructor, the Dean and the Department Chairperson can identify the strengths of your instructor and suggest any improvements where necessary.

Record your answers on the answer sheet provided. You must use a pencil. It is important that you fill-in only the appropriate circles and do not put stray marks on the answer form.

Make sure you have filled in the proper 6-digit identification code on the answer sheet.

The written comments will be seen only by your instructor.

Thank you.

rev. December 2009

DO NOT WRITE ON THIS PAGE.

COURSE

1. This course is compulsory for my program.
a) yes
b) no

2. I am interested in the subject matter of this course.
a) not at all interested
b) somewhat interested
c) interested
d) very interested

3. This course is held:
a) between 8:00 - 10:00
b) between 10:00- 12:00
c) between 12:15- 3:00
d) between 3:05 - 6:00

4. Overall, I am satisfied with how much I am learning about the subject matter in this course.
a) strongly agree
b) agree
c) disagree
d) strongly disagree

STUDENT

5. What program are you in?
a) 200.00 (Science)
b) 300.00 (Social Science)
c) 400.00 (Commerce)
d) 500.01 (Creative Arts)
e) 500.02 (Music)
f) 600.01 (Languages and Literature)
g) 700.01 (Liberal Arts)

6. Approximately how many classes or labs have you missed in this course so far (for whatever reasons)?
a) 0 - 2
b) 3 - 5
c) 6 - 10
d) more than 10

7. How much time are you spending on average <u>per week</u> outside class time in preparation for quizzes, logs, assignments, preparing for class or tests, etc.?
a) less than 1 hour per week
b) 1 hour
c) 2 - 3 hours
d) 4 - 5 hours
e) more than 5 hours per week

8. My grade in this course so far is
a) A (90 - 100) Excellent
b) B (80 - 89) Very Good
c) C (70 - 79) Good
d) D (60 - 69) Fair
e) F (below 60) Poor

INSTRUCTOR

9. The instructor holds classes regularly (at least 90% of the time).
a) strongly agree
b) agree
c) disagree
d) strongly disagree

10. The instructor begins and ends class on time (at least 90% of the time).
a) strongly agree
b) agree
c) disagree
d) strongly disagree

11. The instructor follows the course outline.
a) not at all
b) very little
c) a fair amount
d) very closely

12. The instructor's tests, assignments, essays, and so on, cover the course material.
a) strongly disagree
b) disagree
c) agree
d) strongly agree

13. The instructor returns assignments and tests within a reasonable period of time (about 10 school days).
a) never
b) rarely
c) sometimes
d) most of the time
e) always

14. The instructor grades my work fairly.
a) strongly agree
b) agree
c) disagree
d) strongly disagree

15. The instructor is available during posted office hours.
a) always
b) most of the time
c) sometimes
d) rarely
e) never
f) I do not know because I have not gone to see the instructor during these hours.

16. The instructor presents the course material in an organized way.
a) never
b) rarely
c) sometimes
d) most of the time
e) always

DO NOT WRITE ON THIS PAGE.

17. The instructor is able to explain material in a way I can understand.
a) always
b) most of the time
c) sometimes
d) rarely
e) never

18. The instructor speaks clearly.
a) strongly disagree
b) disagree
c) agree
d) strongly agree

19. The instructor encourages questions and/or participation in class.
a) always
b) most of the time
c) sometimes
d) rarely
e) never

20. The instructor is able to answer questions clearly.
a) always
b) most of the time
c) sometimes
d) rarely
e) never

21. The instructor is enthusiastic about the subject material.
a) never
b) rarely
c) sometimes
d) most of the time
e) always

22. The instructor treats me with respect.
a) strongly disagree
b) disagree
c) agree
d) strongly agree

23. Overall, I would give this instructor a grade of
a) A (90 - 100) Excellent
b) B (80 - 89) Very Good
c) C (70 - 79) Good
d) D (60 - 69) Fair
e) F (below 60) Poor

MARIANOPOLIS COLLEGE

Consultation done via technology
Omnivox
Document printed May 23, 2012 at 14:29:40

Final results

PSI Questionnaire_Winter2012

Consultation done via Omnivox
from April 25, 2012 at 10:30 to May 18, 2012

18 respondents

MARIANOPOLIS COLLEGE

Consultation done via **Omnivox**
PSI Questionnaire_Winter2012
from April 25, 2012 at 10:30 to May 18, 2012
18 respondents - Final results

PSI Questionnaire_Winter2012

This consultation was conducted via Omnivox from April 25, 2012 at 10:30 until May 18, 2012. 18 respondents participated.

Results

Question 1
Please indicate your level of agreement with the following statements:

Statements

1. The Module Study Guides were helpful to my learning
2. The Course Objectives were clearly stated in the Study Guides
3. The Study Guides clearly indicate what is expected in the course
4. The Learning Resources Table at the end of the Study Guide is useful
5. The Study guide made appropriate links to the textbook chapter references for learning purposes

Answers received

		Total	
1. The Module Study Guides were helpful to my learning	1- Strongly disagree	3	(17,6%)
	2	7	(41,2%)
	3	3	(17,6%)
	4	2	(11,8%)
	5 - Strongly agree	2	(11,8%)
	Total	17	(100,0%)
	Average	2,59	
	Median	2	
	Standard deviation	1,24	
2. The Course Objectives were clearly stated in the Study Gu...	1- Strongly disagree	0	(0.0%)
	2	3	(17,6%)
	3	3	(17,6%)
	4	3	(17,6%)
	5 - Strongly agree	8	(47,1%)
	Total	17	(100,0%)
	Average	3,94	
	Median	4	
	Standard deviation	1,16	
3. The Study Guides clearly indicate what is expected in the...	1- Strongly disagree	0	(0.0%)
	2	3	(17,6%)

	3	5 (29,4%)
	4	2 (11,8%)
	5 - Strongly agree	7 (41,2%)
	Total	17 (100,0%)
	Average	3,76
	Median	4
	Standard deviation	1,16
4. The Learning Resources Table at the end of the Study Guid...	1- Strongly disagree	2 (11,8%)
	2	5 (29,4%)
	3	6 (35,3%)
	4	2 (11,8%)
	5 - Strongly agree	2 (11,8%)
	Total	17 (100,0%)
	Average	2,82
	Median	3
	Standard deviation	1,15
5. The Study guide made appropriate links to the textbook ch...	1- Strongly disagree	2 (11,8%)
	2	4 (23,5%)
	3	2 (11,8%)
	4	4 (23,5%)
	5 - Strongly agree	5 (29,4%)
	Total	17 (100,0%)
	Average	3,35
	Median	4
	Standard deviation	1,41

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Question 2

Please indicate your level of agreement with the following statements:

Statements

1. The Mastery Tests were adequate to show mastery in a particular Module
2. Use of MasteringPhysics online enabled quick feedback of Mastery Test results
3. Achieving a score of 80% is adequate to show mastery in a particular Module
4. Due dates for the Mastery Tests were appropriately spaced
5. The MasteringPhyiscs Mastery Test "moveable" due dates enabled appropriate flexibility to meet Module Completion Dates (MCD)

Answers received

		Total
1. The Mastery Tests were adequate to show mastery in a part...	1- Strongly disagree	2 (12,5%)
	2	2 (12,5%)
	3	3 (18,8%)
	4	7 (43,8%)
	5 - Strongly agree	2 (12,5%)
	Total	16 (100,0%)
	Average	3,31
	Median	4
	Standard deviation	1,21
2. Use of MasteringPhysics online enabled quick feedback of ...	1- Strongly disagree	1 (6,3%)
	2	1 (6,3%)
	3	3 (18,8%)
	4	4 (25,0%)
	5 - Strongly agree	7 (43,8%)
	Total	16 (100,0%)
	Average	3,94
	Median	4
	Standard deviation	1,20
3. Achieving a score of 80% is adequate to show mastery in a...	1- Strongly disagree	2 (12,5%)
	2	1 (6,3%)
	3	3 (18,8%)
	4	6 (37,5%)
	5 - Strongly agree	4 (25,0%)
	Total	16 (100,0%)
	Average	3,56
	Median	

		4
	Standard deviation	1,27
4. Due dates for the Mastery Tests were appropriately spaced	1- Strongly disagree	1 (6,3%)
	2	0 (0.0%)
	3	1 (6,3%)
	4	7 (43,8%)
	5 - Strongly agree	7 (43,8%)
	Total	16 (100,0%)
	Average	4,19
	Median	4
	Standard deviation	1,01
5. The MasteringPhyiscs Mastery Test “moveable” due dates en...	1- Strongly disagree	2 (12,5%)
	2	0 (0.0%)
	3	0 (0.0%)
	4	2 (12,5%)
	5 - Strongly agree	12 (75,0%)
	Total	16 (100,0%)
	Average	4,38
	Median	5
	Standard deviation	1,32

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Consultation done via **Omnivox**
PSI Questionnaire_Winter2012
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Question 3
Please indicate your level of agreement with the following statements:

Statements

1. The textbook was useful in this course
2. The textbook was easy to read
3. The Study Guide and textbook were sufficient to learn the course material
4. The textbook EOC problems were appropriate to prepare for tests
5. The textbook was essential to my learning

Answers received

		Total	
1. The textbook was useful in this course	1- Strongly disagree	3	(17,6%)
	2	1	(5,9%)
	3	2	(11,8%)
	4	5	(29,4%)
	5 - Strongly agree	6	(35,3%)
	Total	17	(100,0%)
	Average	3,59	
	Median	4	
	Standard deviation	1,46	
2. The textbook was easy to read	1- Strongly disagree	4	(23,5%)
	2	2	(11,8%)
	3	3	(17,6%)
	4	6	(35,3%)
	5 - Strongly agree	2	(11,8%)
	Total	17	(100,0%)
	Average	3	
	Median	3	
	Standard deviation	1,37	
3. The Study Guide and textbook were sufficient to learn the...	1- Strongly disagree	6	(35,3%)
	2	1	(5,9%)
	3	5	(29,4%)
	4	2	(11,8%)
	5 - Strongly agree	3	(17,6%)
	Total	17	(100,0%)
	Average	2,71	
	Median	3	

	Standard deviation	1,49
4. The textbook EOC problems were appropriate to prepare for...	1- Strongly disagree	1 (5,9%)
	2	0 (0.0%)
	3	4 (23,5%)
	4	5 (29,4%)
	5 - Strongly agree	7 (41,2%)
	Total	17 (100,0%)
	Average	4
	Median	4
	Standard deviation	1,08
5. The textbook was essential to my learning	1- Strongly disagree	2 (11,8%)
	2	1 (5,9%)
	3	3 (17,6%)
	4	4 (23,5%)
	5 - Strongly agree	7 (41,2%)
	Total	17 (100,0%)
	Average	3,76
	Median	4
	Standard deviation	1,35

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PSI Questionnaire_Winter2012
from April 25, 2012 at 10:30 to May 18, 2012
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Question 4
Please indicate your level of agreement with the following statements:

Statements

1. The self-pacing aspect of PSI is a good learning feature to have
2. Quick Rate: Allowed for enriched problem solving and more study time
3. Slow Rate: Allowed for extra help in Collaborative Sessions with the tutor
4. The Term Tests were scheduled to support both the quick learners as well as the slow ones
5. The use of self-pacing enhanced my learning

Answers received

		Total	
1. The self-pacing aspect of PSI is a good learning feature ...	1- Strongly disagree	3	(17,6%)
	2	2	(11,8%)
	3	3	(17,6%)
	4	5	(29,4%)
	5 - Strongly agree	4	(23,5%)
	Total	17	(100,0%)
	Average	3,29	
	Median	4	
	Standard deviation	1,40	
2. Quick Rate: Allowed for enriched problem solving and more...	1- Strongly disagree	4	(23,5%)
	2	2	(11,8%)
	3	3	(17,6%)
	4	4	(23,5%)
	5 - Strongly agree	4	(23,5%)
	Total	17	(100,0%)
	Average	3,12	
	Median	3	
	Standard deviation	1,49	
3. Slow Rate: Allowed for extra help in Collaborative Sessio...	1- Strongly disagree	2	(11,8%)
	2	1	(5,9%)
	3	5	(29,4%)
	4	5	(29,4%)
	5 - Strongly agree	4	(23,5%)
	Total	17	(100,0%)
	Average	3,47	
	Median	4	

	Standard deviation	1,24	
4. The Term Tests were scheduled to support both the quick l...	1- Strongly disagree	1	(5,9%)
	2	0	(0.0%)
	3	4	(23,5%)
	4	4	(23,5%)
	5 - Strongly agree	8	(47,1%)
	Total	17	(100,0%)
	Average	4,06	
	Median	4	
	Standard deviation	1,11	
5. The use of self-pacing enhanced my learning	1- Strongly disagree	4	(23,5%)
	2	4	(23,5%)
	3	3	(17,6%)
	4	3	(17,6%)
	5 - Strongly agree	3	(17,6%)
	Total	17	(100,0%)
	Average	2,82	
	Median	3	
	Standard deviation	1,42	

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Question 5
Please indicate your level of agreement with the following statements:

Statements

1. The tutor was helpful during the collaborative sessions
2. The teacher was helpful during the collaborative sessions
3. The collaborative sessions that replaced the lectures were useful
4. Attending the collaborative sessions was relevant to my learning

Answers received

		Total	
1. The tutor was helpful during the collaborative sessions	1- Strongly disagree	3	(17,6%)
	2	0	(0.0%)
	3	8	(47,1%)
	4	1	(5,9%)
	5 - Strongly agree	5	(29,4%)
	Total	17	(100,0%)
	Average	3,29	
	Median	3	
	Standard deviation	1,36	
2. The teacher was helpful during the collaborative sessions	1- Strongly disagree	2	(11,8%)
	2	0	(0.0%)
	3	4	(23,5%)
	4	3	(17,6%)
	5 - Strongly agree	8	(47,1%)
	Total	17	(100,0%)
	Average	3,88	
	Median	4	
	Standard deviation	1,32	
3. The collaborative sessions that replaced the lectures wer...	1- Strongly disagree	2	(11,8%)
	2	3	(17,6%)
	3	4	(23,5%)
	4	2	(11,8%)
	5 - Strongly agree	6	(35,3%)
	Total	17	(100,0%)
	Average	3,41	
	Median	3	
	Standard deviation		

		1,42
4. Attending the collaborative sessions was relevant to my l...	**1- Strongly disagree**	**2** (11,8%)
	2	**0** (0.0%)
	3	**8** (47,1%)
	4	**2** (11,8%)
	5 - Strongly agree	**5** (29,4%)
	Total	**17** (100,0%)
	Average	**3,47**
	Median	**3**
	Standard deviation	**1,24**

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Question 6

Please indicate your level of agreement with the following statements:

Statements

1. The various modes of communication in this course were adequate for learning
2. The use of MIO in OMNIVOX was an effective communication tool
3. The use of LEA in OMNIVOX was an effective resource tool
4. Teacher availability was adequate for this course

Answers received

		Total	
1. The various modes of communication in this course were ad...	1- Strongly disagree	1	(5,9%)
	2	1	(5,9%)
	3	3	(17,6%)
	4	3	(17,6%)
	5 - Strongly agree	9	(52,9%)
	Total	17	(100,0%)
	Average	4,06	
	Median	5	
	Standard deviation	1,21	
2. The use of MIO in OMNIVOX was an effective communication ...	1- Strongly disagree	0	(0.0%)
	2	1	(5,9%)
	3	3	(17,6%)
	4	2	(11,8%)
	5 - Strongly agree	11	(64,7%)
	Total	17	(100,0%)
	Average	4,35	
	Median	5	
	Standard deviation	0,97	
3. The use of LEA in OMNIVOX was an effective resource tool	1- Strongly disagree	0	(0.0%)
	2	0	(0.0%)
	3	2	(11,8%)
	4	3	(17,6%)
	5 - Strongly agree	12	(70,6%)
	Total	17	(100,0%)
	Average	4,59	
	Median	5	
	Standard deviation		

		0,69
4. Teacher availability was adequate for this course	1- Strongly disagree	0 (0.0%)
	2	0 (0.0%)
	3	3 (17,6%)
	4	4 (23,5%)
	5 - Strongly agree	10 (58,8%)
	Total	17 (100,0%)
	Average	4,41
	Median	5
	Standard deviation	0,77

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Question 7
Please indicate your level of agreement with the following statements:

Statements

1. The elimination of some of the lectures did not affect my learning
2. The lectures that were given were sufficient to continue working on my own
3. The class demonstrations helped me understand the concepts introduced in the lectures
4. The PPt presentations helped me understand the concepts introduced in the lectures
5. The use of Clickers helped me understand the concepts introduced in the lectures
6. It would be best to have lectures for all the class sessions

Answers received

		Total
1. The elimination of some of the lectures did not affect my...	1- Strongly disagree	2 (11,8%)
	2	5 (29,4%)
	3	4 (23,5%)
	4	3 (17,6%)
	5 - Strongly agree	3 (17,6%)
	Total	17 (100,0%)
	Average	3
	Median	3
	Standard deviation	1,28
2. The lectures that were given were sufficient to continue ...	1- Strongly disagree	2 (11,8%)
	2	3 (17,6%)
	3	5 (29,4%)
	4	4 (23,5%)
	5 - Strongly agree	3 (17,6%)
	Total	17 (100,0%)
	Average	3,18
	Median	3
	Standard deviation	1,25
3. The class demonstrations helped me understand the concept...	1- Strongly disagree	0 (0.0%)
	2	0 (0.0%)
	3	5 (29,4%)
	4	7 (41,2%)
	5 - Strongly agree	5 (29,4%)
	Total	17 (100,0%)
	Average	4
	Median	

		4
	Standard deviation	0,77
4. The PPt presentations helped me understand the concepts i...	1- Strongly disagree	1 (5,9%)
	2	4 (23,5%)
	3	5 (29,4%)
	4	5 (29,4%)
	5 - Strongly agree	2 (11,8%)
	Total	17 (100,0%)
	Average	3,18
	Median	3
	Standard deviation	1,10
5. The use of Clickers helped me understand the concepts int...	1- Strongly disagree	1 (5,9%)
	2	5 (29,4%)
	3	1 (5,9%)
	4	5 (29,4%)
	5 - Strongly agree	5 (29,4%)
	Total	17 (100,0%)
	Average	3,47
	Median	4
	Standard deviation	1,33
6. It would be best to have lectures for all the class sessions	1- Strongly disagree	2 (11,8%)
	2	3 (17,6%)
	3	1 (5,9%)
	4	8 (47,1%)
	5 - Strongly agree	3 (17,6%)
	Total	17 (100,0%)
	Average	3,41
	Median	4
	Standard deviation	1,29

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Question 8

Please indicate your level of agreement with the following statements:

Statements

1. The laboratory work was interesting and useful
2. The concepts in the lab work were adequately covered in the course
3. The PreLabs were useful to understand the lab
4. Online hand-in of the PreLab using MIO or LEA was a good method to use
5. The labs helped in the understanding of the concepts in the course

Answers received

		Total	
1. The laboratory work was interesting and useful	1- Strongly disagree	3	(17,6%)
	2	0	(0.0%)
	3	5	(29,4%)
	4	4	(23,5%)
	5 - Strongly agree	5	(29,4%)
	Total	17	(100,0%)
	Average	3,47	
	Median	4	
	Standard deviation	1,38	
2. The concepts in the lab work were adequately covered in t...	1- Strongly disagree	1	(6,3%)
	2	0	(0.0%)
	3	5	(31,3%)
	4	4	(25,0%)
	5 - Strongly agree	6	(37,5%)
	Total	16	(100,0%)
	Average	3,88	
	Median	4	
	Standard deviation	1,11	
3. The PreLabs were useful to understand the lab	1- Strongly disagree	1	(5,9%)
	2	0	(0.0%)
	3	5	(29,4%)
	4	3	(17,6%)
	5 - Strongly agree	8	(47,1%)
	Total	17	(100,0%)
	Average	4	
	Median	4	

	Standard deviation	1,14
4. Online hand-in of the PreLab using MIO or LEA was a good ...	1- Strongly disagree	1 (5,9%)
	2	1 (5,9%)
	3	3 (17,6%)
	4	1 (5,9%)
	5 - Strongly agree	11 (64,7%)
	Total	17 (100,0%)
	Average	4,18
	Median	5
	Standard deviation	1,25
5. The labs helped in the understanding of the concepts in t...	1- Strongly disagree	1 (5,9%)
	2	2 (11,8%)
	3	5 (29,4%)
	4	3 (17,6%)
	5 - Strongly agree	6 (35,3%)
	Total	17 (100,0%)
	Average	3,65
	Median	4
	Standard deviation	1,23

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Question 9
Please indicate your level of agreement with the following statements:

Statements

1. The assignments were helpful and adequate for learning
2. The number of problems assigned was adequate
3. The review sets for the term tests were useful
4. MP practice problems were useful

Answers received

		Total	
1. The assignments were helpful and adequate for learning	1- Strongly disagree	0	(0.0%)
	2	2	(11,8%)
	3	3	(17,6%)
	4	5	(29,4%)
	5 - Strongly agree	7	(41,2%)
	Total	17	(100,0%)
	Average	4	
	Median	4	
	Standard deviation	1,03	
2. The number of problems assigned was adequate	1- Strongly disagree	0	(0.0%)
	2	1	(5,9%)
	3	2	(11,8%)
	4	6	(35,3%)
	5 - Strongly agree	8	(47,1%)
	Total	17	(100,0%)
	Average	4,24	
	Median	4	
	Standard deviation	0,88	
3. The review sets for the term tests were useful	1- Strongly disagree	0	(0.0%)
	2	1	(5,9%)
	3	3	(17,6%)
	4	3	(17,6%)
	5 - Strongly agree	10	(58,8%)
	Total	17	(100,0%)
	Average	4,29	
	Median	5	
	Standard deviation		

		0,96
4. MP practice problems were useful	1- Strongly disagree	0 (0.0%)
	2	2 (11,8%)
	3	4 (23,5%)
	4	5 (29,4%)
	5 - Strongly agree	6 (35,3%)
	Total	17 (100,0%)
	Average	3,88
	Median	4
	Standard deviation	1,02

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PSI Questionnaire_Winter2012
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Question 10

Please indicate your level of agreement with the following statements:

Statements

1. PSI is a preferred way of learning over the traditional method
2. There was more work involved in this course but it was worth it
3. The lecture method used in class is the only way to learn
4. Online PSI should be extended to other courses

Answers received

		Total	
1. PSI is a preferred way of learning over the traditional m...	1- Strongly disagree	5	(27,8%)
	2	3	(16,7%)
	3	4	(22,2%)
	4	2	(11,1%)
	5 - Strongly agree	4	(22,2%)
	Total	18	(100,0%)
	Average	2,83	
	Median	3	
	Standard deviation	1,50	
2. There was more work involved in this course but it was wo...	1- Strongly disagree	1	(5,6%)
	2	7	(38,9%)
	3	3	(16,7%)
	4	2	(11,1%)
	5 - Strongly agree	5	(27,8%)
	Total	18	(100,0%)
	Average	3,17	
	Median	3	
	Standard deviation	1,34	
3. The lecture method used in class is the only way to learn	1- Strongly disagree	3	(16,7%)
	2	2	(11,1%)
	3	8	(44,4%)
	4	2	(11,1%)
	5 - Strongly agree	3	(16,7%)
	Total	18	(100,0%)
	Average	3	
	Median	3	
	Standard deviation		

		1,25
4. Online PSI should be extended to other courses	**1- Strongly disagree**	**7** (38,9%)
	2	**3** (16,7%)
	3	**4** (22,2%)
	4	**1** (5,6%)
	5 - Strongly agree	**3** (16,7%)
	Total	**18** (100,0%)
	Average	**2,44**
	Median	**2**
	Standard deviation	**1,46**

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Question 11
Your overall evaluation of the PSI approach is:

1. Excellent
2. Good
3. Fair
4. Poor

Answers received

	Total
1. Excellent	**3** (16,7%)
2. Good	**5** (27,8%)
3. Fair	**7** (38,9%)
4. Poor	**3** (16,7%)
Total	**18** (100,0%)

Consultation done via **Omnivox**
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Question 12
General Comments

7 participants answered this question.

Methodology

This consultation was conducted via Omnivox from April 25, 2012 at 10:30 until May 18, 2012. 18 respondents participated.

Target audience

- Some specific students are also allowed to participate in this consultation. To obtain the list, consult the "Parameters" section of the consultation.

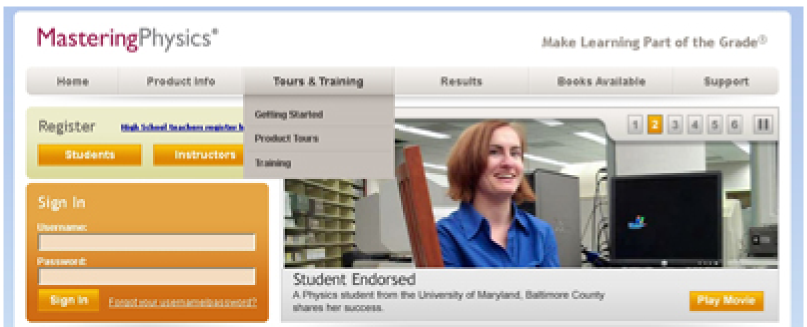
Parameters of the consultation

- Survey: the results are not available during the consultation.
- Anonymous mode: every participation ballot is numbered and may be printed (PDF format or paper) but the participation ballots do not include the identity of the participants.
- Consultation done via Internet (18 participations received).

Using PSI for Active Learning

Rocco Iafigliola Teacher, Marianopolis College

The Personalized System of Instruction (PSI) is a system that helps learners take control of and manage their own learning. Students set their own learning goals, manage their learning, and communicate with others in the process of learning.



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Fred. S. Keller together with J. Gilmour Sherman[1], perfected the PSI method (also known as the Keller Plan) in the late 60s. In the 1970s and 1980s, PSI spread to other disciplines and to other universities, but by the mid 80s, fell out of favour and totally died out in Physics. A key component of PSI was that there had to be an instant response to students in order to permit them to advance independently. The teacher, the proctors, the assistants would have to be writing, preparing and administering tests and then correcting them rapidly. Without computers, it was just too much work for everybody involved.

PSI and Mastering Physics

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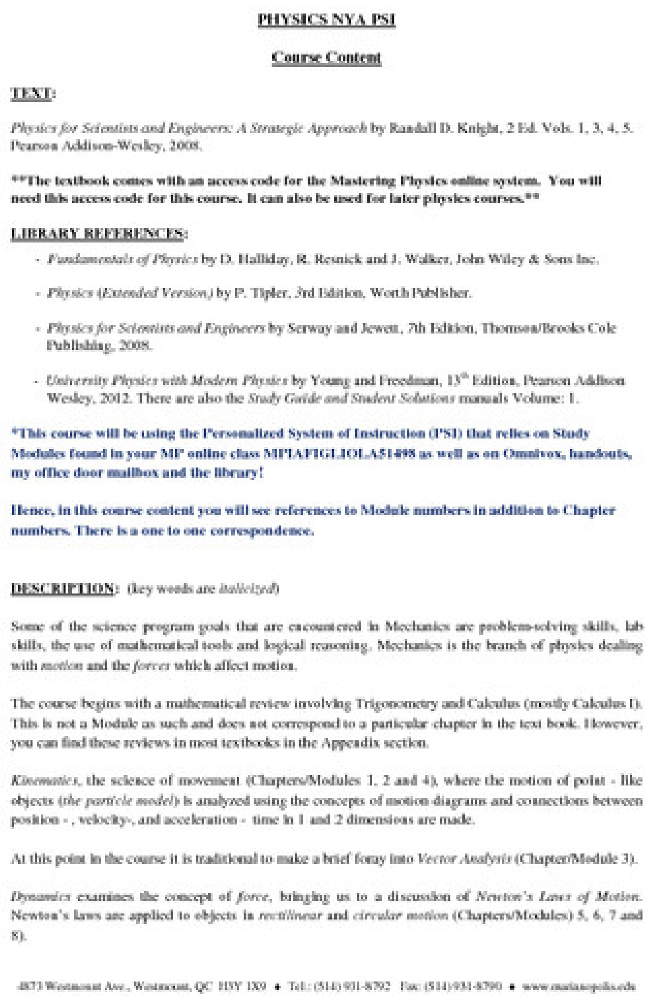
In the Winter of 2005, I was called upon to teach Mechanics to the first student cohort of the newly established Arts and Science program at Marianopolis College. I had reviewed the textbook by Randle D. Knight. It supports physics education research and active learning. But what caught my interest the most was the sealed leaflet that came with the book and contained an access code to “MasteringPhysics”.

MasteringPhysics is a powerful online platform that is linked to several textbooks and that includes self-correcting assignments or tests. Because this online system, where students are able to do self-correcting problems, provides instant feedback, I am now able to incorporate PSI into my class. The self-correcting tests become mastery tests which provide instant feedback to students so they know exactly how they are doing. Once they take a mastery test and get a grade of at least 80% they can move from one unit of work (a chapter) to the next unit. A very good grade demonstrates mastery.



PHYSICS NYA PSI

Course Content

TEXT:

Physics for Scientists and Engineers: A Strategic Approach by Randall D. Knight, 2 Ed. Vols. 1, 3, 4, 5. Pearson Addison-Wesley, 2008.

****The textbook comes with an access code for the Mastering Physics online system. You will need this access code for this course. It can also be used for later physics courses.****

LIBRARY REFERENCES:

- *Fundamentals of Physics* by D. Halliday, R. Resnick and J. Walker, John Wiley & Sons Inc.
- *Physics (Extended Version)* by P. Tipler, 3rd Edition, Worth Publisher.
- *Physics for Scientists and Engineers* by Serway and Jewett, 7th Edition, Thomson/Brooks Cole Publishing, 2008.
- *University Physics with Modern Physics* by Young and Freedman, 13th Edition, Pearson Addison Wesley, 2012. There are also the *Study Guide and Student Solutions* manuals Volume: 1.

***This course will be using the Personalized System of Instruction (PSI) that relies on Study Modules found in your MP online class MPIAFIGLIOLA51498 as well as on Omnivox, handouts, my office door mailbox and the library!**

Hence, in this course content you will see references to Module numbers in addition to Chapter numbers. There is a one to one correspondence.

DESCRIPTION: (key words are *italicized*)

Some of the science program goals that are encountered in Mechanics are problem-solving skills, lab skills, the use of mathematical tools and logical reasoning. Mechanics is the branch of physics dealing with *motion* and the *forces* which affect motion.

The course begins with a mathematical review involving Trigonometry and Calculus (mostly Calculus I). This is not a Module as such and does not correspond to a particular chapter in the text book. However, you can find these reviews in most textbooks in the Appendix section.

Kinematics, the science of movement (Chapters/Modules 1, 2 and 4), where the motion of point - like objects (*the particle model*) is analyzed using the concepts of motion diagrams and connections between position - , velocity-, and acceleration - time in 1 and 2 dimensions are made.

At this point in the course it is traditional to make a brief foray into *Vector Analysis* (Chapter/Module 3).

Dynamics examines the concept of *force*, bringing us to a discussion of *Newton's Laws of Motion*. Newton's laws are applied to objects in *rectilinear* and *circular motion* (Chapters/Modules) 5, 6, 7 and 8).

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Class activity can vary according to the students' mastery of the material, which is why we call it a Personalized System of Instruction. I will give a lecture for example on circular motion, and also that week I will have a collaborative session for students to work in groups covering the same topic. This is part of the mastering; they're learning. Now what could be happening is that some students master certain information more slowly than others, so they need extra help. That's why I'm there and perhaps there is a student assistant who will also help out during the cooperative work.

Students who have gotten ahead can come to class and help out other students or not. What will probably happen is that using MIO on the Omnivox System, they will ask to take the mastery test on circular motion because they have already mastered it. I send them the link to the test and once they have proved their mastery, they will start on the next unit. Other students, who have not yet mastered the topic, will come to class and work with the cooperative group.

PSI and Grading

As important as they are, the mastery tests are nothing more than an assignment mark. I want the students to work on their own, at home or at the library – wherever they are. And, I told them that the importance of the mastery test is to see if they have mastered the material. If they copy that won't help them, because the assignment mark is 5%, a small fraction of the total grade.

The principal means of evaluation comes from two supervised term tests and a final exam. Students know all this in advance, and although they're working at their own pace, they know that, for example, on a given date Test number 1 will cover Chapters 1 to 5. The tests can be worth twenty percent of the total grade or they can be worth forty percent of the total grade depending on which scheme provides the students with a higher final grade taking the results of the final exam into account.

PSI – Actively Engaging Students

Let me fast forward to the present. The Reform stresses learning outcomes and emphasizes the process leading to learning outcomes. It also promotes integration of learning and fosters the development of more complex intellectual problem solving skills[2]. In fact, it has been suggested "that when PSI is implemented correctly, it produces higher levels of achievement among students than the lecture-discussion format. Hence, PSI students may be more likely to develop the necessary knowledge base and problem-solving strategies. Research has demonstrated that students enrolled in PSI improved higher order cognitive skills" [3].

PSI is an "instructional delivery system" and as such would not dictate course content. A competency-based structure would be easily accommodated by PSI. Also, the integration of several subjects can be easily made (e.g. Physics and Mathematics) through appropriate modules. To top it all, we would have extensive integration with technology as all of the modules and tests would be computer-based and online[4]. Computer-based instruction makes for a more active learning experience by allowing students to receive ongoing feedback and evaluation of course content.

A modernized PSI for science instruction would establish a dynamic, student-centered, active learning teaching environment with well-defined learning objectives, activities and assessments. It would move the traditional classroom to one that is student-in-charge (Active Learning). "Numerous teaching methods, based on educational research, have demonstrated that greater student involvement in the classroom enhances learning. This research has demonstrated that students learn more if they are actively engaged with the material they are studying" [5].

How are you integrating third-party online learning platforms into your teaching?

1. Keller, F.S., and Sherman, J.G., The Keller Plan Handbook, W. A. Benjamin, Inc., 1974

2. Ministère de l'Éducation, du Loisir et du Sport (MELS), 2005-05-00512 ISBN 2-550-45276-3

3. Reboy, Lisa M., and Semb, George B., Teaching of Psychology, Vol. 18, 1991

4. Pear, J.J., and Crone-Todd, D.E., PSI in Cyberspace. Journal of Applied Behavior Analysis, 32, 205-209 (2002).

5. Paulson, D.R., and Faust, J., Active Learning, 1998, VII(#2), California State University, Los Angeles.