THE FUNCTION OF ADVANCED PLACEMENT PHYSICS WITHIN THE NEWFOUNDLAND & LABRADOR PHYSICS CURRICULUM

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THE FUNCTION of ADVANCED PLACEMENT PHYSICS
within the
NEWFOUNDLAND & LABRADOR PHYSICS CURRICULUM

By

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Abstract

This study's primary purpose was to determine if exposure to Advanced Placement (AP) physics in Newfoundland & Labrador high schools lead to a more successful first year of physics at Memorial University. Secondly, to determine if AP physics is equivalent to first year university physics. Finally, to determine if AP physics academically challenges and stimulates students' critical thinking abilities beyond which is provided by the present high school curriculum.

A multiple regression was used to determine the relationship between high school science grades, exposure to AP physics, and the final grades of 826 first year university physics students. Two student groups were studied, AP and non-AP. Each group had equivalent high school grades in advanced mathematics, physics, and chemistry. AP students enrolled in a calculus based physics course was found to achieve greater levels of success in their first year university physics than non-AP students. AP students' final grades in an algebra based physics course were not significantly different from their AP peers. Advanced mathematics and chemistry were also determined to have a high predictive value in final grades of first year university physics courses.

A second analysis compared the final grades of 110 students who were enrolled in a second year university physics course. Two groups were identified; AP students who advanced to this course from high school, and non-AP second year university students. No significant difference was found between the students studied in each group. It was

concluded that AP physics can be considered as an academic equivalent to an algebra-based, first year university physics course.

Finally, questionnaire results from 96 physics teachers, and 63 first year university physics students were used to determine the relationship between high school, AP, and first year university physics. A majority of students perceived that high school physics ill-prepares students academically and conceptually for first year university physics. Also cited, were insufficient laboratory exposure and resources in high schools. AP physics was perceived to overcome the deficiencies of a regular high school curriculum, challenging the academically gifted. A need was identified for AP physics as preparation, not a substitute for, university physics.

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Introduction

Introductory Statement

The design of the high school curriculum in Newfoundland & Labrador is most appropriate for the average student. For example, the Government of Newfoundland and Labrador (1991a) in its Physics 2204 Curriculum Guide stated that "Every high school student should be able to study physics! Some students may take physics as part of the physical science program; the others should have fair access to at least one course in the physics program" (p. 2). From personal experience and consultations with other physics teachers, most college or university bound students enroll in the high school physics courses, with the weaker academic students "streamed" into the physical science program. Since the majority of students who seek exposure to physical sciences enroll in high school physics, the comparative academic abilities of student are quite wide. In reality then, the Department of Education and Training's philosophy of "physics for all" resulted in a program that has to be geared towards the slightly above average student.

The Newfoundland & Labrador high school physics curriculum, however, offers little alternative for the academically gifted individuals who wish "to pursue academic studies to the limit of their abilities" (Williams, 1992, p. 300). Quite often, challenging such students involves assigning alternate work such as independent studies, and having them do repetitive practice problems and questions. If this is the accepted practice, then gifted students may never receive the maximum benefit of the educational system. As educators, it should be our duty to challenge and arouse the intellect of all our students.

When students enter university many decide to enroll in physics, especially if their high school exposure was successful. In addition, a first year of university physics course is required for acceptance into many universities and college level programs. From personal experience and feedback from former high school students, there is often one of three general results. Students may drop their physics course (Figures 1.4 & 1.5); their final grade may be significantly lower (Figures 1.1& 1.3) than the grade they had received in high school physics; or they may have failed their physics course (Figure 1.2). A persistent difference continues to exist between the success students experience in their high school physics and Memorial University's Physics 1200 and Physics 1050. Therefore, it would be advantageous to determine what factors in high school have led to a more successful university physics student. It seems reasonable that if high schools were to introduce students to the complexities, intricacies, and applications of physics, then they may have a more successful start to their university career in physics.

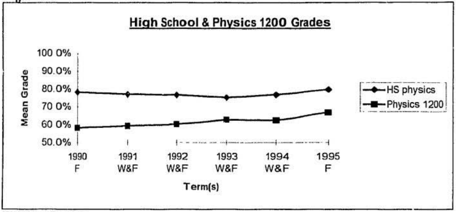
An alternative that may provide the impetus for greater student success in their first year of university physics is the introduction of Advanced Placement (AP) physics into the high school curriculum. According to Hersey (1990, p. 1), "the Advanced Placement Program provides an opportunity for high school students to pursue and receive credit for college-level course work while still in high school." As a result, AP studies attempt to challenge and stimulate students' academic interests far beyond the rigors of the traditional high school physics curriculum. Exposure to AP physics may even encourage students to consider pursuing a career in physics or a physics related area.

The Transition From High School to University

Normally, a study of this nature would attempt to substantiate its purpose by citing published data pertaining to the issue at hand. However, recent reports have not focused exclusively upon nor directly addressed the issue of student success in physics within Newfoundland and Labrador schools. To validate the claim of a discrepancy existing between the high school and university students' ability to perform in physics curricula, an analysis of grade and course enrollment trends within Newfoundland and Labrador was completed. Since the content, level of instruction, expectations and evaluation measures vary from high school to university, a direct comparison between high school and university grades cannot be validly made. For example, physics course evaluations in both high school and university are only partially criterion-based. It is not uncommon for the final grades of students to be adjusted along normal based lines after final examinations have been marked. However, trends can be readily accessed, possibly illustrating some degree of consistency in the transition from high school to first year of university physics

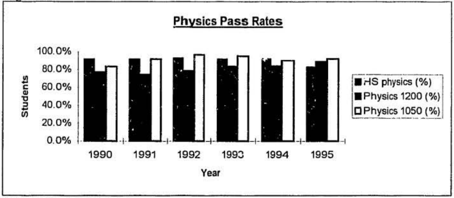
Figure 1.1 illustrates the mean grades of students enrolled in the algebra-based, Physics 1200 at Memorial University, along with those same students' corresponding grades in high school Physics 3204 (HS physics). These results indicate the existence of a persistent, but slowly declining discrepancy between the final grade students receives in their public high school physics course and their Physics 1200 grades at Memorial University. On average, students had a drop of 15.5% from their high school Physics 3204 grade, with a trend toward a decreased discrepancy in later years.

Figure 1.1



W: Winter Semester
F: Fall Semester
See appendix A for Table A.1

Figure 1.2

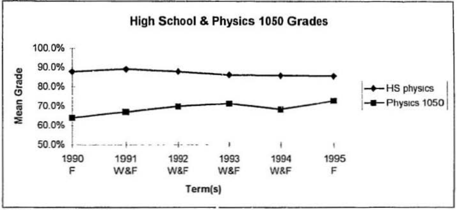


See appendix A for Table A.4

In addition to grades, there exists a discrepancy in student pass rates between high school Physics 3204 (HS physics) and Memorial University's Physics 1200 (Figure 1.2).

In the six year period studied, there was a difference of 9.2% fewer students who had passed Physics 1200 than did Physics 3204. If this comparison was based on the number of students who completed Physics 3204 and subsequently enrolled in Physics 1200, then the discrepancy may be much greater. This is possible given that many of the students who fail high school physics do not pursue physics beyond high school.

Figure 1.3



See Appendix A for Table A.2

An opposite situation exists for the calculus based Physics 1050 at Memorial University. According to the illustrations in Figure 1.2, there was, on average a difference of 1.3% more students who had passed Physics 1050 than Physics 3204. Although it was speculated that the discrepancy was greater for Physics 1200, it is actually the same for Physics 1050. This is due to the entrance requirement for Physics 1050 students Students enrolling in Physics 1050 at Memorial University must have obtained a grade of at least 80% in Physics 3204 (Memorial University of Newfoundland Calendar, 1994). As a result, the pass rate in high school would be 100% for this group, with a subsequent difference of 9.1% fewer students passing the Physics 1050 course. In terms of grades, Figure 1.3 illustrates that there exists a mean decrease of 18.3% in student final grades from Physics 3204 (HS physics) to Physics 1050.

Except for 1994, an emerging trend appears to be a continual decrease in the discrepancy between high school and first year physics grades and Memorial University. This decrease may coincide with the introduction of a more rigorous high school physics public exam course in 1991-1992. With a greater mathematical content and a compulsory laboratory component included in the revised high school physics curriculum, students may be more prepared for the first year of university physics than they had previously. The greater discrepancy in the 1994 results may not be an indication of a reversing trend, but the result of lower admission requirements to first year at Memorial University for this one particular year. This point appears verified by the addition of results for 1995.

Discrepancies in physics grades acquired from high school and university may exist for many reasons. Proper preparation, or lack of it is only one of these. Another example may include that first year university physics courses were more difficult or the standards applied to grading may be raised. In the first instance, the test instruments used are equally difficult relative to the material in both courses, but more difficult material results in lowered grades. In the second, the tests or other evaluations demand more of students in some way. University courses usually fit at least partially in both of these categories when compared to high school courses. The mandate of high school is to provide a broad education to all its students, while universities provide an in-depth education in specialized disciplines. As a result, the emphasis in course structure and grading must be representative of the goals and philosophy of the respective educational institution.

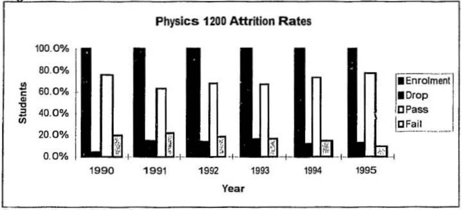
The question to be addressed here is whether a particular treatment such as AP Physics can prepare some students so that they can perform better than they would have been expected to perform without that treatment. The difference between scores at the two levels for students as a group is a structural problem that is not addressed within this research.

Physics Attrition Rates at Memorial University

The suggestion that the new, more rigorous high school Physics 3204 program introduced in 1991-1992 resulted in a better prepared university bound student is speculative. Hypothetically, if students have more preparation for their subsequent university courses, then their success rate would also increase. In an attempt to illustrate student preparedness for first year physics at Memorial University, an overview of student attrition rates in first year physics courses is shown in Figures 1.4 & 1.5.

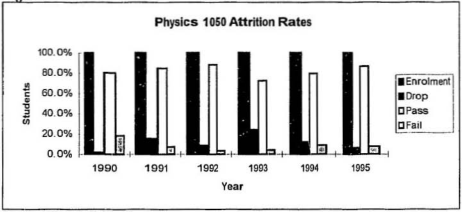
The introduction of this study put forth the argument that students enrolling in first year physics courses at Memorial University face one of three certainties: they either drop physics; their final grade is significantly lower than that which they had received in high school physics; or they fail. The issue of lower grades has already been addressed earlier in this section. According to Figures 1.4 & 1.5, the drop rate, with respect to initial enrollments is not as dramatic as was initially perceived.

Figure 1.4



See Appendix A for Table A.5

Figure 1.5



See Appendix A for Table A.5

From 1990 to 1995 the mean drop rate in Physics 1200 and Physics 1050 were respectively 12.3% and 11.3%. The fail rates were 16.9% and 8.1%. Most noteworthy of the two courses is Physics 1200, with 9.8% more students failing than in Physics 1050. This difference may be attributed to the entrance requirements for each course. As previously noted, Physics 1050 requires first year students to have a minimum average of 80% in their high school Physics 3204 and Advanced Mathematics 3201. However, no such requirement exists for the algebra-based, Physics 1200. While the calculus-based Physics 1050 is conceptually more difficult, the higher academic caliber of its students via entrance requirements ensures that its students have a stronger academic background.

Furthermore, Physics 1050 students, who have higher physics and mathematics grades in high school had a mean decrease of 18.3% in their physics grades from high school to first year of physics at Memorial University. This is in contrast to the Physics 1200 students whose mean decrease in grades from high school to first year physics at Memorial University was 15.5%. Despite a greater decrease in physics grades, Figures 1.4 & 1.5 illustrate that the Physics 1050 students have a higher pass rate in the first year university physics. Physics 1050 has a pass rate of 80.9% as opposed to 69.5% for Physics 1200.

Justifying an Analysis of AP Physics

The preceding argument indicates that enough evidence exists to study the relationship between high school preparedness and success in first year physics courses at

Memorial University. According to the data presented, the decreasing difference between high school and first year physics grades at Memorial University appear to coincide with the introduction of the more mathematically rigorous Physics 3204 course in 1991-1992. Furthermore, the higher academic entrance requirements of Physics 1050 ensure a higher academic caliber of student. Coincidentally, Physics 1050 has a higher student success rate than Physics 1200.

There are two implications of implementing AP physics within the high school curriculum. First, AP studies may challenge and stimulate the interests of academically gifted students far beyond the rigors of the typical high school physics curriculum. Secondly, AP physics may give students the opportunity to become more academically prepared for their first year of university physics. This second implication has an additional benefit to the very strong or academically gifted, and that is the possibility of skipping the first year of university physics altogether and moving directly to second year physics with success. While the first implication involves a fairness in response to the needs of all gifted students, the latter provides justification for its implementation as a prerequisite for university admission, particularly in physics programs.

Problem Statement

The introduction of this thesis described the premise of AP studies as challenging and stimulating students' academic interests far beyond the rigors of the typical high school physics curriculum. Furthermore, this thesis questions whether a more rigorous and challenging high school physics program for the academically gifted would result in a more successful university physics student. An AP course in physics may challenge students and help them to develop the critical thinking skills needed for university studies in physics, and indeed other sciences.

Three questions therefore need to be addressed, and from which the purpose of this thesis is derived. Since its introduction, have AP physics students in Newfoundland and Labrador benefited from this program? That is, have they received greater academic challenge, including a greater stimulation of their critical thinking abilities? Second, have exposure to AP physics in high school led to a more successful first year of university studies in physics? Finally, can AP physics successfully prepare students to move directly into the second year of university physics.

When complete, this study may provide greater recognition of AP programs in Physics and other curriculum areas. With government's current revisions designed to make the educational system more effective, there is a desire to produce stronger science students, who would possess a greater science awareness. If exposure to Advanced Placement physics does enhance student success in post secondary studies, then the concept of Advanced Placement should be an integral component of educational change. Moreover, this study will attempt to determine if AP programs can help lessen the grade differences that existed between high school and university physics.

Chapter Summary

This chapter discussed the Department of Education and Training's philosophy of "physics for all" as it applies to the current high school physics program. The argument presented suggested that the "physics for ail" approach does not adequately challenge the academically gifted students, and thus does not prepare them to achieve to their fullest potential in their first university physics courses. To reinforce this view, descriptive statistics were provided illustrating the discrepancies between rates of success and final grades of students as they proceed from high school to university physics.

While there may be several avenues through which gifted students could be academically challenged, this study set forth the concept of providing a third level to the current physics curriculum. This level would consist of an Advanced Placement (AP) course in physics. It was suggested that through the implementation of AP courses, "physics for all" would be achieved. Also, teaching students a college level course in high school would better prepare them for subsequent studies in their first year of university physics.

Chapter Two

Literature Review & Hypothesis

Literature Review

Advanced Placement (AP) is a concept that has existed since the early 1950's, with the first programs implemented in 1954 (Herr, 1993, p. 1). Despite its 42 year history, there is a paucity of published literature available pertaining to both its effects and position within high school education, particularly with respect to physics education. To gain a broader understanding of AP programs, an extrapolation of conclusions drawn from the findings in related subject areas was required. As well, research into learning theories associated with the academically gifted may provide insight as to the viability of specialized programs such as Advanced Placement. Since the current literature available on this topic is sparse, theories are not readily available to explore. However, there is an opportunity to develop new theories and pursue research pertaining to the function of AP physics within any physics curriculum.

One assumption of this research suggests that the current physics curriculum in Newfoundland and Labrador does not adequately challenge or prepare academically gifted students for further studies in university physics. Studies have shown that the percentage of students obtaining a passing grade in physics drops approximately 15% from high school to university (Crocker, 1989, 70-77). This figure does not consider the number of students who drop out of first year physics courses. Furthermore, those students who complete first year university physics often have final grades significantly lower than that achieved in high school physics. In reality, the difference may be much greater. Associate Professor of Education at Memorial University of Newfoundland, G.W. Clark's (personal communication, February 18, 1995) research supports this position, adding that the more credits a student has earned prior to enrolling in first year physics, the greater their chance of success. Clark's results may imply that most students have not developed sufficiently their critical thinking skills in physics by the time they graduate from high school.

A number of studies suggested that schools have to offer more in-depth, challenging programs designed to meet the demands of today's society, and stimulate students' critical thinking abilities (Williams, 1992; Crocker, 1989; Government of Newfoundland and Labrador, November 1993; Government of Newfoundland and Labrador, February 1994). While the current physics curriculum is comprehensive and intended for the average, or more able student, it may not adequately prepare students for university physics. To lessen this apparent gap, this research thesis is in agreement with the 1992 Williams' Royal Commission, *Our children, our future*. Both suggest that a new revised high school curriculum should give students "more challenging 4000 level courses and an opportunity to write Advanced Placement Examinations" (p. 315).

Advanced Placement Programs

The Advanced Placement Program, sponsored by the College Board administers examinations to high school students in a broad spectrum of disciplines including the sciences, humanities, and the arts. While the College Board provides course descriptions, teaching guides, and references for instructional aides and resources, there is no set curriculum which teachers are required to follow. Teachers are given broad leverage to tailor the AP courses to meet the needs of their particular school and students. The only requirement is for teachers to ensure that their students are prepared to write the College Board Exam.

"The examinations are structured to measure the depth of the students' knowledge and comprehension with the greatest possible validity and reliability, (The College Board, 1995a, p. 2)." Each examination includes both multiple choice and free response questions, with the free response answers graded by over 3500 high school and college faculty members at the program's annual reading. The student's raw score is then converted to a five point scale: One = no recommendation; Two = possibly qualified; Three = qualified, Four = well qualified, Five = extremely well qualified. "This scale equates student performance to that of prior years and to that of college students at selective institutions. AP grades of three or higher are comparable to A's, B's and C's in college courses, (The College Board, 1995a, p. 2)." The results of these examinations are presented to those universities which students indicate they may attend. Depending upon a students' grade on their AP exam, advanced credit for first year university courses in the area that exams were written may be granted.

The College Board has been administering Advanced Placement examinations to high school students since 1956 (Hersey, 1990). Currently, "the AP program is "recognized by nearly 2900 US and foreign colleges and universities" (The College Board, 1994, p. i). Statistics from 1990 show that "2884 exams were written in Canada by 2016 candidates from 128 schools" (Haacke, 1992, p. 10). In 1995, the number of participating students across Canada writing exams was 4960, (The College Board, 1995, p. 5).

AP Physics in Newfoundland & Labrador

Except for 1994, Table 2.1 illustrates a continual growth in the number of students participating in the AP physics program within Newfoundland. During the 1994-95 school year, three high schools had offered the AP physics in Newfoundland and Labrador, with 19 students writing the College Board Exam. Fifteen of these students scored at least three of five possible points to qualify for advance university and/or college physics credit at most post secondary institutions in North America. Although 1994 showed a decline the number of participating students, early indicators suggest this is not a trend, and that the participation rates will continue to increase. During the present school year of 1995-1996, it is estimated that over 40 students from four schools will be enrolled in AP physics in Newfoundland and Labrador.

Table 2.1: AP physics school and exam participation rates in Newfoundland

Year	Participating Schools	Total Students Enrolled	Students writing exam	Score ≥ 3
1990	0	0	0	0
1991	0	0	0	0
1992	1	11	11	9
1993	2	25	15	11
1994	4	39	13	10
1995	3	31	19	15

(Government of Newfoundland and Labrador, 1995; The College Board, 1992, 1993, 1994, 1995c):

While the preceding discussion illustrates the continual growth and success of AP physics in Newfoundland, questions still exist as to its viability in schools. The viability issue may include low student numbers, insufficient resources (teachers and equipment), and the effects of ability grouping and tracking. It was stated in Chapter One that AP studies attempt to challenge and stimulate students' academic interests far beyond the rigors of the normal high school curriculum. In essence, it attempts to enhance students' thinking and reasoning skills. To determine the viability or plausibility of AP physics, a view of whether AP physics can succeed at enhancing thinking and reasoning skills more successfully than the current high school physics curriculum is required.

Theoretical Rationale of Ability Grouping for AP Physics

Glaser (1992) suggest there are four essential points on which educators should concentrate to enable students to attain high levels of competence. These include, the nature of practice; self monitoring; principled performance; and the social context of learning. The first three points may be incorporated into any grouping scenario because they are teacher initiated and depend upon the extent to which students wish to adopt such practices. The fourth, however, requires interaction of individuals in a social context that challenges each individual. That is, placing students who have been identified as gifted in Advanced Placement programs. Such programs may lead to academic interaction and mutual challenge.

Nature of practice suggests that practice problems "should focus on situations where there are complex patterns to be perceived, and where recognition of these patterns implies particular moves and procedures for solution" (Glaser, 1992, p.72). Any course adopting this view would have practice problems increase in complexity. The depth and complexity of concepts would ultimately depend upon how the teacher would perceive students handling the challenge placed before them.

The development of procedural knowledge should be the focus of any curriculum developed for all students, not only for gifted students. Actually, the design of the current physics curriculum attempts to encapsulate this concept. It is designed to challenge the average and slightly above average student. Throughout the curriculum guide for Physics 3204 (Government of Newfoundland and Labrador, 1991b), there are sections provided that teachers may expand upon, or go in to more detail with their students. While a more in-depth analysis may be too involved for some students, it is left to teachers' discretion, but is not included as material for public examination preparation. For example, The Physics 3204 Curriculum Guide (Government of Newfoundland and Labrador, 1991b) introduces the concept of diodes as an example of a "non-linear" circuit element. Although not compulsory, a description of diode and semiconductor theory is provided.

Teachers must realize that there are limits to which students may be challenged in a particular course, without sacrificing the learning of some students and the enrichment of others. If a teacher attempts a too in-depth concept analysis, the material may become incomprehensible for the average and below average ability students. However, gearing a course for average ability students may result in the gifted students becoming bored. Simply assigning extra work based on the same concept with a gradual increase in difficulty may not satisfy the cognitive needs of gifted students. Cross & Coleman (1992) surveyed 100 students at the Tennessee Governor's School for the Sciences and found that the gifted students surveyed did not want to be treated any differently than other students. However, the gifted students surveyed did want their teachers to stimulate their creativity in problem solving and provide more opportunities to apply their knowledge in the courses. As well, students indicated that they did not want to be left alone pursuing trivial practice problems. "Students want to go deeper into the subject matter of a course ... [and] they want more complex subject matter that extends beyond the standard course content," (p. 26). Students of higher academic ability wish to be challenged beyond the normal curriculum.

Cross & Coleman (1992), concluded that teachers in a regular stream of courses may leave gifted students to pursue work independently. However, to accomplish this, teachers would have to spend a great deal of time with these learners at the beginning of their program to provide them with the necessary specialized skills required for independent learning. According to nature of practice theory, increasing levels of cognitive challenge can easily be intertwined into any science curriculum. It is the teacher's choice as to the extent to which a particular course may be enriched, and to what degree students may independently pursue material.

A second method of enhancing thinking skills involves *self-monitoring* techniques. These techniques may be taught and encouraged to any group of students. Self Monitoring, refers to "the ability to observe and, if necessary, reshape one's performance," (Glaser, 1992, p. 73). According to Weinstein & Mayer (1986), students have to "establish learning goals ... , to assess the degree to which these goals are being met, and if necessary, to modify the strategies being used to meet the goals," (p 323). If students are to adopt new learning strategies, then they must know when, where, why, and how to use them. In developing metacognitive processes within students, the emphasis of proper strategy use should gradually move from the teacher to the student "until independent application of the strategies are ascertained," (Palincsar & Brown, 1987, p. 73). Learning, then becomes a function of motivation.

The third element which may lead to enhanced levels of competence is *principled performance*. Performance occurs "in the context of a model, a theory, or a principle that guides performance through constraints and structures for inference, and allows competent individuals to avoid disconnected trial and error" (Glaser, 1992, p.73). Furthermore "an essential aim of instruction and the design of curriculum materials should be to enable the student to acquire structured knowledge along with procedural skill," (p. 74). Glaser is suggesting that teachers must take the initiative to organize materials from textbooks, curriculum guides, and other resources. Often it is the lack of coordination between required course literature and materials that fosters a nonsequential and incoherent organization of knowledge. It is the teacher's role to bring organized thought to a course, and encourage students to bring organization to their learning and thinking.

A key component to knowledge cognition is understanding relationships between concepts, and relating prior knowledge and experiences to new knowledge, (Wittrock, 1990). When studying physics, students may have to use various techniques and learning strategies to comprehend the relationships between many intangible concepts. These same techniques appear to be fundamental in most works of physics and form the basis of many great discoveries by Galileo, Faraday, and Maxwell. These Physicists had used mental imagery, sketched diagrams, and created analogical models that could be manipulated. Nersessian (1992) suggests "that these techniques all involve a process of abstracting from phenomena or existing representations and creating a schematic or idealized model to reason with and quantify," (p. 65). Actually, teachers should utilize such strategies, and encourage students to mimic them in their study of physics.

When faced with a problem, a concept, or a relation, students should be encouraged to visualize what is happening, then they may sketch the scenario before them. That is, if students can "see" what is occurring, then it is as though they can touch, manipulate, and finally, understand the concept. Mayer's (1992) research on *explanative illustrations* supports the theory that modeling enhances cognition. Students who studied text with explanative illustrations yielded a 67% increase in correct solutions on tests of problem solving transfer. Mayer concluded that "when students are encouraged to build mental models of scientific systems, their scientific reasoning is improved," (p. 239). The construction of models, whether physical or pictorial is an effective method for student comprehension. As a concept is being explained to the students, teachers may sketch or build the corresponding model. In effect, the teacher is constructing their thought processes which lead to a solution or an understanding of a given problem. The hope is for students to recognize and use these problem solving strategies in their own work.

Again, these strategies may be used in any course, it is not limited to gifted students, advanced placement classes, or classes of mixed academic abilities. These techniques may be used in any situation to foster enhanced thinking skills and competence

Glaser's fourth point which he contends may establish enhanced thinking skills is also the area which opponents of AP physics cite as causing the greatest concern; *the social context of learning*. Glaser's theory implies that ability grouping is an important feature of encouraging thinking skills. Arguing from a cognitive perspective he suggests that ability grouping can serve several roles.

> First, it extends the locus of self-monitoring activity by providing triggers for cognitive dissatisfaction outside the individual. An audience monitors individual thinking, opinions, and beliefs, and can elicit explanations that clarify points of difficulty. Moreover, the learner's exposure to alternative points of view challenges his or her initial understanding. In addition, with the help of advanced peers or a teacher who can provide supportive scaffolding, the collaborative group maintains a mature version of a target task (Glaser, 1992, p. 74).

Glaser's reasoning provides a theoretical rationale for implementing programs, such as AP, which promote enhanced student thinking. In essence, Glaser suggests that homogeneous grouping encourages students with similar thinking mechanisms to challenge one another, look to others for clarification, provides peer support, and allows all students to work at a similar pace. Since students in an AP class would have approximately the same cognitive level, homogeneous grouping would provide a mutual support mechanism.

Studies show that higher academic ability students think differently than the average and lower academic ability students. Actually, gifted students' thinking & reasoning powers have been shown to be similar to that of experts in their particular field of study. Coleman & Shore (1991) outlines 26 studies which illustrate the greater metacognitive abilities of gifted students as opposed to average ability students. Inherently, high achievers in physics were found to use cognitive processing skills similar to that of expert thinkers (physics teacher, physics graduate student, and a Ph.D. in physics). They concluded that the results of the study illustrate "the importance of metacognition in supporting the assertion that gifted students think qualitatively differently and thereby require a qualitatively differentiated curriculum," (p. 376). However, programs of this nature which promote the establishment of separate curricula for the academically gifted are not well received by many educators. Consequently, the greatest impediment to the AP movement is the belief that AP is a form of streaming or ability grouping.

Opponents of tracking theory suggest that tracking has detrimental effects upon students of all ability levels, and that there are no discernible affects upon gifted students' achievement (Slavin, 1990). Ability grouping is said to be most detrimental to average and lower ability students. According to the Carnegie Council on Adolescent Development, "young people [may be] placed in lower academic tracks ... locked into dull, repetitive instructional programs leading at best to minimum competencies" (as cited in Lynch, 1994, p. 113). If students are heterogeneously grouped, lower or average ability students may at least gain assistance or stimulation from the higher ability students. On the other hand, high achievers become isolated and do not gain the socialization affects of heterogeneous grouping. Analysts such as Braddock & Slavin suggests that ability grouping "inhibits the development of interracial respect, understanding and friendship, and contributes to a stratified society," (as cited in Lynch, 1994, p. 113). The academic argument is plausible because many students may be left behind in uninteresting and unchallenging programs. However, in Newfoundland the racial issue is negligible.

In addressing the preceding arguments, one must understand that AP physics is a course which students elect to do in pursuit of additional and more in-depth studies of a particular discipline. It is true that only high achievers may be successful in AP physics and be able to handle the academic rigor synonymous with a college level program. However, there is no need to track students into an advanced stream of studies prior to AP physics. The current high school program has sufficient material and challenges to offer the majority of students. Most importantly, these courses provide students with the procedural knowledge necessary to pursue more in-depth thinking and concept analysis in another level of physics. Thinking strategies and procedural knowledge need to be an important component of any high school science program, and each program can be geared towards the student body of a particular course.

However, "the inclusion of material for enhancing thinking skills into a course requires a commensurate reduction in the amount of time devoted to traditional content," (Kemler, 1990, p. 6). The result of this would be a course with either fewer topics covered or the same breadth of material, but in less depth. Kelmer (1990) further suggests however, that it is essential "that courses substituting depth for breadth be viewed by students, faculty, and administrators alike not simply as cut down courses with less material to cover, but as classes in which the intellectual challenge has been increased substantially," (p. 7). The fear would be a watered-down content base in the physics curriculum. To achieve the breadth and width as suggested by the Department of Education and Training, as well as the enhancement of thinking skills, both positions may be consolidated. All students would enroll in the current high school program, with students wishing to pursue greater depth with enhanced thinking and academic challenge enrolling in AP physics during their final year of high school.

While the preceding arguments may appear to be an act of proselytization toward the viability of AP physics, it must be noted that AP is an option which may be promoted or reputed upon the theoretical grounds discussed in this chapter. If instructors, students, and administrators feel that enhancement of thinking skill can be achieved, and they may very well be, in a class of mixed academic abilities, then there is evidence to support such claims. However, the issue to be addressed is whether or not *academically gifted students are given the opportunity "to pursue academic studies to the limit of their abilities"* (Williams, 1992, p. 300).

Given the theoretical rationale of offering AP programs, what empirical evidence exists to suggest that AP programs are viable? In a comparative study by Haag (1988), multiple choice sections of AP examinations were administered to non-AP college freshman students over a period of several years. These results were then compared to the grades and scores received on AP exams of high school AP students. Haag's results demonstrate that "Advanced Placement students achieved higher mean scores than did college students, indicating at least slightly superior performance to that of college students" (p. 2). Haag concludes that this study substantiates the strength of AP students.

Despite the apparent support that Haag's results lend to the credibility of AP programs, caution must be taken because there may have been a bias within the testing of both groups. The AP students were tested on materials that they were explicitly prepared for whereas the non-AP college freshman may have been tested on materials that was not a part of their course syllabus and preparation.

Prior to Haag's study, Willingham and Morris (1986) carried out a four year study of AP students who attended nine different colleges throughout the United States. In comparing the academic records of AP and non-AP students, results showed that "the AP students were more likely to maintain a "B" average in the freshman year (59% vs. 44%)

and more likely to graduate with academic honors (40% vs. 33%)," (p. 1). Furthermore, they contend "there is considerable evidence here that as a group, the AP students do even better than expected in college, particularly those students who make AP grades of three or better," (p. 1). While this result appears to provide evidence in support of enhanced academic achievement related to the AP experience, Willingham and Morris do concede that "it is not possible to ascertain from this analysis to what extent the AP effect is caused by strong preparation in secondary school, or by other factors. One good possibility is the self-selection of well-motivated students," (p. 1). It appears that the combination of preparation and self-motivation interact to produce the results of enhanced grades in post-secondary studies.

The rewards in doing AP physics or any pre-college training program are beyond obtaining an advanced college or university level credit. Students also benefit from being exposed to a university level course environment. This course can challenge students, and help develop the critical thinking skills needed to become successful at university (Pizzini & Moore, 1984). Also, students would have an indication of the expected work load, both in the class and the laboratory (Whelan & Espinoza, 1989), rather than becoming anxious from the notions of former physics students. Moreover, the exposure may encourage students to choose a career in physics or some other science related field. According to Ferko (1989), 74.5% of students enrolled in advanced high school physics courses in the United States have aspirations of post secondary "education of more than four years" (p. 74). While Ferko's study analyzed advanced science student aspirations, she did not consider those of AP students. Considering that advanced science courses are less in-depth than AP courses but more in-depth than mainstream science courses, the exposure to AP science may further enhance students' aspirations to pursue more science beyond high school.

Students must have a greater exposure to physics principles and thinking strategies so that they can expand their knowledge base and critical thinking skills. "The most important single factor influencing learning is what the learner already knows Ascertain this and teach (them) accordingly" (Ausebel, Novak, & Hanesian, 1986, p. 440). Theorists, such as Glaser suggest that the enhanced thinking abilities and procedural knowledge of gifted students are similar to that of experts. Furthermore, studies have shown that "experts have a great deal of domain-specific information, [which is] highly organized and conceptually integrated. This organized knowledge appears to account for the experts' capacities for rapid pattern recognition and categorization," (Glaser, 1992, p. 65). Therefore, teachers may wish to encourage similar thinking in their students. Such skills may be taught, encouraged, and fostered in any physics course, whether it is the current high school program, or an Advanced Placement course. The nature of physics lends itself to encouraging such cognitive process. Studies have shown that an exposure to physics in high school will lead to better results in post secondary studies, (Dickie & Farrell, 1991; Ferko, 1989; Hart & Cottle, 1993; Hellman, 1992; Tamir & Amir, 1982; Yager, 1989; Yager & Krajcik, 1989).

In addition to a strong physics background, students' mathematical exposure and aptitude may also enhance their performance in first year of university physics. "Data provided by the College Board ... generally show a stronger correlation between mathematics ability and achievement in college science than between verbal ability and such achievement" (Lynch, 1992, p. 150). Gifford and Harpole's (1986) study of 248 freshman students enrolled in first semester physics at Mississippi State University demonstrate a high correlation between high school physics and math grades with subsequent grades in college freshman physics. Their results suggest that 17.3% and 7.3% of the variance in college freshman physics grades are respectively accounted for by physics and total mathematics exposure in high school.

Although students may gain advanced university or college credit for first year of university physics, not all students enrolling in AP physics programs elect to write the college board exam. In the 1994-95 school year, 31 students in Newfoundland and Labrador enrolled in the AP physics program (Government of Newfoundland and Labrador, Department of Education and Training, 1995), but only 19 students wrote the College Board AP exam (The College Board, 1994). Students typically feel the AP program gives them added preparation for first year university courses. Even if students receive advanced credit, they may not elect to advance to the next level of university physics.

An additional aide to the student's success is the ability of a qualified physics teacher to convey the content of the physics curriculum to the student. Because the level of preparation involved in teaching these courses is very high, the teacher also benefit. According to Herr (1991), "AP not only encourages teachers to obtain greater depth in their fields, but also greater breadth" (p. 628). With this, the teacher of AP programs becomes more qualified and knowledgeable in their discipline, subsequently impacting upon the student. As Layman (1983) points out, "perhaps the greatest single factor in stimulating students into seeking science careers is the enthusiastic and well-informed high school teacher" (p. 28). Obviously, there is a two-fold effect.

If the goal of the Department of Education and Training in Newfoundland and Labrador is to provide all students with the opportunity to be taught to the maximum of their learning potential, (Government of Newfoundland and Labrador, 1994); Crocker, 1989; Williams, 1992), then programs promoting in-depth study and critical thinking have to be available. Such programs may include AP physics, as well as other AP courses. AP physics would be a third level course in the high school physics curriculum. With such a structure, "a goal of greater depth allows teachers to emphasize critical thinking, enables students to gain more ownership of the problems in science, and is more likely to have a lasting impact" (Norris, 1992, p. 219). These skills are a prerequisite for success in university physics. In her doctoral thesis based on the Second International Science Study, Ferko (1989) noted that in the American sample, "when grade level of student, years of mathematics studied, and years of science study were controlled, the AP science students ... had significantly higher achievement scores compared with non-AP students," (p.125).

Does AP physics, or any AP courses deserve a place in our school system? It is not the intent of this research to promote AP solely as a route to achieving college-level credit. The primary goals of AP should be to challenge the academically gifted students and to bridge the gap that exists between high school physics and university physics.

Although AP programs have been in existence since 1956, George Ewonus, the Canadian representative for the College Board (personal communication, July 22, 1994) stated that AP courses were only first introduced to Canada in 1986 in British Columbia. It was not until 1991 that AP courses, including physics, were introduced to Newfoundland and Labrador. Holy Heart of Mary high school was the first school within this province to offer AP physics. Currently, three other schools, Ascension Collegiate in Bay Roberts, Herdman Collegiate in Corner Brook, and St. James Regional High in Port Aux Basques offer AP Physics.

Hypothesis & Research Questions

The premise of this research is: *if students complete an AP high school physics course then they should be more successful in university physics than students who do not take an AP physics course.* The primary focus at the university level was Physics 1200 since it is the most commonly chosen first year physics course. However, the majority of AP physics students and students with equivalent academic grades who attend memorial University enroll in Physics 1050. Therefore, the high school to university comparisons consisted of two components: students enrolled in Physics 1200, and students enrolled in Physics 1050.

A secondary focus includes students enrolled in Physics 2050 at Memorial University. If AP physics students had scored three or more points out of five in their College Board AP physics exam, then they would have received credit for Physics 1200 and Physics 1201. Consequently, these students may have elected to enroll in Physics 2050 along with second year university students who had competed Physics 1200 and Physics 1201. Ideally, if AP physics is to be academically equivalent to first year of university physics, then both groups would be statistically equivalent. That is, AP and non-AP students would be able to achieve similar performance in Physics 2050.

A comparison of students on the basis of physics exposure alone would be incomplete because there are additional variables that may affect student performance. In conjunction with the physics exposure, this research intends to determine the effect of other factors upon student performance in first year of university physics. These include the students' high school mathematics background (AP mathematics, advanced mathematics, or academic mathematics), and their exposure to other core high school sciences such as Chemistry and/or Biology.

Since the main hypothesis is wide in scope, three basic hypotheses were tested. These include:

Hypothesis One:

Students who enroll in AP physics in high school subsequently have higher grades in Physics 1200 and Physics 1050 in their first year of university physics than students who do not enroll in AP physics.

Hypothesis Two:

AP physics students who earn advanced credit for Physics 1200 and Physics 1201, then enroll in Physics 2050 have final grades which are not significantly different from non-AP students who had first completed Physics 1200/1201 at Memorial University.

Hypothesis Three:

Students, teachers, and physics professors perceive that exposure to AP physics enhances student academic abilities and improves student work habits.

Since Hypothesis Three is broad in scope, the following set of questions were generated to test this hypothesis:

1. Why do students enroll in AP physics?
2. (a) Does exposure to high school physics enhance students' critical thinking skills and prepare them academically for first year of university physics?

   (b) Does exposure to AP physics enhance students' critical thinking skills and prepare them academically for first year of university physics?

3. How does the content, concept depth, difficulty level, and work load of first year of university physics compare with high school and AP physics?

4. How much effort, study, time, and work do students place in their first year of university physics, and do AP students take their first year of university physics for granted?

5. How does class size affect learning in first year of university physics?

6. What high school course and grades should be prerequisite for enrollment in AP physics?

7. Should lab work be an essential component to high school and AP physics?

8. Do high schools have the resources and personnel to offer high school physics and/or AP physics?

9. What academic qualifications should teachers be required to have before teaching high school physics and/or AP physics?

10. What role should the university have in AP physics?

Chapter Summary

Through available literature and research, the role of Advanced Placement physics in a high school physics curriculum was described. Since AP courses are designed for the academically gifted, the theoretical rationale of providing academic challenge to these students was discussed. It was suggested that academically gifted students could gain high levels of competence through a variety of methods which may be taught in classrooms of mixed abilities. However, Glaser's (1992) *social context of learning* promotes the concept of ability grouping. He argued that ability grouping encourages students with similar thinking mechanisms to challenge one another, look to others for clarification, provides peer support, and allows all students to work at a similar pace.

While opponents of ability grouping may be justified in their assessment of the adverse effects of streaming, implementation of AP need not be viewed as streaming through all levels of the high school curriculum. Homogeneous grouping can provide students with a broad conceptual understanding of physics and achieve the goal of "physics for all." However, the use of homogeneous grouping diminishes the potential that an instructor has to provide curricular depth and challenge to academically gifted students. A broad physics curriculum can provide academically gifted students with the procedural knowledge required if they are to continue in discipline specific program offering depth, challenge, and enhancement of critical thinking skills. Such programs may include an AP course in physics offered to gifted students in their final year of high school.

Beyond the theoretical argument of promoting AP physics within the curriculum, research findings were presented that supported the role of AP as university preparatory. Findings suggested that AP students generally score higher grades in first year university courses than non-AP students. AP students are also more likely to maintain a "B" average, or graduate with honors in the first year of university studies. While these findings generally involve comparisons between the test scores of AP and non-AP students, it appears that enhanced grades in post-secondary studies are the result of combined preparation and self-motivation.

Finally, three hypotheses were formulated under the auspices of the premise, *if students complete an AP high school physics course then they should be more successful in university physics than students who do not take an AP physics course.* Hypothesis One suggested that AP students should have higher grades in their first year of university physics than non-AP students. For AP physics students who receive advanced university credit, Hypothesis Two implies that these students should not have grades significantly different form non-AP students in a second year university course. Hypothesis Three seeks to determine if exposure to AP physics enhances student academic abilities and improves student work habits.

Chapter Three

Design & Limitations of the Study

Design of the Study

This study's primary purpose was to determine if exposure to AP physics enhances a students' performance in first year university physics. To achieve results that are as comprehensive as possible the research extends over a six year period; June of 1990 to December of 1995. The initial comparison of students' high school results with their first year university results was broken into the two groups of first year physics at Memorial University: Physics 1200 and Physics 1050. While it was necessary to identify students and follow their progression from high school to university, this study did not identify, nor record individual results in the analysis. In this manner, the research maintained student confidentiality.

The initial identification of students involved obtaining student public examination grades in all physics, mathematics, chemistry, and biology courses for the period of June 1990 to June 1995. This data was obtained from the Department of Education and Training in Newfoundland and Labrador. The data from those students who had completed the high school public examination course for Physics 3204 were extracted. Included with this were the students corresponding grades in Advanced Mathematics 3201, Chemistry 3202, and Biology 3201. The same data was then reviewed to determine which students had completed AP physics in high school. This search revealed that AP physics had only been taught in Newfoundland schools since 1992, therefore, student records prior to 1992 were eliminated. Two student data bases of high school grades were then compiled; AP and non-AP physics students.

A third data base was then constructed consisting of students' final grades in Physics 1200, Physics 1050, and Physics 2050 for the periods of the Fall 1992 to Fall 1995 semesters. These dates would correspond with student records from the high school data base. Records for this data base were provided by Memorial University's Office of the Registrar. All three data bases included student Medical Care Plan (MCP) numbers as identifiers so that cross referencing could be made between high school records and Memorial University's physics grades.

Initially, student grades in Physics 3204 were cross referenced with their grades in either Physics 1200 or Physics 1050 at Memorial University. To equate both groups, this study selected only those students who had enrolled in Physics 1200 or Physics 1050 during their first semester at Memorial University. This would ensure that comparable groups with respect to high school exposure would be used in the study and diminish the variable of maturation through related university studies.

The selection of subjects was then refined another step. Hypothesis One sought to compare the final grades of all first year Physics students at Memorial University with their final grade in Physics 3204 from high school. However, not all of those students enrolled in the first year physics program at Memorial University had the ability or opportunity to have enrolled in an AP physics course. Consequently, a comparison of all students enrolled in first year university physics to those students who had completed AP physics in high school would be erroneous and misleading. Therefore, the comparison involved two groups of students who enrolled in first year physics courses during their first semester at

Memorial University. One group will have completed AP physics prior to enrolling in Memorial University, while the second group would have had no exposure to AP physics. The high school data base of those students who had exposure to AP physics was then searched again to find commonalties within the science and mathematics courses they had completed, including their respective final course grades. In addition to completing high school physics, the majority of all AP physics students had completed Chemistry 3202, and Advanced Mathematics 3201. The minimum grades of the AP students in these courses were then determined and used as selection criteria for the non-AP comparison group.

Once the corresponding grades were extracted, the means and standard deviations of student grades of the AP and non-AP students in each of Physics 1200 and Physics 1050 was compared. If a difference existed, an analysis of variance (ANOVA) was applied to the results to determine if the difference was statistically significant. In this manner, the study could determine if exposure to AP did affect student grades in Physics 1200 or Physics 1050.

However, it would be insufficient to assume on the basis of a single factor ANOVA that the type of high school physics exposure was the decisive variable in determining success in university physics. Therefore, this research also considered other related variables such as the students' mathematics background (advanced, or academic), and their exposure to other core sciences such as chemistry and/or biology An analysis of this nature, which attempted to consolidate and differentiate the effects of several variables upon university performance can be achieved through a multiple regression analysis.

The use of the multiple regression analysis equalizes results of the samples (groups) compared. An assumption was made that barring any treatment, such as exposure to the AP physics program, both groups of students are academically equivalent upon completion of high school Physics 3204. Before applying the regression analysis, academic backgrounds of the AP physics students were analyzed to determine the high school science and mathematics courses that these students had completed. Along with course enrollments, the minimum final grades from those courses were determined for that group. As previously stated, both groups were equated with respect to completing physics, chemistry, and advanced mathematics in high school. Once these characteristics were determined, students who had not completed AP physics, but whose academics were otherwise equivalent to their AP peers, were chosen as the comparison group. With this design, both comparison groups had completed the same high school core science and mathematics courses and had comparable final course grades. To ensure that both comparison groups were statistically equal, all factors used to identify students were entered into a regression analysis. Consequently, the comparison of the AP and non-AP student physics grades at MUN would be considered statistically valid.

A second group of AP physics students was also analyzed. If students had scored three or more points out of five in their College Board AP physics exam, then they would have received credit for Physics 1200/1201 at Memorial University. Consequently, these students may have elected to enroll in Physics 2050 along with second year university students who had competed Physics 1200/1201.

However, AP and non-AP groups in Physics 2050 could not be equalized on the same criteria as students who enroll in first year of university studies. AP students enrolling in Physics 2050 directly from high school may do so if they had received advanced credit for Physics 1200 and Physics 1201. Non-AP students were required to first complete Physics 1200 and Physics 1201 during their first year of studies at Memorial University as a prerequisite to Physics 2050. Consequently, students who enroll Physics 2050 via Physics 1200 and Physics 1201 may be more experienced in physics subject matter. Therefore, comparison of AP and non-AP students in Physics 2050 involved the application of a single factor ANOVA. That is, a comparison of final grades in Physics 2050. The only equalization of both groups involved the inclusion of AP and non-AP students who had enrolled in Physics 2050 during the same semesters.

In addition to including numerical grades obtained from high school and university, hypothesis three analyzed the attitudes of students, teachers and university professors concerning high school, AP, and first year of university physics. An analysis of attitudinal responses may help teachers to identify possible candidates for AP, and even provide some ideas of how teachers may adapt their courses for optimum student success. This aspect of the study consisted of a three-part survey sent to students in Physics 1200 and Physics 1050, all high school Physics 3204 teachers, and all identifiable and locatable physics Professors at Memorial University who have taught first year physics.

While each questionnaire was designed for those who were being surveyed, there were numerous items in each section that was common to all three groups. The first section of the questionnaire consists of Likert type response items. Section two consisted of questions that had five responses from which each subject selected one. The final section had one "free response" question to which the subjects are asked to respond. Once results from the questionnaires were compiled, each set of responses was analyzed to determine if one singular response to each item is statistically significant. This will be achieved through the determination of standard errors for each response item. If the error of the most frequent response did not overlap the error of another response on the same item, then the most frequent response would be considered statistically significant.

Limitations of the Study

The major limitation of this research was the novelty of AP in this Province. AP courses, including physics, were first introduced to Newfoundland in 1991. As such, the available data in forming two comparison groups (AP versus non-AP physics students) was limited. Further contributing to the small numbers of students enrolling in AP physics was the scarcity of schools offering the program. Table 3.1 reveals the number of students enrolled in AP physics over the research time interval of this study.

Furthermore, not all students who had completed AP physics subsequently attended Memorial University. A number of students may have enrolled in universities outside of Newfoundland and Labrador, or enrolled in one of the many provincial colleges. Because the physics programs and teaching methods in other post secondary institutions may differ from Memorial University, any attempt to acquire empirical data from those students was deemed to not be useful for this research. To ensure that all participating students had a similar exposure to their first year of university physics, only students attending Memorial University of Newfoundland were surveyed.

Table 3.1: AP Physics Enrollments and School Offerings

Year enrolled in AP physics	High schools offering AP physics	AP Student Enrollment			
		AP physics	Physics 1200	Physics 1050	Physics 2050
1989-1990	0	0	0	0	0
1990-1991	0	0	0	0	0
1991-1992	1	11	0	3	2
1992-1993	2	25	3	5	1
1993-1994	4	39	12	4	1
1994-1995	3	31	3	4	4

Government of Newfoundland and Labrador, 1995, 1994, 1993, 1992)

Results from the questionnaires were further impacted by the limited number of AP physics students at Memorial University who were available to be surveyed. As well, there was limited response acquired from the physics professors teaching Memorial University physics courses. To locate students for the questionnaire, Physics 1050 and Physics 1200 classes in which AP students would most likely be enrolled were selected. While circulating questionnaires in this manner ensures that all AP students and their classmates receive questionnaires, there was no guarantee that all questionnaires would be returned.

As Table 3.2 indicates, the student return rate was limited. While receiving only nine of a possible 27 responses from AP physics students may appear low, one must consider that the surveys were circulated to first year physics classes of which only 16 AP physics students were enrolled during the 1994 Fall semester at MUN. Consequently, the return rate from the AP physics students enrolled in physics was 56%. On the other hand, the physics professors' response rate appears high. Even though Table 3.2 indicates a survey return rate of 61.5%, their actual responses on the questionnaires were low (see appendix D.3). On average, each item had a 70% response rate, with several items having only a 44% response. Consequently, a return rate of 61.5% is not indicative of an equal response rate on individual items. This relatively poor response rate from physics professors teaching physics at Memorial University provided insufficient data from which to draw conclusions. While responses from physics professors will be presented in Appendix D, analysis of their responses will be of little consequence, hence they will be omitted from the discussion in Chapter Four.

Table 3.2: Survey Returns

Surveyee	Surveys	Returns	Return Rate
Physics Professors	26	16	61.5%
Physics 3204 Teachers	148	96	64.9%
AP Physics Teachers	8	5	62.5%
MUN Physics 1200 Students	88	44	50.0%
AP Students		5	
MUN Physics 1050 Students	55	19	34.5%
AP Students		4	

Chapter Summary

The design of this study involves a quantitative analysis of students' final grades in Memorial University's Physics 1200, Physics 1050, and Physics 2050 to determine if a statistical difference exists between AP and non-AP students. To equate the AP and non-AP comparison groups, the final high school grades of AP physics students in Physics 3204, Chemistry 3202, and Advanced Mathematics 3201 was reviewed. The minimum final grades in these courses were then used as selection criteria for the non-AP student sample group. Once comparison groups were formed in each of Physics 1200, Physics 1050, and Physics 2050, descriptive statistics of each group's final grades were generated, then followed by the application of a single factor ANOVA test. If statistical differences did exist between AP and non-AP groups, the source(s) variance was determined using a multiple regression analysis analysis statistical test.

The final aspect of Chapter Three describes the limitations of this study The major limitation included the novelty of AP physics to Newfoundland and Labrador. Consequently, the number of students who had completed AP physics is very low, leaving a small sample size for the AP comparison group. Another limitation included the limited response from students and physics professors to the questionnaire. Although students' response appeared low, they were more comprehensive than the physics professors. A low response rate from the professors' sample group was deemed as unusable and summarily deleted from the study.

Chapter Four

Research & Data

Introductory Comments

The premise of this research was that *students who had completed an AP high school physics course would be more successful in university physics than would students who had not taken an AP physics course.* As indicated in chapter two, support of the hypothesis statement was derived from research and analysis of three basic hypotheses. Hypothesis one was addressed through a quantitative, statistical comparison between AP and non-AP physics students' high school science and mathematics grades with their first year of university physics grades. Hypothesis two also includes a quantitative, statistical comparison between AP and non-AP physics students' grades but in Memorial University's second year physics course, Physics 2050. Hypothesis three includes a qualitative study of student, teacher, and physics professor perceptions of high school physics, AP physics, and first year of university physics. This hypothesis will be tested through an analysis of student and teacher questionnaires. Because of the in-depth nature of the questionnaires, hypothesis three will be assessed through ten research questions.

As previously indicated, there are two streams of first year physics at Memorial University, Physics 1200 and Physics 1050. Even though the grades of most AP students would allow them to enroll in Physics 1050, they may elect to do Physics 1200. In addition, students who attend the Sir Wilfred Grenfell College campus of Memorial University in Corner Brook have the option of enrolling only in Physics 1200. Consequently, separate comparisons had to be made for the Physics 1200 and Physics 1050 groups. In addition to their Physics 3204 final grades, all students in this study had an equivalent range of final grades in Advanced Mathematics 3201 and Chemistry 3202. Since only two AP physics students had completed biology in high school, enrollment and grades in that course were eliminated as a factor in the analysis.

Also, this study has been subject to a revision with an additional year of data analyzed. Initially, there was only three years of data from Physics 1050, and two years of data from Physics 1200 available. The analysis of the initial data yielded unexpected results that will be discussed. In an effort to verify these results, and give them a greater validity, an additional year of data was collected and analyzed. In the discussions that follow, both sets of data are analyzed and compared.

An Analysis of Student Grades In Physics 1200 and Physics 1050

Physics 1200 Data & Research Findings

The first analysis of student grades in Physics 1200 involved a comparison of descriptive statistics from the AP and non-AP groups. According to Table 4.10, the non-AP group of students had a marginally higher mean final grade than their AP peers. In the 1993-1994 study, there was only 0.5% difference between the mean final grades, while the inclusion of an additional year of data resulted in a larger difference of 2.3%. Also, indicating little difference were the standard deviations between the AP and non-AP students. While the standard deviations for the non-AP students remained constant at 14.2 for each year of the study, the AP students' grades were respectively 2.1 and 2.5 standard deviations lower. However, it should be noted that the number of AP students enrolling in Physics 1200 increased only by one from 1994 to 1995. Consequently, this would have little effect upon results from one year to the next.

Table 4.10: Physics 1200 Descriptive Statistics

Students	N	Mean	SD	Variance
1993-1994				
AP	10	68.0	12.1	145.556
non-AP	511	68.5	14.2	202.254
1993-1995				
AP	11	67.3	11.7	136.818
non-AP	629	69.6	14.2	202.004

Confidence Level @ 95%

Beyond descriptive statistics, a single factor ANOVA was used to determine if a significant difference existed between the grades of the AP and non-AP students enrolled in Physics 1200. Even though group sizes are quite different, the use of the ANOVA was acceptable since the variance of the groups being compared are approximately equal. Results from the single factor ANOVA in Table 4.11 verifies that there is no significant difference between AP and non-AP students who enroll in Physics 1200 immediately after completing high school. Comparisons of the raw final grades in Physics 1200 at a confidence level of 95% produced $F(1, 519) = 0.011 < F_C(3.859)$. It was thought that exposure to AP physics would yield higher results in Physics 1200 but this did not occur. Extending the research to an additional year produced similar results, $F(1, 638) = 0.296 < F_C(3.856)$, with no significant difference between AP and non-AP students enrolled in Physics 1200 indicated.

Table 4.11: Physics 1200 Single Factor ANOVA

Source of Variation	df	SS	MS	F	P-value	F-crit
1993-1994						
Between Groups	1	2.292	2.292	0.011	9.151E-01	3.859
Within Groups	519	104459.609	201.271			
Total	520	104461.900				
1993-1995						
Between Groups	1	59.486	59.486	0.296	5.872E-01	3.856
Within Groups	638	128226.608	200.982			
Total	639	128286.094				

Confidence Level @ 95%

Despite results indicating no significant difference between both groups, a regression analysis was carried out to determine what affect, if any, that high school science and mathematics had on students' Physics 1200 final grades. The regression included students' raw final grades in Physics 1200 as the dependent variable, while the independent variables were final grades in students' high school courses Physics 3204, Chemistry 3202, and Advanced Mathematics 3201. The independent treatment variable was enrollment in AP physics. Enrollment was assigned a value of one in the regression, while non-enrollment was assigned zero. Table 4.12 illustrates an adjusted R^2 value of 0.230 and 0.247. Therefore, the regression analysis can account for 23.0%, and 24.7% respectively of the actual variation in the Physics 1200 final grades from the 1994 and 1995 results

Table 4.12: Physics 1200 Regression Statistics

	1993-1994	1993-1995
Multiple R	0.486	0.501
R Square	0.236	0.251
Adjusted R Square	0.230	0.247
Standard Error	12.438	12.298
Observations	521	640

Confidence Level @ 95%

Unlike a single factor ANOVA, the multiple factor ANOVA, through the regression analysis indicates that some of the predictor variables have a significant effect upon Physics 1200 grades (Table 4.13). At a confidence level of 95%, the 1994-1995 results had an F-ratio exceeding the critical value, $F(4, 517) = 39.811 > F_C(2.389)$. An additional year of data from 1995 resulted in a greater significant difference, with $F(4, 636) = 53.292 > F_C(2.386)$.

Table 4.13: Physics 1200 Multiple Factor ANOVA

	df	SS	MS	F	F-crit
1993-1994					
Regression	4	24635.454	6158.864	39.811	2.389
Residual	517	79826.446	154.702		
Total	521	104461.900			
1993-1995					
Regression	4	32241.639	8060.410	53.292	2.386
Residual	636	96044.455	151.251		
Total	640	128286.094			

Confidence Level @ 95%

Table 4.14: Physics 1200 Multiple Regression

	Coefficients	Standard Error	t Stat	P-value
1993-1994				
Intercept	-14.535	6.651	-2.185	2.930E-02
Chemistry 3202	0.242	0.085	2.808	5.176E-03
Advanced Mathematics 3201	0.348	0.076	4.427	1.169E-05
Physics 3204	0.421	0.099	4.255	2.478E-05
Enrollment in AP physics	-0.079	3.999	-0.020	9.843E-01
1993-1995				
Intercept	-14.913	5.936	-2.512	1.224E-02
Chemistry 3202	0.304	0.077	3.971	7.977E-05
Advanced Mathematics 3201	0.378	0.069	5.458	6.921E-08
Physics 3204	0.346	0.087	3.987	7.454E-05
Enrollment in AP Physics	-1.965	3.755	-0.523	6.009E-01

Confidence Level @ 95%

According to the regression coefficients identified in Table 4.14, enrollment in AP physics resulted in a marginal decrease in student grades for Physics 1200. However, this decrease was not statistically significant for either set of data studied. Other variables including Physics 3204, Chemistry 3202, and Advanced Mathematics 3201 final grades were determined to be statistically significant factors contributing to the final grade in Physics 1200.

Physics 1050 Data & Research Findings

The comparison of descriptive statistics between AP and non-AP student grades in Physics 1050 indicated a difference between both groups. For the period of 1992-1994, Table 4.15 depicts AP students having a mean grade 12.3% higher than their non-AP peers. However, this grade difference decreased with the addition of another year of data. In the second analysis, there was a lower difference in the means of 9.1%. However, there is overlap between the standard deviations of the AP and non-AP student grades in Physics 1050 for each year of data analyzed. Although, a difference of mean grades is apparent, there is a large proportion of grades from the AP and non-AP students that do fall within the same range.

To determine if an actual significant difference did exist between the AP and non-AP students, an ANOVA (Table 4.16) was applied to the final grades in Physics 1050. Even though there was a large difference in the AP and non-AP group size, their variance was approximately equal. Consequently, the use of a one-way ANOVA to determine if a difference existed between the comparison groups is appropriate. At a confidence level of 95%, a significant difference between the AP and non-AP students enrolled in Physics 1050 was indicated for both sets of data. However, the difference was slightly larger for the 1992-1994 data, $F(1, 147) = 6.699 > F_C(3.905)$, than for the 1992-1995 data, $F(1, 184) = 5.209 > F_C(3.892)$.

Table 4.15: Physics 1050 Descriptive Statistics

Students	N	Mean	SD	Variance
1992-1994				
AP	10	84.0	14.1	198.889
non-AP	139	71.7	14.6	211.795
1992-1995				
AP	14	81.4	13.5	182.418
non-AP	172	72.3	14.5	209.169

Confidence Level @ 95%

Table 4.16: Physics 1050 Single Factor ANOVA

Source of Variation	df	SS	MS	F	P-value	F-crit
1992-1994						
Between Groups	1	1413.510	1413.510	6.699	1.062E-2	3.905
Within Groups	147	31017.698	211.005			
Total	148	32431.208				
1992-1995						
Between Groups	1	1079.645	1079.645	5.209	2.362E-2	3.892
Within Groups	184	38139.306	207.279			
Total	185	39218.952				

Confidence Level @ 95%

Considering a significant difference existed between AP and non-AP students enrolled in Physics 1050, a regression analysis was then applied to determine the source of variation. The dependent variable in the regression analysis consists of the students' unadjusted final course grades in Physics 1050. The independent variables were final grades in high school Physics 3204, Chemistry 3202 and Advanced Mathematics 3201. The independent treatment variable was enrollment in AP physics. Enrollment was assigned a value of one in the regression analysis, while non-enrollment was assigned zero. Table 4.17 illustrates an adjusted R^2 value of 0.209 and 0.211. Thus the regression analysis can account for 20.9%, and 21.1% respectively of the actual variation in the Physics 1050 final grades from the 1992-1994 and 1992-1995 results.

Table 4.17: Physics 1050 Regression Statistics

	1992-1994	1992-1995
Multiple R	0.480	0.477
R Square	0.231	0.228
Adjusted R Square	0.209	0.211
Standard Error	13.163	12.936
Observations	149	186

Confidence Level @ 95%

The result of the multiple factor ANOVA (Table 4.18) indicates a greater significant difference exists between the AP and non-AP students when high school science and mathematics grades were considered. When only the raw final grades were applied to a single factor ANOVA (Table 4.16), the F-ratios had a lower value. At a confidence level of 95%, the data analysis for the 1992-1994 period reveals $F(4,145) = 10.792 > F_C = 2.434$, while for 1992-1995 $F(4,182) = 13.346 > F_C = 2.421$. This result suggests that there is an increased significant difference between AP and non-AP students.

Table 4.18: Physics 1050 Multiple Factor ANOVA

	df	SS	MS	F	F-crit
1992-1994					
Regression	4	7479.733	1869.933	10.792	2.434
Residual	145	24951.475	173.274		
Total	149	32431.208			
1992-1995					
Regression	4	8932.697	2233.174	13.346	2.421
Residual	182	30286.255	167.327		
Total	186	39218.952			

Confidence Level @ 95%

Consistent with the results from the initial ANOVA in Table 4.16, the coefficients of the regression analysis (Table 4.19) show that students enrolled in AP physics have correspondingly higher scores in Physics 1050. Actually, the enrollment in AP physics variable for the 1992-1994 period resulted in AP students having a mean increase of 15.118% in their Physics 1050 grades from that of their non-AP peers. However, the addition of another year of data resulted in the mean increase lowered to 11.870%. That is, students who completed AP physics in high school would have, on average, a 11.870% higher grade in Physics 1050 during their first semester at Memorial University than non-AP students.

Table 4.19: Physics 1050 Multiple Regression

	Coefficients	Standard Error	t Stat	P-value
1992-1994				
Intercept	-34.261	19.37	-1.769	7.903E-2
Chemistry 3202	0.535	0.213	2.511	1.313E-02
Advanced Mathematics 3201	0.600	0.233	2.576	1.100E-02
Physics 3204	-0.050	0.233	0.216	8.292E-01
Enrollment in AP physics	15.118	4.366	3.463	7.037E-04
1992-1995				
Intercept	-31.630	17.228	-1.836	6.801E-02
Chemistry 32002	0.729	0.184	3.964	1.059E-04
Advanced Mathematics 3201	0.390	0.194	2.015	4.543E-02
Physics 3204	-0.058	0.203	-0.286	7.756E-01
Enrollment in AP Physics	11.870	3.629	3.271	1.284E-03

Confidence Level @ 95%

There appears to be a contradictory outcome of the regression analysis. From the 1992-1994 data to the 1992-1995 data there was a decrease in the mean difference between AP and non-AP final grades in Physics 1050. However, the regression analysis leads to a conclusion that there is a greater significant difference between AP and non-AP students. Even though the mean grade difference had decreased, the larger F-ratio indicates that there is a greater possibility that AP students will receive higher grades in Physics 1050 than non-AP students.

Discussion of Results

The results of grade comparison between AP and non-AP students yielded at least one unexpected result; hypothesis one was rejected for AP students in Physics 1200, but was supported for AP students in Physics 1050. Due to this rejection, the analysis was extended to include another year of data; 1995. The revised analysis confirmed the results of the initial analysis of the 1992-1994 data. This discussion attempted to integrate the results of the data analysis to determine what factors may have contributed to the respective rejection and acceptance of Hypothesis One by the Physics 1200 and Physics 1050 data analyses. Once compiled, suggestions for students planning to enroll in physics at Memorial University were made.

Hypothesis One stated that: *Students who enroll in AP physics in high school subsequently have higher grades in Physics 1200 and Physics 1050 in their first year of university physics than students who do not enroll in AP physics.* It was assumed that since Physics 1200 and AP physics were theoretically an academic equivalent, AP students would view Physics 1200 as a review and consequently have higher grades than non-AP students. Not only did AP and non-AP students have nearly identical mean grades and standard deviations (Table 4.10), but the results of a single factor ANOVA indicates no significant difference between both groups. Consequently Hypothesis One is rejected for AP students enrolled in Physics 1200.

A further analysis on the Physics 1200 grades included a multiple regression. This analysis was meant to determine the effects of AP participation, science grades, and mathematics grades upon final grades in Physics 1200. Results of this analysis revealed a large F-ratio as compared to the critical F-value, $F(4, 636) = 53.292 > F_C(2.386)$. Furthermore, when the high school final grades of Physics 3204, Chemistry 3202, Advanced Mathematics 3201, and AP physics enrollments were factored into the analysis, their inclusion indicated a strong predictor value for Physics 1200 final grades. Although enrollment in AP physics indicated an approximate 2% lower final grade in Physics 1200, its predictor value was not statistically significant. Considering that the algebra-based Physics 1200 is conceptually less difficult than the calculus-based Physics 1050, it may have been assumed that AP students in Physics 1200 would have grades significantly higher than their non-AP peers. Even though this assumption may have appeared plausible, the lack of difference may be attributable not to academics but other factors such as attitude and work ethic. Reason(s) for this outcome cannot be inferred from descriptive statistics nor the regression analysis used in this study, but may be revealed through analysis of the questionnaires.

The regression analysis did suggest the importance of a strong, well-rounded academic background in high school mathematics and science as contributing to the final grade in Physics 1200 for those students who had not received AP physics. Results indicated that for every 1% in their final grade of high school Chemistry 3202, Advanced Mathematics 3201, and Physics 3204, there was a corresponding increase in the Physics 1200 final grades by 0.304%, 0.378%, and 0.346% respectively (Table 4.14). These results must be interpreted considering that the regression analysis generated the students base score (intercept) in Physics 1200 was 14.913%. That is, considering no previous academic background in mathematics, or science.

Unlike the results from Physics 1200, Hypothesis One was verified for students enrolling in Physics 1050. AP students in Physics 1050 had mean grades 9.1% higher than their non-AP peers (Table 4.15). Even though the standard deviations between both groups did overlap, the results of the single factor ANOVA (Table 4.16) indicated a significant difference between AP and non-AP students.

Sources of variance were then determined through the application of a regression analysis. Results of the accompanying multiple factor ANOVA indicates that once high school science and mathematics scores were considered, there was a larger significant difference between AP and non-AP students. The regression coefficients illustrate that students who complete AP physics in high school will have, on average, a grade of approximately 12% higher in Physics than students who did not do AP physics.

Through the regression analysis it was discovered that Physics 3204 had a slight negative effect upon final grades in Physics 1050. For every 1% a student received in their final Physics 3204 grade, there was a subsequent decrease of 0.058% in their Physics 1050 final grade. In the final tally of a student's grade, this decrease may be considered negligible. Excluding AP physics, high school chemistry had the largest coefficient with a 0.729% increase per percentage point in Chemistry 3202. This large coefficient may be indicative of the need for students to be exposed to critical thinking and science concepts beyond what they receive in high school physics. Often the techniques a student learns are relegated to applications in that particular course and not carried over to their other courses. Consequently, the exposure to chemistry allows students to utilize the skills and scientific methods from one course to another. Students exposed to both physics and chemistry develops a broader conceptual understanding of science, which may carry over to their university studies.

Another predominant factor contributing to grades in first year university physics is students' mathematics background. Given the in-depth mathematical nature of first year university physics, it is not surprising that the coefficient assigned to mathematics in both analyses is greater than the high school physics coefficients. While only speculation, this result may be attributable to the lack of an in-depth mathematical treatment of concepts in high school physics. However, the difference is most predominant for Physics 1050 students; the Advanced Mathematics 3201 coefficient is 0.390 as opposed to -0.058 for Physics 3204. Considering that Physics 1050 is calculus based, students are required to have a strong mathematics background. Therefore mathematics would be an integral component to student success in physics.

What implications do these results have for students intending to enroll in physics at Memorial University? First, students would be better served if they were aware that there are two streams for first year physics available at Memorial University. Students whose average in their high school Physics 3204 and Advanced Mathematics 3201 is less than 80%, or who have taken Academic Mathematics 3203 are required to enroll in Physics 1200. These students would be advised not to consider AP physics. Instead, a successful exposure to high school chemistry, physics, and advanced mathematics would, according to the results of the regression analysis coefficients (Table 4.18) would be more beneficial as preparation for Physics 1200.

The second stream of high school students whose averages in Advanced Mathematics 3201 and Physics 3204 are 80% or greater are encouraged to enroll in Physics 1050. If these students intend upon pursuing physics beyond high school and throughout university, they would be well advised to enroll in AP physics.

The regression analysis revealed AP physics to be a predominant factor in determining success in Physics 1050 at Memorial University. As indicated, not all students have the opportunity to enroll in AP physics. There are however, other academic variables that students can access which were found to contribute significantly to student success in Physics 1050. Excluding AP physics, the predominant factor would be an exposure to, and an in-depth understanding of high school chemistry and advanced mathematics.

It may be argued that due to the high entrance requirements for Physics 1050, these students often have a much stronger academic science background. Since Physics 1200 students generally have a weaker academic background, the additional exposure to high school chemistry and advanced mathematics strengthens their high school academics. Consequently, the inclusion of these courses to a students' high school career would enhance the probability of having a more successful first year of university physics.

An Analysis of Student Grades In Physics 2050

Physics 2050 Data & Research Findings

The comparison of AP and non-AP students in Physics 2050 was limited because it was impossible to equate students in terms of high school exposure prior to entering their first semester at Memorial University. While the AP and non-AP students could possibly have similar academic backgrounds in high school, the non-AP students will have taken one year of university studies prior to enrolling in Physics 2050. This may actually give non-AP students an advantage because they will have had a year of maturation. This maturation may be academic, personal, and/or social. As a result, they may have adapted to university life, thus be more prepared for Physics 2050. In addition, Physics 1200/1201 are prerequisites for Physics 2050. Consequently, non-AP students may have had their Physics 1200/1201 tailored as preparation for Physics 2050.

Table 4.20: Physics 2050 Descriptive Statistics (1992-1995)

Students	N	Mean	SD	Variance
AP	7	74.3	16.9	286.905
non-AP	104	69.9	13.2	174.494

Confidence Level @ 95%

The result of the descriptive statistics outlined in Table 4.20 appear to contradict the assumption made in the previous paragraph. AP students who enrolled in Physics 2050 after completing high school had a mean average final grade of 4.4% higher than their non-AP peers. However, the difference is not as large as it appears once standard deviations are considered. The standard deviations of the AP and non-AP students were 16.9 and 13.2 respectively, thus there is a large overlap of student final grades in the same range.

The single factor ANOVA that compared the raw final grades in Physics 2050 of AP and non-AP students further verified the results of the descriptive statistics (Table 4.21). The F-ratio provided from the ANOVA was much smaller than the critical value, $F(1, 109) = 0.712 < F_C(3.928)$, thus there is no significant difference between AP and non-AP students enrolled in Physics 2050. As previously indicated, a regression analysis was impossible based upon high school grades, due to the maturation factor of non-AP students having completed a year of university studies before enrolling in Physics 2050.

Table 4.21: Physics 2050 Single Factor ANOVA (1992-1995)

Source of Variation	df	SS	MS	F	P-value	F-crit
Between Groups	1	128.708	128.708	0.712	4.005E-01	3.928
Within Groups	109	19694.265	180.681			
Total	110	19822.973				

Confidence Level @ 95%

Discussion of Results

The analysis of data from Physics 2050 resulted in the verification of Hypothesis Two. This hypothesis stated, *"AP physics students who earn advanced credit for Physics 1200/1201, then enroll in Physics 2050 have final grades which are not significantly different from non-AP students who had first completed Physics 1200/1201."*

Consequently, AP physics may be considered as a valid prerequisite for Physics 2050 at Memorial University.

Caution must be taken however before such a broad conclusion can be made. Given the results in the analysis of Physics 1200 and Physics 1050, AP will not have the same effect for all students. AP students who enroll in Physics 1200 generally have a weaker academic background, with their Physics 3204 and Advanced Mathematics final grades less than 80%. Results indicate that enrollment in AP physics has no significant affect upon physics 1200 grades. Conversely, AP students enrolled in Physics 1050 whose advanced mathematics and physics grades are equal to or above 80%, were found to have a mean grade increase of approximately 12% from their non-AP peers.

These results appear to indicate that students who had a strong academic background in high school tend to respond positively to more rigorous academic challenges in university physics. AP is a program that attempts to challenge and stimulate the interests of academically gifted students far beyond the rigors of the typical high school curriculum. As a result, AP students may become accustomed to the academic workload of university physics while attending high school.

According to the preceding argument, despite exposure to AP physics, these high ability, or gifted students may be successful despite exposure to AP physics. However, these same students would not advance to Physics 2050 at Memorial University without first having the prerequisite knowledge and skills provided by Physics 1200/1201. Despite the ability of these students, the prerequisite knowledge and skills are not provided in the current high school physics curriculum. AP physics is an option in addition to the current high school physics curriculum that may provide the prerequisite knowledge and skills for success in Physics 2050.

Before students may gain advanced admission to Physics 2050 from high school, they must have scored a minimum of three out of five possible points on the College Board physics exam. If students score the minimum three points then they are considered by the university to be competent to enroll in Physics 2050. Verification of this competence was revealed in the analysis of Physics 2050 Grades. The results indicated no significant difference existed between AP and non-AP students' final grades in Physics 2050. This result indicates that AP students were as adequately prepared for Physics 2050 as were Physics 1200 and Physics 1201 students. Consequently, it may be inferred that AP physics, and Physics 1200 and Physics 1201 both academically prepare students equivalently for studies in Physics 2050.

Questionnaire & Survey Analysis

It was hypothesized in the introduction of this chapter that there may not be a discernible difference between AP and non-AP physics students' results in first year physics at Memorial University. Even though this possibility seemed implausible, other variables besides student grades, exposure to science courses and AP physics may contribute to the outcomes. Consequently, a survey of students, teachers, and physics professors was carried out to determine which such extraneous variables may exist. While the tallies of responses are quantitative in nature, the survey analysis is qualitative in design.

The hypothesis, *if students complete an AP high school physics course then they should be more successful in university physics than students who do not take an AP physics course* has been found acceptable for AP Physics 1050 student sample. However, AP students enrolled in Physics 1200 had a marginally lower mean grade than the non-AP Physics 1200 students, causing a rejection of the hypothesis for this group. On the other hand, there was no significant difference between AP and non-AP students who were enrolled in Physics 2050. Although the reasons for the variation in these results may be inferred from the quantitative analysis, the inferences may be clarified through the following survey analysis.

Results from each group surveyed have been sorted and complied into ten sections. Where applicable, qualitative comparisons are made between and within groups. One final note involves the responses from physics professors. Fifty percent of the physics professors who had returned their questionnaires stated that they had little or no knowledge of the AP program nor which of their students had taken such a program (Appendix D). Furthermore, their comments on AP physics or high school physics appeared to be from a personal perspective, unqualified with direct knowledge of the high school and AP physics programs. Consequently, inclusion of their responses was not viewed as contributing to the final analysis of AP programs, comparisons to the current high physics school program, or comparisons to first year university physics. Despite the unreliability of data, their responses are tabulated Appendix D.

Data & Research Findings

Hypothesis Three states that "*students, teachers, and physics professors perceive that exposure to AP physics enhances student academic abilities and improves student work habits.*" This hypothesis was tested through questionnaires sent to first year of university physics students, all Physics 3204 physics teachers in Newfoundland, and first year of university physics professors at Memorial University. The analysis of the responses will involve the responses of students and teachers because they have direct knowledge of high school physics, student work habits, and first year of university physics Analysis of the questionnaire involved summarizes the responses under the following ten questions.

1. Why do students enroll in AP physics?

Although AP physics does offer an opportunity for students to gain university credit while still in high school, this reason was not predominant. Two thirds of students and teachers suggested the intrinsic rewards of doing AP physics was the main reasons for doing the course (Table 4.31). As well, 88.9% of AP students and all AP teachers agreed that students view AP physics as a means to prepare for university. This latter point may be indicative of the perception that high school physics was insufficient preparation for studies physics at a university or college level.

Table 4.31: Why students enroll in AP physics

	N	Agree (%)	Undecided (%)	Disagree (%)
Students' reasons:				
Receive university credit	9	33.3	44.4	22.2
Preparation for university	9	**88.9**	0.0	11.1
To be academically challenged	9	**66.7**	11.1	22.2
Enjoyment & desire to learn	9	**66.7**	11.1	22.2
AP teachers' perceptions:				
Receive university credit	5	40.0	40.0	20.0
Preparation for university	5	**100.0**	0.0	0.0
To be academically challenged	5	**100.0**	0.0	0.0
Enjoyment & desire to learn	5	**60.0**	40 0	0.0

Confidence Level @ 95%
Bold results are statistically significant within standard error

2. (a) Does exposure to high school physics enhance students' critical thinking and prepare them academically for first year of university physics?

There appears to be a lack of consensus between teachers and students as to the challenge offered by high school physics (Table 4.32a). While 58.1% of teachers agreed that high school physics challenges the academically gifted students, there was no significant response by students. This discrepancy may result from the different vantage points from which each group view high school physics. High school teachers teach more students than just the university bound, so they may perceive the high school physics curriculum as challenging. Students, however, may have responded to this question with reference to their own academic ability.

Table 4.32a: High school physics prepares students for Memorial University

High school physics ...	N	Agree (%)	Undecided (%)	Disagree (%)
Challenges the academically gifted:				
Physics Teacher	93	**58.1**	24.7	17.2
Academically challenging:				
Student	62	29.0	32.3	38.7
Academically prepares students:				
Physics Teacher	93	**61.3**	22.6	16.1
Students	62	30.6	37.1	32.3
Broadens concept understanding:				
Physics Teacher	96	**72.9**	19.8	7.3
Helps develop critical thinking skills:				
Student	61	39.3	29.5	31.1
Physics Teacher	96	**74.0**	18.8	7.3
Prepares for the work load for university:				
Student	62	9.7	24.2	**66.1**
Physics Teacher	93	**49.5**	22.6	28.0

Confidence Level @ 95%
Bold results are statistically significant within standard error

Table 4.32a indicates a conflict between the perceptions of high school physics teachers and students surveyed as to the challenge of the current high school physics program. A majority of teachers (61.2%) perceived that high school physics challenged students, while only 49.5% believed that high school physics prepared students for studies in university physics. However, only 29.0% of the responding students thought that the high school physics program was challenging, with just 9.7% believing that high school physics prepared them for the subsequent workload in university physics. However, university bound physics students consist of the "average" and the more able students These students may have found the high school physics program unchallenging. Considering the diversity in their academic abilities and the varieties of challenge related to high school physics, the students' lack of consensus on the question related to challenge offered by high school physics is explainable.

In the previous section, teachers and students perceived that enrollment in AP physics would provide intrinsic rewards for students. However, teachers and students were in disagreement as to the intrinsic rewards, if any, of high school physics. A significant number of teachers believed that high school physics broadened concept understanding (72.9%) and helped students to develop critical thinking skills (74%). Meanwhile, 66.1% of students did not believe that high school physics had prepared them for university. In contrast, 49.5% of teachers indicated that high school physics did prepare students for university.

These results must be considered from the individual group perspectives since high schools and universities have differing expectations for students. Although high school is a prerequisite for acceptance to university, its primary mandate is to provide a well-rounded education for all its students and not to provide university preparation courses. Consequently, the much greater workload and independence related to university study is characteristic of a university education.. On the other hand, teachers are far removed from the university environment. Table 4.32c indicates that a majority of teachers have little physics background; less than eight courses (58.4%). Moreover, a number of teachers in their free responses indicated that they have not done any physics since graduation from university. Consequently, these teachers may have some uncertainty as to the degree to which high school physics prepares students for university. Nonetheless, liaisons between high schools and universities as well as teacher in-service and training could alleviate this problem.

2. (b) Does exposure to AP physics enhance students' critical thinking and prepare them academically for first year of university physics?

There is an unanimous acceptance amongst AP physics teachers and a large percentage of AP students that AP physics is an equivalent to first year university physics in its academic challenge, concept development, and stimulation of thinking skills (Table 4.32b). Even though AP physics teachers (100%) and Physics 1200 AP students (80.0%) believe that AP physics prepares students for the workload of first year physics at Memorial University, there was no significant agreement amongst AP students in Physics 1050.

AP physics has the potential to provide adequate preparation for first year of university physics. Moreover, there is strong evidence that AP students may not need to enroll in first year university physics. However, the AP physics program may be at a disadvantage because it is taught within the confines of a high school system. Within the high school system students may have more direct contact with their teacher than they would in a university course. Secondly, high school students typically have eight or nine courses on their schedule, whereas they have a maximum of five courses during their first year of university studies. Third, the work load and scheduling of high school teachers do not allow them the additional time for lab and assignment preparation. Furthermore, there are no weekly, three hour lab periods, or lab instructors to handle the additional expectations of this demanding course. Finally, since most teachers are teaching at least six courses, little time may be available for the in-depth preparation required for an AP course. The end result may be a course that covers the theory content of first year of university physics, but can legitimately duplicate neither the workload nor the lab component.

Table 4.32b: AP physics prepares students for Memorial University

	N	Agree (%)	Undecided (%)	Disagree (%)
Challenges the academically gifted:				
AP Teacher	5	100.0	0.0	0.0
Academically prepares students:				
AP Student	9	55.6	33.3	11.1
AP Teacher	5	100.0	0.0	0.0
Broadens concept understanding:				
AP Student	9	77.8	11.1	11.1
AP Teacher	5	100.0	0.0	0.0
Enhances concept understanding:				
AP Student	9	55.6	33.3	11.1
AP Teacher	5	100.0	0.0	0.0
Helps develop critical thinking skills:				
AP Student	9	66.7	11.1	22.2
AP Teacher	5	100.0	0.0	0.0
Prepares students for the work load:				
AP Student	9	22.2	44.4	33.3
(enrolled in Physics 1050)	(4)	(25.0)	(50.0)	(25.0)
(enrolled in Physics 1200)	(5)	**(80.0)**	(20.0)	(0.0)
AP Teacher	5	100.0	0.0	0.0

Confidence Level @ 95%

Bold results are statistically significant within standard error

( ) results of AP students divided according to enrollment in either Physics 1050 or Physics 1200

2. (c) Is there a need for AP physics and if so, would you recommend this course to students who plan to pursue physics beyond high school.

According to Table 4.32c, a large majority of students (85.5%) and teachers (57.0%) indicated a need for AP physics in high school. Correspondingly, 85.5% of the students and all AP teachers said they would recommend AP physics to students planning to pursue physics beyond high school. These responses may be indicative of the perceived need to challenge academically gifted students that are unchallenged by the current high school curriculum.

Table 4.32c: The need for AP physics in high school

	N	Agree (%)	Undecided (%)	Disagree (%)
There is a need for AP physics in HS:				
Student	62	**85.5**	11.3	3.2
Teacher	93	**57.0**	22.6	20.4
I would recommend AP to students:				
Student	62	**85.5**	6.5	8.1
AP Teacher	4	**100.0**	0.0	0.0

Confidence Level @ 95%
Bold results are statistically significant within standard error

3. (a) How does the content, concept depth, difficulty level, workload, and lab work of first year of university physics compare with HS physics?

There was significant agreement amongst all students and teachers that the course difficulty level, depth, and workload of first year physics at Memorial University were greater than that of high school physics (Table 4.33a). This is not unexpected considering the level of independence and depth of material characteristic of university study.

Table 4.33a: Course content, difficulty level, & workload of first year Memorial University physics vs. HS physics

	N	More than (%)	Equal to (%)	Less Than (%)
Difficulty level:				
Student	63	**96.8**	3.2	1.6
Physics Teacher	90	**96.7**	2.2	1.1
Depth of material & concepts:				
Student	63	**95.2**	3.2	1.6
Physics Teacher	86	**96.5**	2.3	1.2
Content & number of topics:				
Student	62	**66.1**	27.4	6.5
Physics Teacher	45	37.8	**55.6**	6.7
Work load:				
Student	63	**95.2**	4.8	0.0
Physics Teacher	88	**90.9**	8.0	1.1
Amount of lab work:				
Student	63	**95.2**	3.2	1.6
Physics Teacher	84	**82.1**	16.7	1.2

Confidence Level @ 95%
Bold results are statistically significant within standard error

Even though all physics students indicated that the course content and number of topics covered in their first year of university physics was more than they had covered in high school, agreement was not unanimous amongst teachers. A majority of physics teachers (55.6%) indicated that the course content and number of topics in first year university physics were equal to that of high school physics. This point may illustrate the lack of familiarity that many physics teachers have with first year of university physics as previously discussed in section 2(a). Second, while there is an attempt by the high school physics curriculum to cover a broad range of topics, the coverage is more general in nature. In addition, these topics in high school often exclude important concepts such as buoyancy, circular motion, and projectile motion.

3. (b) How do the content, concept depth, difficulty level, workload, and lab work of first year Memorial University physics compare with AP physics?

In comparing first year of physics at Memorial University to AP physics (Table 4.33b), a significant number of students indicated that the difficulty level (88.9%), and the depth of material & concepts (87.5%) was greater than in their AP physics course. However, a significant number of AP teachers (60%) claimed that the difficulty level and depth of the material & concepts (80%) were equal. The teachers' perceptions may arise from the fact that the AP courses are promoted by the College Board as being equivalent to university courses. A quick comparison of the syllabus of each course in Appendix E illustrates that AP physics has a broader range of topics. Since all universities do not have the same core curriculum, AP attempts to ensure that its students will have covered the core requirements of most university's first year physics course.

With respect to workload and lab work, AP students unanimously agree that it is greater in first year physics courses at Memorial University than in AP physics. The response of AP students may be considered accurate considering they had completed both levels of physics. On the other hand, 60.0% of the AP teachers believe that AP and university courses are equivalent in their work loads. The AP teachers' response may derive from the fact that the College Board promotes its courses as being equivalent to university courses.

Table 4.33b: Course content, difficulty level, & workload of first year Memorial University physics vs. AP physics

	N	More than (%)	Equal to (%)	Less than (%)
Difficulty level:				
AP Student	9	**88.9**	11.1	0.0
AP Teacher	5	40.0	**60.0**	0.0
Depth of material & concepts:				
AP Student	8	**87.5**	12.5	0.0
AP Teacher	5	20.0	**80.0**	0.0
Content & number of topics:				
AP Student	8	37.5	37.5	25.0
AP Teacher	5	40.0	40.0	20.0
Work load:				
AP Student	9	**100.0**	0.0	0.0
AP Teacher	5	40.0	**60.0**	0.0
Amount of lab work:				
AP Student	8	**100.0**	0.0	0.0
AP Teacher	5	**80.0**	20.0	0.0

Confidence Level @ 95%
Bold results are statistically significant within standard error

3. (c) How do the content, concept depth, difficulty level, workload, and lab work of AP physics compare with HS physics?

AP teachers and AP students unanimously agreed that the difficulty level, and the depth of material and concepts of AP physics was greater than high school physics (Table 4.33c). Although there was very high agreement that the content and work load were greater for AP physics, there was no consensus on lab work comparisons. Since there is no core lab requirement for AP physics there may exist a wide variation in the depth and coverage of lab work amongst AP physics schools. Hence, there would be little to be gained in comparing the number of prescribed labs in high school physics and the lack of a required lab component in AP physics.

Table 4.33c: Course content, difficulty level, & workload of AP physics vs. HS physics

	N	More than (%)	Equal to (%)	Less than (%)
Difficulty level:				
AP Student	9	**100.0**	0.0	0.0
AP Teacher	5	**100.0**	0.0	0.0
Depth of material & concepts:				
AP Student	8	**100.0**	0.0	0.0
AP Teacher	5	**100.0**	0.0	0.0
Content & number of topics:				
AP Student	8	**62.5**	37.5	0.0
AP Teacher	5	**100.0**	0.0	0.0
Work load:				
AP Student	9	**77.8**	11.1	11.1
AP Teacher	5	**80.0**	20.0	0.0
Amount of lab work:				
AP Student	8	12.5	50.0	37.5
AP Teacher	4	50.0	0.0	50.0

Confidence Level @ 95%
Bold results are statistically significant within standard error

4. (a) How much effort do students place in their physics?

One premise of this study suggests that differences existed between high school and first year university physics. The results in Table 4.34a support this premise with a majority of students (90.5%) and a large percentage of physics teachers (78.8%) agreeing that students expend more effort in their first year of physics at Memorial University than they did in their high school physics. With respect to AP students, all but one admitted to placing more effort in first year of university physics than they had in AP physics

Given the larger workload associated with AP physics, it is not surprising that AP students and their teachers agree that there is more student effort placed in AP than in high school physics (Table 4.34a). However, there is a large discrepancy between the percentage who agree. Although all AP teachers agreed with this statement, only 55.6% of the students concurred. The unanimous AP teacher response may be a perception based on the required workload, whereas the student response is a reflection of their actual effort.

Table 4.34a: Student Effort

Students' effort in ...	N	More than (%)	Equal to (%)	Less than (%)
AP compared to HS physics:				
AP Student (Physics 1050)	4	50.0	50.0	0.0
AP Student (Physics 1200)	5	60.0	20.0	20.0
AP Teacher	5	**100.0**	0.0	0.0
MUN compared to HS physics:				
Student	63	**90.5**	7.9	1.6
Teacher	85	**78.8**	16.5	4.7
MUN compared to AP physics:				
AP Student (Physics 1050)	4	**100.0**	0.0	11.1
AP Student (Physics 1200)	5	**80.0**	20.0	0.0

Confidence Level @ 95%
HS = high school
MUN = Memorial University
Bold results are statistically significant within standard error

4. (b) How much time do students spend studying and/or working at their physics?

Consistent with their effort, students spend more time working with their physics courses in first year of physics at Memorial University than they had in their high school physics (Table 4.34b). With respect to high school, 45.2 % of the students admitted they had spent less than one hour each week working at their physics. However, when enrolled in first year physics at Memorial University, they had to spend considerably more time.

All but one AP student and 69.8% of the non-AP students indicated they had to spend more than three hours each week studying and working on their physics.

The greater amount of effort and time students spend working at and studying physics in university further verify the greater expectations of first year university physics as compared to high school. Although AP physics is theoretically an equivalent to a first year university physics course, Physics 1200 at Memorial University required a greater effort. This difference may be attributed to the nature of the courses, as discussed in section 2(b). Furthermore, AP students have their course spread over an eight month period from September until May when they write the AP College Board exam. In contrast, the physics courses at Memorial university are comprised of two, thirteen week instructional semesters. Consequently, Memorial University physics students have less time to acquire concepts than AP students in high school.

Table 4.34b: Average time per week studying or working at physics

	N	<1 (%)	1-2 (%)	2-3 (%)	3-4 (%)	>4 (%)
High school physics:						
Student	62	**45.2**	17.7	17.7	12.9	6.5
AP Student	9	44.4	11.1	22.2	22.2	0.0
HS Teacher	88	38.6	28.4	14.8	13.6	4.5
AP physics						
AP Student	9	33.3	11.1	22.2	22.2	11.1
AP Teacher	5	0.0	20.0	0.0	**60.0**	20.0
Memorial University physics						
AP student (Physics 1050)	4	0.0	25.0	0.0	50.0	25.0
AP student (Physics 1200)	5	0.0	0.0	0.0	**60.0**	40.0
non-AP Student	63	3.2	7.9	19.0	34.9	34.9

Confidence Level @ 95%
HS ≡ high school
Bold results are statistically significant within standard error

4. (c) Do AP students take their first year of university physics for granted?

Given the possibility that AP physics may not enhance student results in first year of university physics, all groups were asked if AP students take their first year of physics at Memorial University for granted. This is a hypothetical question for teachers because they may not actually know their students true intentions with respect to their physics course. The results from the AP students were unexpected, yet helped to clarify why Hypothesis One was rejected for Physics 1200 students. Seventy-five percent of the Physics 1050 students indicated they had not taken their first year of Memorial University physics for granted, while only 20.0% of the Physics 1200 students admitted the same.

Table 4.34c: AP students take first year of physics at Memorial University for granted.

	N	Agree (%)	Undecided (%)	Disagree (%)
AP Student (Physics 1050)	4	25.0	0.0	**75.0**
AP Student (Physics 1200)	5	40.0	40.0	20.0
AP Teacher	3	33.3	33.3	33.3

Confidence Level @ 95%
Bold results are statistically significant within standard error

Also relevant to explaining the rejection of Hypothesis One by the Physics 1200 data is the students' response to whether AP physics prepared them academically for first year of physics at Memorial University. Table 4.32b revealed that only a slight majority of AP students felt that AP physics had prepared them for university physics. In this grouping, 25.0% of the Physics 1050 students felt that AP physics did not prepare them for first year of physics at Memorial University, while 50.0% were undecided.

Conversely, 80.0% of the Physics 1200 students indicated that AP physics had prepared them academically. Because the Physics 1200 students felt prepared for their first year physics course at Memorial University, they may have taken the course for granted. By assuming they did not have to work at their university physics, their subsequent course grade may have been lower.

These results call into question the validity of students' assessment of AP as being preparatory for first year of university physics. Physics 1050 students did not perceive AP physics as preparing them academically for the challenge of first year of university physics. In contrast, Physics 1200 students did. The content of Physics 1200 may appear to students as being a replication of material covered in AP physics, thus perceiving little or no challenge. What may be evident from the data is that students equate course preparedness with a course that offered them no challenge and less learning.

5. *How does class size affect learning in first year of university physics?*

A common descriptor of university classes is "overcrowded." However, does this adjective describe the physical nature of the class, or a psychological deterrent to learning? Both questions were asked to students and the results are outlined in Tables 4.45a and 4.45b respectively. A majority of students (58.1%) had indicated that their average high school physics class had a student population between 21 to 30 students (Table 4.35a). In contrast, 71.9% of the respondents indicate that their first year physics course at Memorial University exceeded 30 students. AP physics classes on average have less than 20 students. When asked if the larger class sizes affected student learning, 61.3% of responding students said it did not (Table 4.35b). Even though class sizes are larger in first year university physics, it does not appear to be perceived as a factor inhibiting student learning.

Table 4.35a: Student indication of physics' class sizes

Class Size	N	1-10	11-20	21-30 (%)	31-40 (%)	41-50 (%)	>50 (%)
High school	62	8.1	12.9	**58.1**	16.1	4.8	0.0
AP	9	44.4	55.5	0.0	0.0	0.0	0.0
Memorial University	64	0.0	7.8	20.3	**34.4**	9.4	28.1

Confidence Level @ 95%
Bold results are statistically significant within standard error

Table 4.35b: Does class size affect student learning?

	N	Agree (%)	Undecided (%)	Disagree (%)
Student	62	12.9	25.8	**61.3**
Teacher	87	41.1	34.5	24.1

Confidence Level @ 95%
Bold results are statistically significant within standard error

6. What high school courses and grades should be prerequisite for enrollment in AP physics?

As with many university courses, AP courses should also have prerequisite requirements. Even though Advanced Placement programs are governed by the College Board and approved by the Department of Education and Training, it is the decision of individual schools to insist upon any course prerequisites. First, 100.0% of AP teachers and 66.7% of AP students who responded to this question suggested that students should have high school Physics 3204 completed before enrolling in AP physics (Table 4.36a). Of the responding teachers 75.0% suggested AP candidates should have at least a grade of 80% in Physics 3204 to be eligible for AP physics (Table 4.36b). Most students (66.7.0%) on the other hand, thought a minimum grade 70% would be sufficient as a cut off grade for AP physics candidates.

Table 4.36a: Physics 3204 should be prerequisite for AP physics

	N	Agree (%)	Undecided (%)	Disagree (%)
AP Student	9	**66.7**	22.2	11.1
AP Teacher	4	**100.0**	0.0	0.0

Confidence Level @ 95%
Bold results are statistically significant within standard error

Table 4.36b: Physics 3204 grade prerequisite for AP physics

	N	>50 (%)	>60 (%)	>70 (%)	>80 (%)	>90 (%)
AP Student	9	0.0	0.0	**66.7**	22.2	11.1
AP Teacher	4	0.0	0.0	25.0	**75.0**	0.0

Confidence Level @ 95%
Bold results are statistically significant within standard error

Amongst the groups surveyed, there was no consensus as to the minimum mathematics prerequisite for AP physics candidates (Table 4.36c). AP students (77.8%) thought that a completed level II advanced mathematics would be sufficient, while AP teachers were evenly split between having level III advanced mathematics completed and concurrently doing AP mathematics. The AP mathematics option is similar to that of Physics 1200 at Memorial University in which students must have completed or are concurrently doing introductory calculus.

Table 4.36c: Mathematics prerequisite for AP physics

	N	Acd II complete (%)	Acd III complete (%)	Adv II complete (%)	Adv III complete (%)	AP Math (%)
AP Student	9	0.0	0.0	**77.8**	22.2	0.0
AP Teacher	4	0.0	0.0	0.0	50.0	50.0

Confidence Level @ 95%
Acd ≡ academic mathematics
Adv ≡ advanced mathematics
II, III ≡ Level II, and Level III respectively
Bold results are statistically significant within standard error

If schools were to implement prerequisite requirements in a similar manner to Memorial University, then students would be required to concurrently enroll in AP calculus with their AP Physics. The students' mathematics background as indicated in Tables 4.14 and 4.24 was a predominant factor in predicting student success in first year of university physics. Correspondingly, mathematics is essential to the AP program because many of its concepts require an in-depth mathematical treatment. Commonly, physics teachers have to take a considerable amount of time to cover mathematics concepts essential to the understanding of physics. This practice also exists in high school 2204 and 3204 physics, though not as pronounced in AP physics.

The above results do not provide this research with conclusive evidence as to exact prerequisite requirements for AP physics. However, the results do provide insight into teachers' and students' perceptions of what these requirements should be. Of the two groups, the teachers' responses may be more indicative of any prerequisites that would ensure success in AP physics, both conceptually and academically. Before enrolling in AP physics, it would be advantageous for students to have a command of basic skills in physics and mathematics. These skills may be acquired by completing Physics 3204 and Advanced Mathematics 3201 as prerequisites to AP physics. Although no minimum grade requirements can be derived from the data, it would not be naive to suggest that students be required to have an "A" grade in Physics 3204 and Advanced Mathematics 3201.

7. ***Should lab work be an essential component to high school and AP physics?***

Lab work is an important component to any science program. Presently the high school physics curriculum requires the completion of core lab exercises. Of the responding teachers, 89.6% agree that lab work is an essential part of high school physics (Table 4.37a). However, no definite agreement exists amongst AP physics teachers as to the essentialness of a lab component to the AP program.

While the content of the AP physics program includes all topics found in a first year of university physics course, there is no laboratory requirement. Furthermore, teachers do not have the time and resources to implement a lab component equivalent to that of a university. If the AP physics program is to be truly equivalent to a first year university physics program, then an equal emphasis should be placed on the laboratory exercises. However, AP physics students (89.6%) agree that labs should be an essential component to an AP program (Table 4.37a). Despite their consideration that labs are essential, 66.7% of physics teachers suggested that labs should not exceed 10% of class time; 75.0% of AP physics teachers agreed.

Table 4.37a: Laboratory work is essential to AP physics.

	N	Agree (%)	Undecided (%)	Disagree (%)
AP Student (in AP)	9	**66.7**	33.3	0.0
AP Teacher (in AP)	4	50.0	50.0	0.0
HS Teacher (in HS)	96	**89.6**	5.2	5.2

Confidence Level @ 95%
Bold results are statistically significant within standard error

Table 4.37b: Laboratory time allocations.

	N	5 (%)	10 (%)	15 (%)	20 (%)	>20 (%)
HS teacher (in HS)	96	31.3	35.4	20.8	11.5	1.0
AP teacher (in AP)	4	50.0	25.0	0.0	25.0	0.0

Confidence Level @ 95%
HS = high school
Bold results are statistically significant within standard error

Often teachers may not be aware that many concepts in physics can be more effectively taught in a lab environment. As one student responded on the survey, "labs help to demonstrate the principles we learn so that they can make more sense" (Appendix

D). Teacher's reluctance to utilize more lab time may derive from their adaptation to working in substandard lab facilities or no laboratory facilities at all.

8. *Do high schools have the resources and personnel to offer high school physics and/or AP physics?*

When the new high school physics curriculum was implemented in 1991-1992, the Department of Education and Training did not assist with the purchase of new lab equipment. Moreover, there are schools in the province that have inadequate, even non-existent lab facilities. Only a minority of high school physics teachers (45.8%) agreed that their schools were equipped to offer physics (Table 4.38a). In terms of AP physics, 77.8% of responding physics professors felt that most high schools are not equipped to offer AP physics. This response was consistent with that of high school teachers. Often high schools only have enough resources to equip their labs for the required core labs. If only a minority of schools (45.8%) are equipped to offer high school physics, it may be assumed that the number of schools capable of offering AP physics is much lower. Only half of the responding AP teachers in the survey said that their schools are equipped to offer AP physics.

In terms of instruction, a majority of physics students who responded felt that the level of instruction they had received from their high school physics teacher was adequate. Fifty percent of the AP students concurred with this response, indicating that instruction received from their AP teachers was adequate (Table 4.38b). Similarly, 75% of AP physics teachers felt that their level of instruction was adequate.

Table 4.38a: High schools are physically equipped to offer physics.

	N	Agree (%)	Undecided (%)	Disagree (%)
HS teacher for high school physics	96	**45.8**	26.0	28.1
Students for high school physics	62	29.0	16.1	**54.8**
AP teacher for AP physics	4	50.0	25.0	25.0
AP Student for AP physics	9	22.2	22.2	**55.6**

Confidence Level @ 95%
HS ≡ high school
Bold results are statistically significant within standard error

Table 4.38b: Physics instruction was adequate.

	N	Agree (%)	Undecided (%)	Disagree (%)
Student (my HS physics teacher)	62	**53.2**	22.6	24.2
AP student (my AP physics teacher)	9	**55.6**	33.3	11.1
AP teacher (personally in AP physics)	4	75.0	25.0	0.0

Confidence Level @ 95%
HS ≡ high school
Bold results are statistically significant within standard error

9. What academic qualifications should teachers be required to have before teaching high school physics and/or AP physics?

A good teacher is not necessarily qualified on the merit of the number of credits they may have attained in a given subject area. However, it is essential for a teacher to have considerable knowledge and understanding of the subject areas in which they teach. According to Table 4.39a, most all physics teachers said they are comfortable (92.7%) teaching at the level required for the high school Physics 3204 course, and feel their background in physics is sufficient (84.4%). In terms of academic qualifications, 46.7% of the physics teachers (Table 4.39b) stated that high school physics teachers should have a minimum of a physics major. While 41.6% of the responding physics teachers stated that they had at least a minor in physics, 36.5% of physics teachers indicated they had between four and eight university physics courses (Table 4.39c).

Of the AP physics teachers who responded, 47.9% felt their physics background is sufficient to teach AP physics (Table 4.39a). Seventy-five percent of the responding AP teachers said they were comfortable teaching at that level required for AP physics. In addition, teachers appear to gain intrinsic rewards from teaching AP physics. All responding AP teachers said they that through teaching AP physics they had become more knowledgeable about physics, while 75.0% indicated that it made them a more effective teacher. In terms of qualifications, 60% of the AP physics teachers indicated that AP physics teachers should have at least a major in physics. Of the AP teachers, only 40% had a physics major.

Table 4.39a: Teachers' perspectives on teaching physics:

	N	Agree (%)	Undecided (%)	Disagree (%)
Comfortable teaching HS physics	96	**92.7**	2.1	5.2
Physics background sufficient for HS	96	**84.4**	8.3	7.3
Physics background sufficient for AP	94	**47.9**	21.3	30.9
Physics background sufficient for AP	4	**100.0**	0.0	0.0
Comfortable teaching AP physics	4	75.0	0.0	25.0
Have become more knowledgeable through teaching AP physics	4	**100.0**	0.0	0.0
Have become more effective teacher through teaching AP physics	4	**75.0**	25.0	0.0

Confidence Level @ 95%
HS = high school
Bold results are statistically significant within standard error

Table 4.39b: Sufficient minimum physics background for a physics teacher.

	N	<4 (%)	4<8 (%)	minor (%)	major (%)	masters (%)
Teacher (in HS)	92	15.2	27.2	**46.7**	9.8	1.1
Professor (in HS)	15	0.0	7.1	42.9	**72.9**	7.1
AP Teacher (in AP)	5	20.0	0.0	20.0	40.0	20.0

Confidence Level @ 95%
HS ≡ high school
Bold results are statistically significant within standard error

Table 4.39c: Physics backgrounds of high school Physics 3204 & AP Teachers

	N	<4 (%)	4<8 (%)	minor (%)	major (%)	masters (%)
HS physics	96	21.9	**36.5**	20.8	17.7	3.1
AP physics	5	0.0	20.0	20.0	40.0	20.0

Confidence Level @ 95%
HS ≡ high school
Bold results are statistically significant within standard error

Table 4.39d: Average weekly teacher preparation time for physics

	N	<1 hr (%)	1-2 hr (%)	2-3 hr (%)	3-4 hr (%)	>4 hr. (%)
HS Physics 3204	94	7.4	31.9	28.7	16.0	16.4
AP physics	5	0.0	0.0	20.0	0.0	**80.0**

Confidence Level @ 95%
HS ≡ high school
Bold results are statistically significant within standard error

In the free response section of the surveys, one teacher commented that "many teachers with limited numbers of courses in a subject area spend more time in seeing the material is presented in an understandable fashion" (Appendix D). According to the results in Table 4.39c a majority (58.4%) of physics teachers stated they have less than 8 university physics courses. Ideally, personal research and preparation time may compensate for the limited physics background, but the findings in Table 4.39d are contradictory. The largest percentage of teachers, 31.9% and 28.7% respectively, spends between one to three hours per week on physics. Over time, the amount of preparation time may decrease, but if the assumption is correct, the majority of teachers should be spending more than one to three hours per week on preparation and research. On the other hand, 80% of AP teachers said they spend in excess of four hours per week in preparation for their AP classes. This additional preparation time for AP physics may have resulted from several factors that include a greater level of preparation required, a greater course difficulty, a greater interest and dedication of the course.

10. What role should the university have in AP physics?

If teachers are to have a better understanding of first year of university courses, and professors a better understanding of high school courses, then there has to be greater communication between high schools and the university. Since physics teachers, and AP teachers in particular may not be aware of the university's expectations, AP students and their teachers were asked if the Memorial University should provide schools with a first year physics syllabus which may be used in their AP courses. All responding AP teachers and 87.5% of the AP students indicated that Memorial University should provide the AP syllabus (Table 4.30). It should be noted however, that the College Board while not providing a specific syllabus for AP physics does compile a comprehensive list of topics which AP teachers are encouraged to follow in preparation for the College Board examinations. While using the first year physics syllabus from Memorial University may aid students entering Memorial University, that syllabus may not be the same for other universities.

Another area in which the university may become involved in AP physics is through training and upgrading. Amongst all responding physics teachers, 88.4% said that the university in conjunction with the Department of Education and Training should offer seminars to prepare AP teachers (Table 4.30) to teach AP physics. AP and non-AP teachers have indicated a need for greater cooperation between the university and the high schools.

Table 4.30: University's role in AP physics.

Memorial University ...	N	Agree (%)	Undecided (%)	Disagree (%)
Should provide the AP syllabus:				
AP Student	8	**87.5**	0.0	12.5
AP Teacher	4	**100.0**	0.0	0.0
Should administer entrance exams to determine advance credit:				
Student	9	**55.6**	11.1	33.3
Teacher	4	25.0	25.0	50.0
Memorial University & the Dept. of Education and Training should offer seminars to prepare AP teachers:				
Teacher	95	**88.4**	2.1	9.5

Confidence Level @ 95%
Bold results are statistically significant within standard error

Discussion of Results

Beyond the quantitative data in the first two sections of this chapter, the opinions and perspectives of students and teachers may help to clarify the relationship between high school, Advanced Placement, and first year of university physics. Since the university and high schools function as two separate entities, teachers' perceptions of Memorial University's current physics program may have been skewed. Therefore, any uncertainties as to the relationship between the physics programs in high school and the university would possibly be clarified through student responses. Students have current and direct knowledge of both levels of physics.

Although high school is a prerequisite for acceptance to university, not all high school teachers view the high school program in that role. Some view the high school's primary mandate as providing a well-rounded education for all students. When teaching, complexity of concepts, depth of material, level of instruction, instructional time, and quantity of extracurricular work must be considered relative to the abilities and needs of all students. In addition, teacher work load and scheduling do not always permit time for meaningful laboratory preparation, demonstrations, and assignments. A number of students indicated that they had completed their high school physics course in schools with substandard laboratory equipment, or no labs at all. Consequently, the greater workloads, compulsory laboratory activities, and the required independent study characteristic of a university education may seem foreign to these students.

Despite the perceived inadequacies of the high school system, most comments are primarily in response to inadequacies of the high school curriculum and its facilities. Level of instruction in high school Physics 3204 and AP physics were deemed adequate by most students. Most teachers agreed, indicating that their physics background was adequate to teach high school physics.

The majority of teachers have less than eight courses in physics and a number of teachers have not had any liaison with the university since prior to their convocation. For some, it has been over twenty years. Consequently, many teachers are far removed from the university environment, and are not certain of Memorial University's expectations for students. In such situations, teachers would benefit from conjoint efforts by the Department of Education and Training and Memorial University's Department of Physics to implement seminars or Physics Institutes. Even though the survey asked if such a program should be established for AP physics teachers, the overwhelming response from all teachers may be more indicative of need for the training and upgrading of all high school physics teachers.

There is a common perception, though not amongst a majority of teachers that high school physics leaves students ill-prepared for university study. AP, on the other hand, is thought to achieve that task. AP physics offers students intrinsic rewards such as providing an academic challenge, knowledge acquisition, and a refinement of critical thinking skills, in essence supporting Hypothesis Three. Although the academic level of AP physics is much greater than high school physics, it is still not perceived as an equivalent, nor a substitute for first year physics at Memorial University. Additionally, students exert a greater effort in their first year of physics at Memorial University than in AP physics, but this may be more attributable to the nature of the AP course, as described in Chapter Two.

Since Memorial University may give advance physics credit for AP physics, the university may have some role in its promotion and maintenance. Such a role would include assisting the Department of Education and Training with teacher training and preparation. In addition, teachers and students thought that Memorial University should provide the syllabus for AP physics, although it was not clear in what manner this syllabus would be used. Since Memorial University's syllabus may differ from other universities, teachers would best find its use as a reference guide.

Though not explicitly stated, several suggestions as to prerequisites for AP physics may be made with reference to the results of the regression analysis, Memorial University prerequisites, and survey responses. Students should have a broad understanding of physics concepts and have a command of the mathematics skills required for AP physics. In which case, it may be suggested that students should have completed Physics 3204 and Advanced Mathematics 3201 before enrolling in AP physics. Preferable, but not supported by evidence in this research, "A" grades in both courses would be ideal. Concurrent enrollment in AP mathematics would further benefit students. If students were to have their advanced mathematics completed before level III, they would either have to start level I advanced mathematics in grade nine or semesterize their high school mathematics courses. Considering the in-depth mathematical treatment of many AP physics concepts, it is essential that students have a strong mathematics background. If not, teachers have to use valuable course time teaching the required mathematics concepts. While not as prevalent, this practice also exists in physics 2204 and Physics 3204.

One of the major problems of the AP program appears to be its lack of required laboratory exercises and the subsequent lack of consensus amongst AP teachers as to whether the laboratory component is essential. If the AP program is to be considered by students and university professors an equivalent to first year university physics, then an equal emphasis should also be placed on laboratory exercises. To obtain university credit in physics via the AP physics, a student has to score a minimum of three of five possible points on the final College Board physics exam. Meanwhile, first year physics students at Memorial University must not only pass their course, but they must also have a passing grade in their laboratory assignments.

If such requirements were implemented, many schools would not be able to offer AP physics. In addition to the time restraints and scheduling, few schools have the resources to fulfill the lab requirements. Therefore, the possibility of schools having the capabilities to offer AP physics is much lower. Nonetheless, all groups surveyed do indicate a need for AP physics, and indeed more AP courses. AP physics has the potential to be entirely equivalent to a first year university physics course, but it is confined by its administration in a high school environment. Consequently, the course may cover the theory content of first year university physics, but cannot legitimately duplicate the workload, nor the lab component. AP physics falls amongst the gray area that exists between high school and university physics, with expectations slightly behind Memorial University's algebra based, Physics 1200.

Chapter Summary

This chapter sought to test the three hypotheses statements formulated in Chapter Two. Hypothesis One was rejected for the data analyzed from Physics 1200. Through the application of a single factor ANOVA no significant difference was determined to exist between AP and non-AP students enrolled in Physics 1200. Conversely, Hypothesis One was verified for the data collected from Physics 1050. The results of a single factor ANOVA indicated that a significant difference did exist between AP and non-AP students enrolled in Physics 1200. A regression analysis determined that major source of variance for this result was student enrollment in AP physics. Enrollment in AP physics resulted in a subsequent increase of approximately 12% towards the final grade of Physics 1050. Advanced mathematics and chemistry were also determined to be important factors contributing to student success in Physics 1050 and in Physics 1200.

The rejection of Hypothesis One for AP students enrolled in Physics received partial clarification through the analysis of the survey responses. It appears that student motivation and work ethic plays an important role in student success in university. Students generally exert a greater effort in their first year of physics at Memorial

University than in AP physics. This was more apparent for students in Physics 1050 than in Physics 1200. Since AP students in Physics 1200 appeared to take their course for granted, it was inferred that they did not place an effort required for success. Consequently, the exposure to AP physics did not aid students enrolled in Physics 1200.

Hypothesis Two was veritied when the result of a single factor ANOVA revealed that no significant difference existed between AP and non-AP students enrolled in Physics 2050. This result validates the advanced credit AP students receive which allow them to advance to the second year physics course, Physics 2050, at Memorial University.

From the responses provided, Hypothesis Three was partially accepted. AP physics offers students intrinsic rewards such as providing an academic challenge, knowledge acquisition, and a refinement of critical thinking skills. However, the academic level of AP physics is not perceived as an equivalent, nor a substitute for Physics 1200 and Physics 1201 at Memorial University. Many schools do not have the scheduling capacity, facilities, or resources to offer a truly equivalent first year university program. In essence, AP physics does provide the challenge for academically gifted students that the current high school physics program lacks.

Chapter Five

Recommendations & Conclusion

Introductory Statement

This thesis sought out to determine *if students who complete an AP high school physics course will be more successful in university physics than students who do not take an AP physics course.* Through statistical measures and an analysis of teacher and student perceptions of AP physics, this hypothesis was partially supported. This conclusion was reached through a comprehensive analysis of the three basic hypotheses presented in chapter two. The following discussion provides a synopsis of the conclusions drawn from each research question and how the central hypothesis was supported.

Discussion

The introduction of Advanced Placement programs to this province appears to be an option through which academically gifted students can be challenged and also prepare them for university studies. While there is an agreement amongst students and teachers of a need for AP physics, there is concern over the ability of high schools to offer a course that is a theoretical academic equivalent to the first year university physics. There is an additional concern toward the distribution of resources, including time and money, to programs designed to meet the needs of a minority of academically gifted students.

The literature review of Chapter Two discussed several theoretical methods through which academically gifted students could be challenged and gain high levels of competence. The most prominent was the social context of leaning; suggesting that ability grouping encourages students with similar thinking mechanisms to challenge one another, look to others for clarification, provides peer support, and allows all students to work at a similar pace. Any programs designed for gifted physics students appear to be of concern that it may be viewed as promoting streaming to all levels within the school curriculum. However, the addition of a single physics course to the current high school curriculum does not imply the necessity of streaming at all levels.

Homogeneous grouping as it exists in the current high school curriculum can provide students with a broad conceptual understanding of physics, fundamentally achieving the goal of "physics for all." Despite this, a broadly based physics curriculum may lack the depth and challenge which academically gifted students require. Therefore, gifted physics students may have to seek challenge through alternate programs. Such programs may include a third level of physics designed for gifted physics students and those who intend on pursuing physics beyond high school. As such, Physics 2204 and Physics 3204 could provide a broad conceptual base and the procedural knowledge gifted students require if they are to enroll in subsequent courses offering depth, challenge, and enhancement of critical thinking skills. A course of this nature may include Advanced Placement physics.

Several obstacles appear to prevent the implementation of AP physics courses. First, only a minority of teachers have a sufficient physics background to teach at the level required for AP physics. It was viewed as essential that AP physics teachers have a broad and in-depth background in physics; ideally a major in physics will suffice. Second, most schools did not have adequate laboratory facilities to offer a first year of university physics course. Since a majority of schools are not fully equipped to offer the laboratory component of the current high school physics program, the possibility of offering first year of university equivalent courses is very unlikely. Third, considering the level of instruction required for AP physics, teachers would need additional preparation time. Finally, given declining enrollments and the vast number of small rural schools in this province, there may not be an adequate number of students in a particular school to justify offering AP programs within those schools. Several teachers expressed on their questionnaires (Appendix D.2) that they could not see justification in allocating public funds for the implementation of a program that only meets the needs of a few.

There is a legitimate concern that AP classes will have very few students at the cost of other classes becoming over crowded. To alleviate this problem, minimum student enrollments must be set. According to one teacher in his free response, his "board has a policy of not streaming students and there must be at least 18 students selecting a course before it will be offered" (Appendix D.2). While this number may be lower than the normal student to teacher ratios in schools, the in-depth nature of an AP course may require smaller numbers of students to be more affective. However, the numbers cannot be so small that other courses will suffer with over crowding. Considering that 21.0% (Table 4.35a, Chapter 4) of high schools have fewer than 20 students enrolled in their Physics 3204 classes, a minimum number of 15 students in an AP physics class would not be unrealistic, nor unjustified.

Nonetheless, a number of schools in this province have the resources and student population to offer AP programs. The problem of small schools not having the resources or student numbers to justifiably offer AP programs may be alleviated with school amalgamations. As schools amalgamate, the student and teacher population of a given school may increase. Accordingly, the pool of potential AP candidates will increase. This trend can only result in an increased number of schools being able to justifiably offer and implement AP programs.

Statistical Comparisons Between AP and Non-AP Physics Students' Grades

This research included a study of AP physics with respect to university preparation, and students subsequent rates of success in first and second year of university physics. Hypothesis one suggested that AP students would have higher grades in first year of university physics than non-AP students. This hypothesis was verified, but only for AP students who were enrolled in the calculus based, Physics 1050. Meanwhile, AP students in Physics 1200 had a slightly lower mean grade than their non-AP peers. Considering that Physics 1200 is less academically challenging than Physics 1050, it would have been expected that AP students enrolling in this course would have higher results than AP students enrolling in Physics 1050. The contrasting results may be attributed to differing student attitudes and work ethic. Physics 1200 students had the belief that AP physics prepared them academically for first year of university physics and subsequently may have taken Physics 1200 for granted.

In addition to AP physics, other high school courses were found to affect student success in first year of university physics. The factors, included Advanced Mathematics 3201, Physics 3204, and Chemistry 3201. The effect of chemistry was most significant for students enrolled in Physics 1050, indicating that a strong high school background is important for Physics 1050 students. While chemistry was important to student success in Physics 1200, its prominence was approximately equal to that of Physics 3204 and Advanced Mathematics 3201.

As suggested in the chapter one, many students have not developed their critical thinking skills by the time they leave high school. Exposure to additional science courses such as chemistry provides an opportunity for students to practice and enhances their thinking skills. For non-AP students enrolled in Physics 1050, the addition of chemistry in their high school studies contributes to the probability of obtaining higher grades in their first year of university physics.

In addition to depth of understanding and development of critical thinking skills provided via AP physics, a student's mathematics background is also of importance. One of the major differences between high school and first year of university physics is the mathematical nature of the courses. First year of university physics is highly mathematical with Physics 1200 and Physics 1050 requiring introductory calculus as a co-requisite. According to the analysis in Chapter Four, high school Advanced Mathematics 3201 is a greater determining factor in student success than high school Physics 3204. Given the predominance of mathematics as a factor in predicting success in first year of physics at

Memorial University, it may be inferred that the current high school physics program lacks the mathematical rigor of a first year university physics course. Students who do AP physics in high school are exposed to the mathematical complexities nearer to first year of university physics, hence are better prepared for the challenge of first year physics at Memorial University. Moreover, students who have a strong mathematics background have a greater opportunity to grasp mathematically complex physics concepts. Students who have a command of the necessary mathematics skills required for first year of university physics can spend more time on concept acquisition than on acquiring the required mathematics skills.

AP physics appears to be a logical alternative for students who are planning to pursue physics beyond high school. Its breadth, and depth of concept coverage, in addition to its mathematical treatment of concepts, prepares students for the academic challenge of first year university physics. In addition, students should ensure that they have a strong mathematics background. However, if students do not have access to an AP physics course they can enhance their chances of success in first year of university physics by enrolling in chemistry and advanced mathematics.

Although the AP physics course offered in Newfoundland and Labrador (Physics B) is algebra-based, this does not imply that mathematics is not as important as it is in first year university physics. The same concerns still exist, and students should ensure that they have a solid mathematical background. Too often AP physics teachers will have to take valuable time to address mathematics topics to ensure that students will be able to apply mathematics principles in understanding physics concepts and solving problems. Therefore, the minimum mathematics prerequisite of an AP physics student should include Advanced Mathematics 3201. Accordingly, students would either have to start level I advanced math in grade nine or have their high school mathematics courses semesterized.

Also contributing to the validation of AP physics as an academic equivalent to first year university physics was acceptance of Hypothesis Two. It was hypothesized that "*AP physics students who earn advanced credit for Physics 1200 and Physics 1201, then enroll in Physics 2050 have final grades which are not significantly different from non-AP students who had first completed Physics 1200/1201.*" Results indicate that there was no significant difference between the final grades of AP students who advanced to Physics 2050 from high school and non-AP students who first had to complete Physics 1200 and Physics 1201. Hence, the results imply that AP physics and Physics 1200/1201 are academically equivalent.

Questionnaire & Survey Analysis

Hypothesis three sought to determine if students and teachers perceived exposure to AP physics in high school would enhance student's academic abilities, and work ethics. This hypothesis was verified, but also indicated that AP students who had enrolled in Physics 1200 at Memorial University had taken this course for granted and subsequently achieved lower mean grades than their non-AP peers. Further analysis of the survey and questionnaire responses revealed attitude and perceptions of the current high school physics program that calls its relevance into question.

In terms of the academically gifted students, the current high school physics curriculum appears to be weak in two areas, its design, and its intent. This position, while set forth in the introduction, derives support in this study's survey results. The intent of the high school physics curriculum is to meet the needs of all high school students. Its level of difficulty and depth of study is best suited for the "average" student. Consequently, the needs of two groups of students, the academically weak and the academically gifted are not entirely met by current high school physics curriculum. The academically weak may be over challenged, resulting in disillusionment with subsequent failures, and possibly lowering their academic esteem. However, these students have the opportunity to enroll in less academically oriented courses to obtain their high school science credits. On the other hand, there are no science courses offered in the standard high school curriculum to meet the needs of the academically gifted. Even though these students easily accomplish their assigned tasks, there may be little challenge nor enhancement of critical thinking skills.

With respect to the current high school physics program, university students felt that high school physics did not challenge students nor help develop their critical thinking skills. High school teachers, on the other hand, disagree. The responses primarily develop with respect to the respondent's position within the educational system. Students traverse from high school to university, enabling them to compare both systems. Teachers, for the most part, are far removed from the university environment, not knowing what is expected of high school students entering university. Furthermore, many teachers have not taken a physics course since prior to their convocation from university. For some teachers it may have been at least twenty years since they had completed their last university physics course.

Although high school is a prerequisite for acceptance to university, many high school teachers do not see the high school program in that role. Their primary mandate is to provide a well-rounded education for all students. When teaching, the complexity of concepts, depth of material, level of instruction, instructional time, and quantity of extracurricular work must be considered relative to the abilities and needs of all students. In addition, teacher work load and scheduling do not permit time for laboratory preparation, demonstrations, and assignments. In a majority of cases high school students may have completed their high school physics in schools with substandard laboratory equipment, or no laboratories at all. Consequently, the greater workloads, scheduled compulsory laboratories, and the required independent study characteristic of a university education may seem foreign to most students.

Second, a central component to the design of the current high school physics program includes a core laboratory component. However, a number of schools find it very difficult to fulfill the course requirements due to inadequate or nonexistent laboratory facilities. In unanimous agreement, students and teachers suggest that the level of laboratory work is not sufficient in high school physics. This result stems from the laboratory deficiencies noted, rather than instructional inadequacies. Teachers and students alike feel instruction is adequate. Even though teachers may deem their physics background adequate, the physical inadequacies of many school laboratories demand an insight that a teacher can only derive from an in-depth understanding of their subject area. Where apparatus is lacking, teachers may have to improvise with common everyday objects and analogies that a teacher's guide, physics texts, and basic physics knowledge cannot offer. For some teachers whose sole resource and knowledge base is the course textbook, the illustrations and analogies used in concept development may be foreign to many students. The result for students may be confusion rather than comprehension.

Instances in which there are insufficient laboratory resources available, teachers may have to improvise in an attempt to convey the meaning of concepts For example, a dynamics cart is not necessary to illustrate straight line motion, or collisions. Instead, an in-depth understanding of the subject area and a gift to convey understanding will suffice. In some instances, an equipped laboratory may be a bonus. This argument does not imply that the laboratory component of a physics course is nonessential. Instead, laboratories exist to provide a broad range of laboratory experiment skills and insights, with goals in the psycho-motor domain. Although the high school physics program in Newfoundland and Labrador is meant to have a significant laboratory component, there are schools that do not have sufficient laboratory facilities or equipment. A teacher, then may have to rely upon their own knowledge, background and ingenuity to improvise laboratory demonstrations and activities.

This argument does not pertain to all teachers. Knowledge in a subject area does not necessarily make someone a good teacher. A teacher must not only have understanding, but have the ability to instill understanding. In some circumstances, as was suggested in the surveys, personal research and interest in the subject area may compensate for the lack of a physics background. However, the amount of time required would certainly be more than the one to three hours per week that the majority of teachers indicated. Considering lesson and laboratory preparations, demonstrations, testing, assignments, grading, and science projects, there is little time left out of that one to three hours for personal research.

Considering all arguments, the minimum qualifications of a physics teacher at the Physics 3204 level should be a physics minor. However, there are a limited number of available teachers who have this specialization. For those teachers who do spend endless hours in preparation for their classes, an alternative would be in-servicing or summer institutes in physics education. In such a situation, teachers will not only benefit from their professor's instruction, but from consultations with other teachers. In many situations, teachers would best learn from other teachers who have found novel approaches to teaching in inadequate laboratory facilities.

Despite the recognized inadequacies of the high school system, most comments are primarily in response to inadequate facilities and a curriculum designed for the "average" student. If students are to be given the opportunities "to pursue academic studies to the limit of their abilities" (Williams, 1992, p. 300), then, a third option must exist for these students. While it is unrealistic to assume that a majority of students would fit into the "academically gifted" category, there is a significant number of hard working and academically talented students in the schools. Hence, the consideration of implementing a third option may be warranted. Given the opportunity, these students may excel in an accelerated program. The option that this research study examined was Advanced Placement physics.

The data analysis reveals the benefit of AP physics for students who are self-motivated and academically gifted. These students, when enrolling in first year of physics at Memorial University excel in their physics with an average approximately 12% higher than their peers (Physics 1050). However, as noted in Chapter Three, there is a limited amount of data existing to be analyzed. AP physics was first introduced to students in Newfoundland in 1991-1992. Consequently, generalizations and conclusions from the data must be viewed with this limitation in mind. Despite this limitation, the results of the raw data as reported do exist, and the subsequent conclusions derived from the data analysis are statistically valid. The results do provide impetus for further study and debate as to the viability of AP physics. It may be predicted that additional study would further substantiate the conclusions made within this research study.

Recommendations

In reference to the preceding discussion and the findings outlined in Chapter Four, several recommendations may be made pertaining to high school and AP physics. The first group of recommendations are derived from the results of the statistical analysis. The second group of recommendations are a synopsis of suggestions and comments taken from the survey analysis.

Recommendations from the statistical analysis:

1. Department of Education and Training in Newfoundland and Labrador should review its policy on minimum core laboratory requirements for AP physics to determine whether they need to be similar to their physics course equivalent at Memorial University.

2. Where numbers warrant (minimum 15 students), an AP school should be given funding to upgrade their facilities to offer core laboratory assignments similar to those required by Memorial University.

3. Students planning to pursue physics beyond high school are recommended to do AP physics (if available), Advanced Mathematics 3201 (and AP mathematics if available), and Chemistry 3202.

4. Students who complete AP physics in high school but do not receive advanced credit for Physics 1200/1201 should be required to enroll in Physics 1050.

5. The progress of AP physics students at Memorial University should be monitored for a longer period of time. A greater number of subjects would increase the validity of comparisons between the final grades of AP and non-AP students enrolled in Physics 1200 and Physics 1050.

Recommendations from surveys:

1. High school Physics 3204 teachers should have a minimum of a physics minor.

2. A summer institute or course should be offered to teachers who wish to teach, or who are currently teaching high school physics. Required topics and laboratories from high school Physics 2204 and Physics 3204 should be covered in greater depth. Emphasis should be placed on laboratory preparation & instruction, as well as teaching of concepts & concept applications. This course should be given full university credit in the area of science education (either graduate or undergraduate) and offered over the duration of a Summer Semester at Memorial University.

3. A summer institute or course should be offered to teachers who wish to teach, or who are currently teaching AP physics. Required topics and laboratory assignments from Memorial University's Physics 1200 and Physics 1201 should be

covered as well as any additional topics that are a part of the AP physics program. This course should be given full university credit in the area of science education (either graduate or undergraduate) and offered over the duration of a Summer Semester at Memorial University.

4. AP physics teachers should have a minimum of a physics major.

5. High school AP physics teachers should have access to all first year physics syllabus from Memorial University, to be used as a reference guide.

6. A minimum of fifteen students should be enrolled in an AP course before that course may be offered in a school.

7. Students deemed potential candidates for Advanced Placement physics should have completed at end of level II, Advanced Mathematics 3201. This may be achieved by either:

    a) Completing Advanced Mathematics 1201 during grade nine or

    b) Semesterizing Advanced Mathematics 1201/2201 in level I, or

    c) semesterizing Advanced Mathematics 2201/3201 in level II

8. Students should require an "A" grade in Physics 3204 and Advanced Math 3201 prior to enrolling in AP physics. Depending upon student work ethic and motivation, this grade minimum may be lowered to 70% as recommended by first year university students.

9. An assessment and inventory of school laboratories should be conducted and funding made available to upgrade facilities to ensure that required core laboratories in the high school physics curriculum can be completed.

10. Memorial University, Stem~Net, and the Department of Education and Training should consider entering a partnership to develop and offer advanced placement courses via distance education or the Internet.

Conclusion

Once, high school was the last step on the educational ladder before many students sought a career. Now, high schools are becoming the entry point to one's education and career training. In the past ten years, Newfoundlanders have seen the demise of the railway, the closure of the fishery, and the introduction of the information super highway. With this revolution, the demand now is for highly skilled workers rather than trained laborers. As competition to gain acceptance into educational institutions grows, so does the demand for students to excel in their high school careers. High schools have to grow beyond its self-imposed boundaries of yesterday, and prepare students for tomorrow

Despite achieving its mandate of providing a well-rounded physics curriculum to most students, the design of the current high school physics program appears to provide little challenge for the academically gifted and little opportunity for them to enhance their critical thinking skills. If the Task Force on Mathematics and Science Education, *Towards an Achieving Society* (Crocker, 1989), and the Royal Commission, *Our Children, Our Future* (Williams, 1992) are to achieve the goal of all students having the opportunity to be taught to the maximum of their learning potential, then a third level may have to be provided within the current high school physics curriculum. An option within this third level may include AP physics. With such a structure, "a goal of greater depth allows teachers to emphasize critical thinking, enables students to gain more ownership of the problems in science, and is more likely to have a lasting impact" (Norris, 1992, p. 219). In addition to a strong mathematical aptitude and a broad science background via chemistry, these skills are a prerequisite for success in university physics. As society grows, so does the realization that critical thinking skills are more than a prerequisite, they are a necessity.

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Appendix A

Tables of Data for Chapter One

Table A.1: High School & Physics 1200 Grades.

	HS Public Physics			MUN Physics 1200			Difference
Term	N	M	SD	N	M	SD	in Means
1990 F	226	78.1	10.0	226	58.3	16.6	19.8
1991 F & W	562	77.0	11.7	562	59.4	17.9	17.6
1992 F & W	651	76.6	11.0	651	60.2	17.0	16.4
1993 F & W	578	75.1	11.5	578	62.8	17.5	12.3
1994 F & W	562	76.7	10.9	562	62.4	15.2	14.3
1995 F	248	79.5	9.3	248	66.7	15.7	12.8
Mean		77.1			61.6		15.5

Table A.2: High School & Physics 1050 Grades.

	HS Public Physics			MUN Physics 1050			Difference
Term	N	M	SD	N	M	SD	in Means
1990 F	88	87.8	6.0	88	63.8	20.8	23.9
1991 F	96	89.2	6.1	96	66.9	12.0	22.3
1992 F	64	88.0	6.7	64	69.8	14.2	18.2
1993 F	69	86.3	7.1	69	71.3	13.9	15.0
1994 F	65	85.9	8.5	65	68.3	18.5	17.6
1995 F	32	85.7	4.9	32	72.7	14.4	13.0
Mean		87.1			68.8		18.3

Table A.3: First Year Physics Attrition Numbers At Memorial University

	1990	1991	1992	1993	1994	1995
Physics 1200						
N	716	1414	1511	1357	1360	1233
Drop	29	209	211	222	162	160
Pass	545	894	1024	908	997	954
Fail	142	311	276	227	201	119
Physics 1050						
N	120	125	94	104	92	95
Drop	2	19	8	25	11	6
Pass	96	97	83	75	73	82
Fail	22	9	3	4	8	7

Table A.4: First Year Physics Pass Rates at Memorial University

	1990	1991	1992	1993	1994	1995
Physics 1200						
N	687	1205	1300	1135	1198	1073
Pass (%)	79.3	74.2	78.8	80.0	83.2	88.9
Fail (%)	20.7	25.8	21.2	20.0	16.8	11.1
Physics 1050						
N	118	106	86	79	81	89
Pass (%)	98.3	91.5	96.5	94.9	90.1	92.1
Fail (%)	1.7	8.5	3.5	5.1	9.9	7.9

Table A.5: First Year Physics Attrition Rates at Memorial

	1990	1991	1992	1993	1994	1995
Physics 1200						
N	716	1414	1511	1357	1360	1233
Drop (%)	4.1	14.8	14.0	16.4	11.9	13.0
Pass (%)	76.1	63.2	67.8	66.9	73.3	77.4
Fail (%)	19.8	22.0	18.3	16.7	14.8	9.7
Physics 1050						
N	120	125	94	104	92	95
Drop (%)	1.7	15.2	8.5	24.0	12.0	6.3
Pass (%)	80.0	84.8	88.3	72.1	79.3	86.3
Fail (%)	18.3	7.2	3.2	3.8	8.7	7.4

Appendix B

Surveys: Letters of Consent

February 10, 1995

Superintendent
Name of School Board
Address
City/Town, Province
Postal Code

Dear *Name of Superintendent*;

My name is Tom Pike and I am a graduate student at Memorial University of Newfoundland's Faculty of Education. Presently, I am doing research on my thesis, entitled *The Function of Advanced Placement Physics within the Newfoundland and Labrador Physics Curriculum*. The aim of my research is to determine if exposure to Advanced Placement physics in high school enhances student performance in first year university physics.

This research involves correlating high school and university physics marks as well as studying the views of university students, high school physics teachers, and university physics professors. The questionnaire that I am asking your physics 3204 teachers to complete focuses on their views of high school physics, Advanced Placement physics, university physics, and the relationship amongst all three levels of physics curriculum. As well, the questionnaire will address teacher qualifications, their physics backgrounds, teacher training, and the physical capabilities of Newfoundland schools being able to offer Advanced Placement programs. To achieve more comprehensive results, I am sending this questionnaire to ALL 3204 physics teachers in our province

All information gathered in this study is confidential. At no time will this study identify any individual, school, or school district. Furthermore, participation in this survey is voluntary; teachers may withdraw from completing the survey or omit any question at their discretion. This study has received approval from the Faculty of Education's Ethics Review Committee. The results of my research will be made available to you upon request.

If you are in agreement with allowing your Physics 3204 teachers to participate in this study, please sign below and return this paper in the self-addressed return envelope. If you have any questions or concerns please do not hesitate to contact me at 364-5467, or my supervisor, Dr. Glenn Clark at 737-7612. If at any time you wish to speak with a resource person not associated with the study, please contact Dr. Patricia Canning, Associate Dean, Research and Development.

As I indicated in our telephone conversation on *Date of Telephone Conversation*, I have enclosed a copy of the questionnaire for your records, as well as a list of the teachers involved.

Thank you for consideration of this request.

Sincerely yours,

Thomas N. Pike

I, ________________________, Superintendent of the *Name of School Board* hereby give permission for the physics 3204 teachers in this district to participate in the above described questionnaire. I understand that participation is voluntary and that teachers may opt out of completing the questionnaire at any time. All information is strictly confidential and no individual teacher, school, or district will be identified.

________________ ________________________

Date Superintendent's signature

February 10, 1995

Dear _Name of Teacher_;

My name is Tom Pike and I am a graduate student at Memorial University of Newfoundland's Faculty of Education. Presently, I am doing research on my thesis, entitled *The Function of Advanced Placement Physics within the Newfoundland and Labrador Physics Curriculum.* The aim of my research is to determine if exposure to Advanced Placement physics in high school enhances student performance in first year university physics.

This research involves correlating of high school and university marks as well as studying the views of university students, high school physics teachers, and university physics professors. The questionnaire that I am asking you to complete focuses on your views of high school physics, Advanced Placement physics, university physics, and the relationship between high school and university physics. As well, the questionnaire will address teacher qualifications, teacher training, and the physical capabilities of our schools being able to offer Advanced Placement programs. To achieve more comprehensive results, I am sending this questionnaire to ALL 3204 physics teachers in our province. Therefore, I urge you to participate in this study.

All information gathered in this study is strictly confidential and at no time will individuals be identified. Furthermore, participation in this survey is voluntary; you may withdraw from completing the survey or omit any question at your discretion. This study has received approval from the Faculty of Education's Ethics Review Committee. The results of my research will be made available to you upon request.

If you are in agreement with completing the following questionnaire and participating in this study, please sign below and return this paper with the questionnaire by Friday, March 17, 1995. If you have any questions or concerns please do not hesitate to contact me at 364-5467, or my supervisor, Dr. Glenn Clark at 737-7612. If at any time you wish to speak with a resource person not associated with the study, please contact Dr. Patricia Canning, Associate Dean, Research and Development.

Thank you for consideration of this request.

Sincerely yours,

Thomas N. Pike

I ______________________ understand that the participation in the above described study is voluntary and may withdraw from completing the questionnaire at any time. All information is strictly confidential and no individual will be identified.

______________ ______________________________

Date Teacher's signature

______________ ______________________________

Date Principal's signature

Thursday, February 16, 1995

Dear Student;

My name is Tom Pike and I am a graduate student at Memorial University of Newfoundland's Faculty of Education. Presently, I am doing research on my thesis, entitled *The Function of Advanced Placement Physics within the Newfoundland and Labrador Physics Curriculum.* The aim of my research is to determine if exposure to Advanced Placement physics in high school enhances student performance in first year university physics.

This research involves correlating high school and university marks as well as studying the views of university students, high school physics teachers, and university physics professors. The questionnaire that I am asking you to complete focuses on your views of high school physics, Advanced Placement physics, university physics, and the relationship between high school and university physics. As well, the questionnaire will address teacher qualifications, their physics backgrounds, teacher training, and the physical capabilities of Newfoundland schools being able to offer Advanced Placement programs.

All information gathered in this study is strictly confidential and at no time will individuals be identified. Furthermore, participation in this survey is voluntary; you may withdraw from completing the survey or omit any question(s) at your discretion. This study has received approval from the Faculty of Education's Ethics Review Committee. The results of my research will be made available to you upon request.

If you are in agreement with completing the following questionnaire and participating in this study, please sign below and return this paper with the questionnaire. If you have any questions or concerns please do not hesitate to contact me at 364-5467, or my supervisor, Dr. Glenn Clark at 737-7612. If at any time you wish to speak with a resource person not associated with the study, please contact Dr. Patricia Canning, Associate Dean, Research and Development.

Thank you for consideration of this request.

Sincerely yours,

Thomas N. Pike

I _________________________ understand that the participation in the above described study is voluntary and may withdraw from completing the questionnaire at any time. All information is strictly confidential and no individual will be identified.

______________ ______________________

Date Student's signature

Thursday, February 16, 1995

Dear Physics Professor;

My name is Tom Pike and I am a graduate student at Memorial University of Newfoundland's Faculty of Education. Presently, I am doing research on my thesis, entitled *The Function of Advanced Placement Physics within the Newfoundland and Labrador Physics Curriculum.* The aim of my research is to determine if exposure to Advanced Placement physics in high school enhances student performance in first year university physics.

This research involves correlating high school and university marks as well as studying the views of university students, high school physics teachers, and university physics professors. The questionnaire that I am asking you to complete focuses on your views of high school physics, Advanced Placement physics, university physics, and the relationship between high school and university physics. As well, the questionnaire will address teacher qualifications, their physics backgrounds, teacher training, and the physical capabilities of Newfoundland schools being able to offer Advanced Placement programs.

All information gathered in this study is strictly confidential and at no time will individuals be identified. Furthermore, participation in this survey is voluntary; you may withdraw from completing the survey or omit any question at your discretion. This study has received approval from the Faculty of Education's Ethics Review Committee. The results of my research will be made available to you upon request.

If you are in agreement with completing the following questionnaire and participating in this study, please sign below and return this paper with the questionnaire. If you have any questions or concerns please do not hesitate to contact me at 364-5467, or my supervisor, Dr. Glenn Clark at 737-7612. If at any time you wish to speak with a resource person not associated with the study, please contact Dr. Patricia Canning, Associate Dean, Research and Development.

Thank you for consideration of this request.

Sincerely yours,

Thomas N. Pike

I _________________________ understand that the participation in the above described study is voluntary and may withdraw from completing the questionnaire at any time. All information is strictly confidential and no individual will be identified.

_______________ ___________________________

Date Physics Professor's Signature

Appendix C

Surveys: Questionnaires

Student Survey

Section I

Part One: **ALL STUDENTS are asked to answer the following questions.**

For the following statements, please respond as to whether you agree or disagree.

strongly agree				strongly disagree
1	2	3	4	5

1.	High school physics prepared me academically for university	1 2 3 4 5
2	I found high school physics academically challenging.	1 2 3 4 5
3	High school physics helped me develop critical thinking skills.	1 2 3 4 5
4.	High school physics prepared me for the work load of first year university physics.	1 2 3 4 5
5.	The larger number of students in first year university physics classes inhibits understanding of material.	1 2 3 4 5
6.	My high school physics lab was well equipped to offer physics.	1 2 3 4 5
7	The level of instruction from my high school physics teacher was adequate.	1 2 3 4 5

8.	There is a need to have Advanced Placement physics in high school.	1 2 3 4 5
9.	If they have the opportunity, I would recommend Advanced Placement physics to high school students who plan to attend university or college.	1 2 3 4 5

Part Two: **<u>ONLY</u> those students who did <u>AP PHYSICS</u> in high school are asked to answer questions <u>#10 to #26</u> below:**

10.	I did AP physics to receive university credit.	1 2 3 4 5
11.	I did AP physics to prepare myself for university.	1 2 3 4 5
12.	I did AP physics to be academically challenged.	1 2 3 4 5
13.	I did AP physics because I enjoy physics and wanted to learn more physics.	1 2 3 4 5
14.	AP physics broadened my understanding of physics.	1 2 3 4 5
15.	AP physics helped me to develop critical thinking skills.	1 2 3 4 5
16.	AP physics prepared me academically for first year university physics more so than if I had only completed high school physics.	1 2 3 4 5
17.	AP physics prepared me for the expected work load of first year university physics.	1 2 3 4 5

18.	My background in AP physics enhanced my understanding of first year university physics.	1 2 3 4 5
19.	If high school students have the opportunity, I would recommend they do AP physics before they attend university or college.	1 2 3 4 5
20.	Physics 3204 should be a prerequisite to AP physics.	1 2 3 4 5
21.	Universities should have an entrance exam for advanced placement students to determine if they should receive advanced credit.	1 2 3 4 5
22.	I had taken first year university physics for granted because I did AP physics.	1 2 3 4 5
23.	Lab work should be an essential part of AP physics.	1 2 3 4 5
24.	There is a need to have AP physics in high school.	1 2 3 4 5
25.	My high school physics lab was well equipped to offer AP physics.	1 2 3 4 5
26.	The Physics Department at Memorial University should provide the syllabus (course outline) for the Advanced Placement physics course.	1 2 3 4 5

Section II

Part One: **ALL STUDENTS are asked to answer the following questions:**

For the following statements and questions, please choose the most appropriate response.

1. How many students were in your high school physics class?

   a. 1 to 10
   b. 11 to 20
   c. 21 to 30
   d. 31 to 35
   e. in excess of 35; approximately how many students? _____

2. How many students were in your first year university physics class?

   a. 11 to 20
   b. 21 to 30
   c. 31 to 40
   d. 41 to 50
   e. in excess of 50; approximately how many students? _____

3. The difficulty level of first year university physics was

   a. much higher than high school physics.
   b. higher than high school physics.
   c. equal to high school physics.
   d. lower than high school physics.
   e. much lower than high school physics.

4. The required work load (i.e. assignments, labs, tests, and readings) of first year university physics was

   a. much higher than high school physics.
   b. higher than high school physics.
   c. equal to high school physics.
   d. lower than high school physics.
   e. much lower than high school physics.

5. The effort I placed in first year university physics was

   a. much more than high school physics.
   b. more than high school physics.
   c. equal to high school physics.
   d. less than high school physics.
   e. much less than high school physics.

6. First year university physics is

   a. much more in-depth than high school physics
   b. more in-depth than high school physics
   c. equal in-depth to high school physics
   d. less in-depth to high school physics
   e. much less in-depth to high school physics

7. The course content (# of topics) in the first year university physics is

   a. much greater than high school physics.
   b. greater than high school physics.
   c. equal to high school physics.
   d. less than high school physics.
   e. much less than high school physics.

8. The amount of lab work in first year university physics

   a. much more than in high school physics
   b. more than in high school physics
   c. equal to high school physics
   d. less than in high school physics
   e. much less than in high school physics

9. On average, the amount of time I spent each week studying and/or working at high school physics was

   a. up to one hour
   b. up to two hours
   c. up to three hours
   d. up to four hours
   e. in excess of four hours; approximately how many hours? _____

10. On average, the amount of time I spent each week studying and/or working at first year university physics was

    a. up to one hour
    b. up to two hours
    c. up to three hours
    d. up to four hours
    e. in excess of four hours; approximately how many hours? _____

11. I did not do AP physics in high school because

    a. it was not offered in my high school.
    b. my marks in physics 3204 was too low.
    c. I felt that AP physics would be too difficult for me.
    d. I did not want to take on the extra work load.
    e. I did not feel that I needed to do another physics course.

12. How many university credits do you have to date?

    a. 1 to 5
    b. 6 to 10
    c. 11 to 15
    d. 16 to 20
    e. in excess of 20; approximately how many credits? _____

Part Two: **<u>ONLY</u> those students who did <u>AP PHYSICS</u> in high school are asked to answer questions <u>#13 to #28</u> below:**

13. What grade should a student have in Physics 3204 to be considerec for AP physics.

    a. 50 - 59
    b. 60 - 69
    c. 70 - 79
    d. 80 - 89
    e. 90 - 100

14. What should be the mathematics level of a student who is doing AP physics?

    a. level II academic completed
    b. level II advanced completed
    c. level III academic completed
    d. level III advanced completed
    e. concurrently doing AP Mathematics

15. How many students were in your AP physics class?

    a. 1 to 5
    b. 6 to 10
    c. 11 to 15
    d. 16 to 20
    e. more than 20; approximately how many students? _____

16. The difficulty level of AP physics was

    a. much higher than physics 3204.
    b. higher than physics 3204.
    c. equal to physics 3204.
    d. lower than physics 3204.
    e. much lower than physics 3204.

17. The difficulty level of first year university physics was

    a. much higher than AP physics.
    b. higher than AP physics.
    c. equal to AP physics.
    d. lower than AP physics.
    e. much lower than AP physics.

18. The required work load (i.e. assignments, labs, tests, and readings) of AP physics was

    a. much higher than physics 3204.
    b. higher than physics 3204.
    c. equal to physics 3204.
    d. lower than physics 3204.
    e. much lower than physics 3204.

19. The required work load (i.e. assignments, labs, tests, & readings) of first year university physics was

    a. much higher than AP physics.
    b. higher than AP physics.
    c. equal to AP physics.
    d. lower than AP physics.
    e. much lower than AP physics.

20. The effort I placed in AP physics was

    a. much more than I placed in high school physics
    b. more than I placed in high school physics
    c. equal to what I placed in high school physics
    d. less than I placed in high school physics
    e. much less than I placed in high school physics

21. The effort I placed in first year university physics was

    a. much more than I placed in AP physics
    b. more than I placed in AP physics
    c. equal to what I placed in AP physics
    d. less than I placed in AP physics
    e. much less than I placed in AP physics

22. AP physics is

    a. much more in-depth than high school physics
    b. more in-depth than high school physics
    c. equal in-depth to high school physics
    d. less in-depth to high school physics
    e. much less in-depth to high school physics

23. First year university physics is

    a. much more in-depth than AP physics
    b. more in-depth than AP physics
    c. equal in-depth to AP physics
    d. less in-depth to AP physics
    e. much less in-depth to AP physics

24. The course content (# of topics) in AP physics is

   a. much greater than high school physics.
   b. greater than high school physics.
   c. equal to high school physics.
   d. less than high school physics.
   e. much less than high school physics.

25. The course content (# of topics) in first year university physics is

   a. much greater than AP physics.
   b. greater than AP physics.
   c. equal to AP physics.
   d. less than AP physics.
   e. much less than AP physics.

26. The amount of lab work in AP physics was

   a. much more than in high school physics
   b. more than in high school physics
   c. equal to that in high school physics
   d. less than in high school physics
   e. much less than in high school physics

27. The amount of lab work in first year university physics is

   a. much more than in AP physics
   b. more than in AP physics
   c. equal to that in AP physics
   d. less than in AP physics
   e. much less than in AP physics

28. On average, the amount of time I spent each week studying and/or working at AP physics was

   a. up to one hour
   b. up to two hours
   c. up to three hours
   d. up to four hours
   e. in excess of four hours; approximately how many hours? _____

Section III

ALL STUDENTS are asked to answer the following free-response question:

Are there any further comments that you would like to make regarding high school physics and/or Advanced Placement physics and their relevance to the high school system or university?

High School Physics Teacher Survey

Section I

Part One: **ALL TEACHERS** **are asked to answer the following questions.**

For the following statements, please respond as to whether you agree or disagree.

strongly agree				strongly disagree
1	2	3	4	5

1.	High school physics challenges the academically gifted students.	1 2 3 4 5
2.	High school physics gives students a broad understanding of physics.	1 2 3 4 5
3.	High school physics helps students develop critical thinking skills.	1 2 3 4 5
4.	High school physics prepares students academically for first year university physics.	1 2 3 4 5
5.	High school physics prepares students for the work load in first year university physics.	1 2 3 4 5
6.	The larger number of students in first year university physics classes inhibits understanding of material.	1 2 3 4 5
7.	Lab work should be an essential part of high school physics	1 2 3 4 5

8.	My high school physics lab is well equipped to offer the required labs.	1 2 3 4 5
9.	I feel comfortable teaching at the level required for high school physics.	1 2 3 4 5
10.	I feel that my physics background is sufficient to teach high school physics.	1 2 3 4 5
11.	I feel that my physics background is sufficient to teach Advanced Placement physics.	1 2 3 4 5
12.	There is a need to have Advanced Placement physics in high school.	1 2 3 4 5
13.	The department of education in conjunction with the university should offer some form of seminar to prepare physics teachers who wish to teach Advanced Placement Physics.	1 2 3 4 5

Part Two: **ONLY those teachers who are teaching or who have taught AP PHYSICS are asked to answer questions #14 to #35 below:**

14.	AP physics challenges academically gifted students.	1 2 3 4 5
15.	Students enroll in AP physics to receive college or university credit.	1 2 3 4 5
16.	Students enroll in AP physics to prepare themselves for college or university.	1 2 3 4 5

17.	Students enroll in AP physics to be challenged.	1 2 3 4 5
18.	Students enroll in AP physics because they enjoy physics and wanted to learn more physics.	1 2 3 4 5
19.	AP physics broadens students' understanding of physics.	1 2 3 4 5
20.	AP physics helps students develop critical thinking skills.	1 2 3 4 5
21.	AP physics prepares students academically for first year university physics more so than if they had only completed high school physics.	1 2 3 4 5
22.	AP physics prepares students for the expected work load in first year university physics.	1 2 3 4 5
23.	AP physics enhanced students' understanding of first year university physics.	1 2 3 4 5
24.	I would recommend AP physics to students who plan to attend college or university.	1 2 3 4 5
25.	Students take first year university physics for granted because they did AP physics.	1 2 3 4 5
26.	Physics 3204 should be a prerequisite to AP physics?	1 2 3 4 5
27.	High school students should be allowed to do AP physics and Physics 3204 concurrently.	1 2 3 4 5

28.	Universities should have an entrance exam for advanced placement students to determine if they should receive advanced credit.	1 2 3 4 5
29.	Lab work should be an essential part of AP physics	1 2 3 4 5
30.	My high school physics lab is well equipped to offer AP physics.	1 2 3 4 5
31.	I feel comfortable teaching at the level required for AP physics?	1 2 3 4 5
32.	I feel that my level of instruction is adequate for AP physics.	1 2 3 4 5
33.	I feel that I have become more knowledgeable about physics.	1 2 3 4 5
34.	I feel that I have become a more effective teacher through teaching AP physics.	1 2 3 4 5
35.	The Physics Department at Memorial University should provide the syllabus for the Advanced Placement physics course.	1 2 3 4 5

Section II

Part One: ALL TEACHERS are asked to answer the following questions:

For the following statements and questions, please choose the most appropriate response.

1 The difficulty level of first year university physics is

a much higher than high school physics.
b higher than high school physics.
c equal to high school physics.
d lower than high school physics.
e much lower than high school physics.

2 The work load of first year university physics is

a. much higher than high school physics.
b higher than high school physics.
c. equal to high school physics.
d lower than high school physics.
e much lower than high school physics.

3 The effort students placed in first year university physics is

a much higher than high school physics.
b higher than high school physics.
c equal to high school physics.
d lower than high school physics.
e much lower than high school physics.

4 First year university physics is

a much more in-depth than high school physics
b. more in-depth than high school physics
c. equal in-depth to high school physics
d less in-depth than high school physics
e much less in-depth than high school physics

5. The course content (# of topics) in first year university physics is

   a. much greater than AP physics.
   b. greater than AP physics.
   c. equal to AP physics.
   d. less than AP physics.
   e. much less than AP physics.

6. The amount of lab work in first year university physics is

   a. much greater than in high school physics
   b. greater than in high school physics
   c. equal to high school physics
   d. less than in high school physics
   e. much less than in high school physics

7. How much time, on average, do you believe your students spend studying and/or working at high school physics

   a. up to 1 hour
   b. up to 2 hours
   c. up to three hours
   d. up to four hours
   e. in excess of four hours; approximately how many hours? ___

8. What percentage of class time do you allocate for labs?

   a. up to 5%
   b. up to 10%
   c. up to 15%
   d. up to 20%
   e. in excess of 20%; approximately what percentage? ___

9. The average amount of time each week you spend preparing for physics 3204 is

   a. up to 1 hour
   b. up to 2 hours
   c. up to three hours
   d. up to four hours
   e. in excess of four hours; approximately how many hours? ___

10. The minimum physics background for a high school physics teacher should be

    a. less than four courses in university physics
    b. less than eight courses in university physics
    c. minor in physics (at least 8 courses)
    d major in physics
    e. masters in physics

11. What is your physics background?

    a. less than four courses in physics
    b. less than eight courses in physics
    c. minor in physics (at least 8 courses)
    d. major in physics
    e. masters in physics

Part Two: **<u>ONLY</u> those teachers are teaching or who have taught <u>AP PHYSICS</u> in high school are asked to answer questions <u>#12 to #30</u> below:**

12. What grade should a student have in Physics 3204 to be considered for AP physics?

    a. 50 - 59
    b. 60 - 69
    c. 70 - 79
    d. 80 - 89
    e. 90 - 100

13. What should be the mathematics level of a student who is doing AP physics?

    a. level II academic completed
    b. level II advanced completed
    c. level III academic completed
    d. level III advanced completed
    e. concurrently doing AP Mathematics

14. How many students on average are there in your AP physics classes?

    a. 1 to 5
    b. 6 to 10
    c. 11 to 15
    d. 16 to 20
    c. more than 20; approximately how many students? _____

15. What is the maximum number of students that should be in an AP physics class?

    a. 1 to 5
    b. 6 to 10
    c. 11 to 15
    d. 16 to 20
    e. 21 to 25; approximately how many students? _____.

16. The difficulty level of AP physics is

    a. much higher than physics 3204.
    b. higher than physics 3204.
    c. equal to physics 3204.
    d. lower than physics 3204.
    e. much lower than physics 3204.

17. The difficulty level of first year university physics

    a. is much higher than AP physics.
    b. is higher than AP physics.
    c. is equal to AP physics.
    d. is lower than AP physics.
    e. is much lower than AP physics.

18. The required work load (assignments, labs, tests, & readings) of AP physics is

    a. much higher than physics 3204.
    b. higher than physics 3204.
    c. equal to physics 3204.
    d. lower than physics 3204.
    e. much lower than physics 3204.

19. The required work load (i.e. assignments, labs, tests, and readings) of first year university physics is

    a. much more than AP physics.
    b. more than AP physics.
    c. equal to AP physics.
    d. less than AP physics.
    e. much less AP physics.

20. The effort students place in AP physics is

    a. much more than they place in high school physics
    b. more than they place in high school physics
    c. equal to what they place in high school physics
    d. less than they place in high school physics
    e. much less than they place in high school physics

21. AP physics is

    a. much more in-depth than high school physics
    b. more in-depth than high school physics
    c. equal in-depth to high school physics
    d. less in-depth to high school physics
    e. much less in-depth to high school physics

22. The course content (# of topics) in AP physics is

    a. much greater than high school physics.
    b. greater than high school physics.
    c. equal to high school physics.
    d. less than high school physics.
    e. much less than high school physics.

23. First year university physics is

    a. much more in-depth than AP physics
    b. more in-depth than AP physics
    c. equal in-depth to AP physics
    d. less in-depth to AP physics
    e. much less in-depth to AP physics

24. The course content (# of topics) in first year university physics is

    a. much greater than AP physics.
    b. greater than AP physics.
    c. equal to AP physics.
    d. less than AP physics.
    e. much less than AP physics.

25. How much time, on average, do you believe your AP students spend studying and/or working at their physics.

    a. up to 3 hours per week
    b. up to 4 hours per week
    c. up to 5 hours per week
    d. up to 6 hours per week
    e. in excess of 7 hours per week; approximately how many hours? ______

26. What percentage of class time do you allocate for lab work?

    a. up to 5%
    b. up to 10%
    c. up to 15%
    d. up to 20%
    e. in excess of 20%; approximately what percentage? ______

27. The amount of lab work in AP physics is

    a. much greater than in high school physics
    b. greater than in high school physics
    c. equal to high school physics
    d. less than in high school physics
    e. much less than in high school physics

28. The amount of lab work in first year university physics is

    a. much greater than in AP physics
    b. greater than in AP physics
    c. equal to AP physics
    d. less than in AP physics
    e. much less than in AP physics

29. How much time on average do you spend each week preparing for AP physics

 a. up to one
 b. up to two hours
 c. up to three hours
 d. up to four hours
 e. in excess of four hours; approximately how many hours? _____

30. The minimum physics background for an AP physics teacher should be:

 a. less than four courses in university physics
 b. less than eight courses in university physics
 c. minor in physics (at least 8 courses)
 d. major in physics
 e. masters in physics

Section III

<u>ALL TEACHERS</u> are asked to answer the following free-response question:

Are there any further comments that you would like to make regarding high school physics and/or Advanced Placement physics and their relevance to the high school system or university?

Physics Professor Survey

Section I

For the following statements, please respond as to whether you agree or disagree.

strongly agree				strongly disagree
1	2	3	4	5

1.	High school physics challenges academically gifted students.	1 2 3 4 5
2.	Students who have taken Advanced Placement Physics tend to be more academically prepared for university than students who had not taken Advanced Placement physics.	1 2 3 4 5
3.	Advanced Placement physics students have a broader understanding of physics than students who had not taken Advanced Placement physics.	1 2 3 4 5
4.	Advanced Placement physics students have a more in-depth understanding of first year university physics than students who had not taken Advanced Placement physics.	1 2 3 4 5
5.	Advanced Placement physics prepares students for the work load in first year university physics.	1 2 3 4 5
6.	In first year university physics, Advanced Placement physics students demonstrate a higher level of critical thinking than students who had not taken Advanced Placement physics.	1 2 3 4 5

7.	Advanced Placement physics students outperform students who had not taken Advanced Placement physics.	1 2 3 4 5
8.	Advanced Placement students tend to take first year university physics for granted because they did Advanced Placement physics.	1 2 3 4 5
9.	If high school students have the opportunity, I would recommend they do AP physics before they attend university or college.	1 2 3 4 5
10.	Universities should have an entrance exam for Advanced Placement students to determine if they should receive university/college credit.	1 2 3 4 5
11.	Lab work should be an essential part of Advanced Placement physics	1 2 3 4 5
12.	Most high schools are not equipped to teach Advanced Placement physics.	1 2 3 4 5
13.	The university should make available, on loan, lab equipment, to schools that offer Advanced Placement physics.	1 2 3 4 5
14.	The larger number of students in first year university physics classes inhibits understanding of material?	1 2 3 4 5
15.	The Physics Department at Memorial University should provide the syllabus for the Advanced Placement physics course.	1 2 3 4 5

16.	The department of education in conjunction with the university should offer some form of seminar to prepare teachers to teach Advanced Placement physics.	1 2 3 4 5
17.	There is a need to have Advanced Placement physics in the high school.	1 2 3 4 5

Section II

For the following questions, please choose the most appropriate response.

1. What grade should a student have in high school physics to be considered for physics 1200.

   a. 50 - 59
   b. 60 - 69
   c. 70 - 79
   d. 80 - 89
   e. 90 - 100

2. What grade should a student have in high school physics to be considered for physics 1050.

   a. 50 - 59
   b. 60 - 69
   c. 70 - 79
   d. 80 - 89
   e. 90 - 100

3. What should be the mathematics level of a student that is doing AP physics.

   a. level II academic completed
   b. level II advanced completed
   c. level III academic completed
   d. level III advanced completed
   e. concurrently doing AP Mathematics

4. How many students on average are there in a first year physics university class?

   a. 10 to 19
   b. 20 to 29
   c. 30 to 39
   d. 40 to 49
   e. in excess of 50; approximately how many students? _____

5. The difficulty level of first year university physics

   a. is much higher than AP physics.
   b. is higher than AP physics.
   c. is equal to AP physics.
   d. is lower than AP physics.
   e. is much lower than AP physics.

6. The work load of first year university physics

   a. is much higher than AP physics.
   b. is higher than AP physics.
   c. is equal to AP physics.
   d. is lower than AP physics.
   e. is much lower than AP physics.

7. The effort AP physics students place in first year university physics is

   a. much more than other students
   b. more than other students
   c. equal to that of other students
   d. less than other students
   e. much less than other students

8. First year university physics is

   a. much more in-depth than AP physics
   b. more in-depth than AP physics
   c. equal in-depth to AP physics
   d. less in-depth to AP physics
   e. much less in-depth to AP physics

9. The course content (# of topics) in first year university physics is

   a. much greater than AP physics.
   b. greater than AP physics.
   c. equal to AP physics.
   d. less than AP physics.
   e. much less than AP physics.

10. The minimum physics background for a high school physics teacher should be

   a. less than four courses in university physics
   b. less than eight courses in university physics
   c. minor in physics (at least 8 courses)
   d. major in physics
   e. masters in physics

11. The minimum physics background of an Advanced Placement physics teacher should be

   a. less than four courses in university physics
   b. less than eight courses in university physics
   c. minor in physics (at least 8 courses)
   d. major in physics
   e. masters in physics

12. The amount of lab work in AP physics should be

   a. up to 5% of class time.
   b. up to 10% of class time.
   c. up to 15% of class time.
   d. up to 20% of class time.
   e. in excess of 20% of class time; approximately what percentage? _____

13. How much time, on average, do you believe AP students spend studying and/or working at first year university physics?

   a. up to 3 hours per week
   b. up to 4 hours per week
   c. up to 5 hours per week
   d. up to 6 hours per week
   e. in excess of 7 hours per week; approximately how many hours? _____

14. How much time, on average, do you believe students who had not done AP physics spend studying and/or working at first year university physics?

a. up to 3 hours per week
b. up to 4 hours per week
c. up to 5 hours per week
d. up to 6 hours per week
e. in excess of 7 hours per week; approximately how many hours? ___

15. Compared to students who have completed Physics 1200/1201, AP students who complete Physics 2050, score

a. much higher than Physics 1200/1201 students
b. higher than Physics 1200/1201 students
c. equally as well with Physics 1200/1201 students
d. higher than Physics 1200/1201 students
e. much higher than Physics 1200/1201 students

Section III

Please answer the following free-response question.

Are there any further comments that you would like to make regarding high school physics and/or Advanced Placement physics and their relevance to the high school system or university?

Appendix D

Survey Data & Statistics

Section A: Student Survey Data

Question	Number	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
A1	62	8	11	23	12	8
A2	62	2	16	20	18	6
A3	61	5	19	18	16	3
A4	62	3	3	15	17	24
A5	62	0	8	16	23	15
A6	62	6	12	10	14	20
A7	62	14	19	14	9	6
A8	62	38	15	7	1	1
A9	62	43	10	4	4	1
A10	9	0	3	4	0	2
A11	9	3	5	0	0	1
A12	9	3	3	1	1	1
A13	9	4	2	1	1	1
A14	9	4	3	1	1	0
A15	9	2	4	1	2	0
A16	9	1	4	3	0	1
A17	9	0	2	4	3	0
A18	9	3	2	3	0	1
A19	9	5	1	1	2	0
A20	9	5	1	2	0	1
A21	9	5	0	1	1	2
A22-1050	4	0	1	0	3	0
A22-1200	5	1	1	2	1	0
A23	9	6	0	3	0	0
A25	9	1	1	2	3	2
A26	8	3	4	0	1	0

Responses A10-A26 are from AP physics students only.
-1050. responses from students enrolled in Physics 1050.
-1200: responses from students enrolled in Physics 1200.

Section A: Student Survey Statistics

Question	Number	Mean Response	Standard Deviation	Standard Error	Confidence Level @ 95%
A1	62	3.02	0.799	0.102	0.20
A2	62	3.10	0.824	0.105	0.21
A3	61	2.92	0.843	0.108	0.21
A4	62	3.56	0.668	0.085	0.17
A5	62	3.48	0.718	0.091	0.18
A6	62	3.26	0.886	0.113	0.22
A7	62	2.71	0.837	0.106	0.21
A8	62	2.18	0.463	0.059	0.12
A9	62	2.23	0.584	0.074	0.15
A10	9	2.89	0.782	0.261	0.51
A11	9	2.22	0.667	0.222	0.44
A12	9	2.56	0.882	0.294	0.58
A13	9	2.56	0.882	0.294	0.58
A14	9	2.33	0.707	0.236	0.46
A15	9	2.56	0.882	0.294	0.58
A16	9	2.56	0.726	0.242	0.47
A17	9	3.11	0.782	0.261	0.51
A18	9	2.56	0.726	0.242	0.47
A19	9	2.56	0.882	0.294	0.58
A20	9	2.44	0.726	0.242	0.47
A21	9	2.78	0.972	0.324	0.63
A22-1050	4	2.50	1.000	0.500	0.98
A22-1200	5	2.00	1.000	0.447	0.88
A23	9	2.33	0.500	0.167	0.33
A24	9	2.22	0.866	0.222	0.44
A25	9	3.33	0.667	0.289	0.80
A26	8	2.25	0.707	0.250	0.49

Responses A10-A26 are from AP physics students only.
-1050: responses from students enrolled in Physics 1050.
-1200: responses from students enrolled in Physics 1200.

Section B: Student Survey Data

Question	Number	(a)	(b)	(c)	(d)	(e)
B1	62	5	8	36	10	3
B2	64	5	13	22	6	18
B3	63	39	22	2	0	0
B4	63	46	14	3	0	0
B5	63	33	24	5	1	0
B6	63	38	22	2	1	0
B7	62	8	33	17	4	0
B8	63	51	9	2	1	0
B9	62	28	11	11	8	4
B10	63	2	5	12	22	22
B10-1050*	4	0	1	0	2	1
B10-1200*	5	0	0	0	3	2
B11	53	47	0	0	1	3
B12	64	29	9	20	5	1
B13	9	0	0	5	4	0
B14	9	0	7	0	2	0
B15	9	0	4	4	1	0
B16	9	1	8	0	0	0
B17	9	4	4	1	0	0
B18	9	0	7	1	1	0
B19	9	6	3	0	0	0
B20-1050	4	0	2	2	0	0
B20-1200	5	2	1	1	0	1
B21-1050	4	3	1	0	0	0
B21-1200	5	2	2	1	0	0
B22	8	1	7	0	0	0
B23	8	4	3	1	0	0
B24	8	2	3	3	0	0
B25	8	1	2	3	2	0
B26	8	0	1	4	3	0
B27	8	8	0	0	0	0
B28	9	3	1	2	2	1

Responses B13-B28 are from AP physics students only.
* AP sudent responses
-1050: responses from students enrolled in Physics 1050.
-1200: responses from students enrolled in Physics 1200.

Section B: Student Survey Statistics

Question	Number	Mean Response	Standard Deviation	Standard Error	Confidence Level @ 95%
B1	62	2.97	0.905	0.115	0.23
B2	64	3.30	1.293	0.162	0.32
B3	63	2.03	0.177	0.022	0.04
B4	63	2.05	0.215	0.027	0.05
B5	63	2.11	0.364	0.046	0.09
B6	63	2.06	0.304	0.038	0.08
B7	62	2.40	0.613	0.078	0.15
B8	63	2.06	0.304	0.038	0.08
B9	62	2.18	1.312	0.167	0.33
B10	63	3.90	1 073	0.135	0.27
B10-1050*	4	3.75	1.258	0.692	1.23
B10-1200*	5	4.40	0.548	0.245	0.48
B11	53	1.29	1.026	0.144	0.28
B12	64	2.06	1.111	0.139	0.27
B13	9	3.44	0.527	0.176	0.34
B14	9	2.44	0.882	0.294	0.58
B15	9	2.67	0.707	0.236	0.46
B16	9	2.00	0.000	0.000	
B17	9	2.11	0.333	0.111	0.22
B18	9	2.33	0.707	0.236	0.46
B19	9	2.00	0.000	0.000	0.57
B20-1050	4	2.50	0.577	0.289	0.57
B20-1200	5	2.40	1.673	0.748	1 47
B21-1050	4	1.25	0.500	0.250	0.49
B21-1200	5	2.00	1.225	0 548	1.07
B22	8	2.00	0.500	0.000	
B23	8	2.13	0.354	0.125	0.24
B24	8	2.38	0.518	0.183	0.36
B25	8	2.88	0.835	0.295	0.58
B26	8	3.25	0.707	0.250	0.49
B27	8	2.00	0.000	0.000	
B28	9	2.67	1.500	0.500	0.98

Responses B13-B28 are from AP physics students only.
* AP sudent responses
-1050: responses from students enrolled in Physics 1050.
-1200: responses from students enrolled in Physics 1200.

__Section C: Student Free Response__

Students (AP)

1. High school and AP physics cover a much broader range of topics than university physics and are much less in depth. I think high school physics/AP physics should include more labs because in university physics labs I felt very unprepared. Labs help to demonstrate the principles we learn so that they can make more sense. In high school I found that the principles just flew past me, there was nothing to enforce what we learned. High school gives a decent overview of a lot of topics, however, once at the AP level we should be taught topics more related to the university curriculum.

2. I really feel that AP physics should be offered in high schools. In my situation, the teacher was not familiar enough with the course to properly handle the AP physics but, I feel with a good instructor its a great course. The topics are the same so it gives you a background for the material in university physics.

3. I sincerely believe that any high school student who takes AP physics should be required to complete the necessary laboratory experiments (whichever are possible due to limited equipment). A student should not be able to get credit for first year university physics without completmg the labs, since laboratory sessions are so vital in college physics.

4. After competing the AP physics I felt more confident about the university physics.

5. In my high school the lab work was lacking because we didn't have the gear to do them. If we did the AP physics would have been much bettei with respect to preparing us for university physics.

Students (non-AP)

6. I think the physics course in high school if our teacher done a bit more work. I did a lot of work from the book in Physics 3204 (I think that's the number) and I found the book really good. With a bit more effort from the teacher the course would have been really good.

   I don't know anything about Advanced Placement, its the first time I heard of it, so I don't think I will be much help in your research.

7. I think high school physics is sufficient for the average high school student However, having a more in-depth and challenging AP course would be of greater benefit to those students who plan to attend university and study physics or other science courses.

8. AP physics should be made available to every student in this province regardless of their school size.

   Not only would it better prepare you for university physics but it would for those who could accelerate faster or go further in physics a chance to do so, and by doing so be on a level playing field to work with / discover with /challenge themselves against their fellow classmates in university physics.

9. High school physics should probably have a more in depth look at vectors which was the main concept throughout Physics 1050.

10. It is my opinion, that an average high school physics is not adequate preparation for first year university physics courses.

11. High school physics is much too easy and do not prepare you for university. Advanced Placement physics should be offered in high school so that people who go to university will have a better physics background.

12. High school physics was very simple. Although some topics covered in high school are covered now in university. I feel that I was prepared for the workload.

13. The major problem I found with high school physics was the lack of lab material, or in our school, the lack of a lab. We were learning a lot of concepts in the classroom but ere unable to apply these things in the laboratory. This limited our education and made the course a little less exciting. As well, when we came to the university, the whole process of labs, which is very demanding was new to us and made the physics course more difficult.

14. I did very well in high school physics so if there was an AP physics offered I would have taken it. The teacher I had asked the class questions constantly as he did not know the physics himself. The biggest problem with high school physics is the labs. There were very few labs and they were really trivial. I think high school students should do one lab a week like university to get some preparation for university physics labs.

15. I think that Advanced Placement physics offered to a select group of high school students with high averages in 3204 would better prepare students for university physics.

16. The high school physics program should be upgraded to prepare students for the level of difficulty that university physics poses. I would recommend AP physics to anyone planning on doing any university physics.

17. I think AP physics should be strongly recommended in high schools.
I also think high schools should have only physics majors teaching physics. I have often seen other types of science teachers teaching physics. (Let the Biology & Chemistry department teach Biology & Chemistry).

18. Personally, I feel that high school physics helped a little bit in preparing you for university but I think that it should be more in depth and in more details. They should make it more complicated. I also feel that the Advanced Placement physics should be offered in more high schools.

19. I think all students in high school should have the option of doing AP physics. I would have do it had it been offered in my school. I did to AP math and found it helped me a lot with university math.

20. The advanced placement math does not prepare you for the math required in physics. Also, if it is a university credit it should follow the same course outline as the university course it is supposed to give credit to. My younger brother did AP physics it was a well rounded course touching on many topics but going in-depth in none. this is a good idea however in university the physics course is mechanics or thermo, or E-M, or modern, so what are you going to give credit for you touched on topics covered in each but never completed the material in either. It should not be university credit or follow maybe the 1200 exactly so students can skip and go on to 1201 in university. I think a better idea is to use high school to prepare for university but not to give university credit.

21. First year university physics did not prepare me for second year university physics.
My teacher in high school was very good. So, the transition from high school physics to university physics (1st year) was not very 'bad'. Our lab in high school was poorly equipped, as it was for both chemistry and Biology
First year university physics used basically the same concepts but went deeper in analysis. First year was easy compared to second year. the work load of second year is absurdly large. Anybody who enjoyed 1st year physics and its elegance for making the seemingly complex so easy, will acquire a sour taste for physics after the bullshit work they must do for second year.

22. I feel that if students are interested in sciences then they should have the opportunity to grab at all the sciences they can get in high school. Therefore they will have the opportunity to maybe understand what sciences (physics, chemistry, like) are all about.

23. I did not have the opportunity to do AP physics in high school. Now that I'm in university, I realize that high school physics did not encourage students to think, I got through with good marks simply by memorizing what the teacher told me. University was a complete shock to me because not only did I have to know the formulas, I had to apply my knowledge in order to decide how to use the formula.

24. High school physics gave the most basic ideas and the more basic formula University physics further develops the ideas taught in high school. in high school a lot of emphasis was placed on knowing how to apply basic the basic ideas, in university we are taught where the ideas come from as well as how to apply them.

25. The level of difficulty of high school physics is fine for many students in the system. But for myself, I would have liked a course which would have made me work. I slept through high school physics and still received an 83% after the public. I believe the challenge of AP physics would have been good for me and other students in the class.

I also believe that there shouldn't be a grade limit in order to be accepted into advanced placement courses. Referring to myself, the marks I received in lower grades did not reflect my ability. I also know of one guy who took part in AP math but only received a high 60 in grade 10. The same guy received an award for the highest math mark during graduation ceremonies, and getting all A's in engineering.

I'd like to finish by saying that I'm a bit biased on the level of difficulty of high school after slaving away in university for almost two years.

26. I feel that the gap between high school and university is still very great and difficult to overcome.

27. My grade in high school was comparable to my grade after 1st year. there was however a near 50% fail rate in my first year classes, this is because the lack of high school prep and the level of testing. Firstly, there aren't enough physics majors teaching high school physics (which was not so in my case). Secondly, the level of testing was too low in high school.

As an illustration, let me tell you a story. My best friend and I who had taken physics 3204 together and finished with mid 90's each, were taking 'AP' simultaneously. The difference was that I was taking 1st year at SWGC, he was doing high school 'AP'. My final grade in 1201 was 90% while he 'barely' got 3/5 on his AP exam. I saw the AP exam and many of the questions were common to both and I feel that I could have written at least a 4/5!

I definitely think that an 'AP' course is only as good as the 'preparation.' I think that MUN should definitely prescribe the syllabus, and even administer the quizzes in order for the maximum benefit of such a course to be achieved. Furthermore I think that once 'high' standards for AP preparation is maintained, teachers should under no circumstances lower them because of failing numbers - Physics is tough and very few in high school is prepared (adequately) for the transition - so should be the case with 'AP' if it is to be beneficial," 1200-8.

28. I strongly recommend high school physics to any students who feel they may be interested in it.

29. In order to have AP physics in rural Newfoundland high schools, the academic level of the physics teachers will have to be raised first. In most small communities, these teachers are but adequately capable of teaching physics 3204, and totally incapable of handling an advanced placement course. This is a problem faced by not only AP physics, but AP mathematics, chemistry, etc. I indicated that I would have done AP physics had it been offered in my high school, but the limitations of my teacher were more of a deterrent to the program's availability than the small population of the school. Before any widespread implementation of AP physics in Newfoundland schools, the academic qualifications of the teachers will have to be addressed first.

30. I believe AP should be offered in all high schools for extra preparation for university.

31. Advanced Placement Physics should be offered in high school to prepare people for college, to give students an idea as to what university studies involve.

32. Time was not provided in my school to do AP physics, I was forced to do crap courses instead (it was offered but not in place of the less challenging courses. High schools should allow physics gifted students to pursue this during class time rather than slacker courses and still grant core credits.

33. <u>Physics 3204</u> - teacher did not have a clue.

34. I am <u>NOT</u> sure if this applies to AP physics as I did not do it but I <u>DID</u> do AP math, I found the teacher was not prepared to teach the course. It was too much material for a high school setting (e.g. 8 other courses and <u>1</u> university course). AP math scared me off from calculus even though now (in university) it has helped to have done the course.

35. Wish I could have did AP physics at (my school), but it wasn't offered.

Section A: High School Physics Teacher Survey Data

Question	Number	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
A1	93	12	42	23	13	3
A2	96	11	59	19	5	2
A3	96	26	45	18	7	0
A4	93	15	42	21	13	2
A5	93	8	38	21	17	9
A6	87	10	26	30	17	4
A7	96	59	27	5	2	3
A8	96	17	27	25	15	12
A9	96	63	26	2	2	3
A10	96	53	28	8	5	2
A11	94	28	17	20	19	10
A12	93	20	33	21	13	6
A13	95	60	24	2	3	6
A14	5	5	0	0	0	0
A15	5	2	0	2	1	0
A16	5	4	1	0	0	0
A17	5	3	2	0	0	0
A18	5	3	0	2	0	0
A19	5	3	2	0	0	0
A20	5	4	1	0	0	0
A21	5	5	0	0	0	0
A22	5	2	3	0	0	0
A23	5	5	0	0	0	0
A24	4	4	0	0	0	0
A25	3	1	0	1	1	0
A26	4	4	0	0	0	0
A27	4	0	0	0	2	2
A28	4	1	0	1	0	2
A29	4	2	0	2	0	0
A30	4	1	1	1	1	0
A31	4	2	1	0	1	0
A32	4	2	1	1	0	0
A33	4	4	0	0	0	0
A34	4	3	0	1	0	0
A35	4	3	1	0	0	0

Responses A14-A35 are from AP physics teachers only.

Section A: High School Physics Teacher Survey Statistics

Question	Number	Mean Response	Standard Deviation	Standard Error	Confidence Level @ 95%
A1	93	2.49	0.996	0.103	0.20
A2	96	2.25	0.808	0.082	0.16
A3	96	2.06	0.868	0.089	0.17
A4	93	2.41	0.992	0.103	0.20
A5	93	2.80	1.138	0.118	0.23
A6	87	2.76	1.045	0.112	0.22
A7	96	1.57	0.926	0.095	0.19
A8	96	2.77	1.269	0.130	0.25
A9	96	1.50	0.894	0.091	0.18
A10	96	1.70	0.975	0.099	0.19
A11	94	2.64	1.375	0.142	0.28
A12	93	2.52	1.216	0.125	0.25
A13	95	1.64	1.110	0.114	0.22
A14	5	1.00	0.000	0.000	
A15	5	2.40	1.342	0.600	1.18
A16	5	1.20	0.447	0.200	0.39
A17	5	1.40	0.548	0.245	0.48
A18	5	1.80	1.095	0.490	0.96
A19	5	1.40	0.548	0.245	0.48
A20	5	1.20	0.447	0.200	0.39
A21	5	1.00	0.000	0.000	
A22	5	1.60	0.548	0.245	0.48
A23	5	1.00	0.000	0.000	
A24	4	1.00	0.000	0.000	
A25	3	2.67	1.528	0.882	1.73
A26	4	1.00	0.000	0.000	
A27	4	4.50	0.577	0.289	0.57
A28	4	3.50	1.915	0.957	1.88
A29	4	2.00	1.155	0.577	1.13
A30	4	2.50	1.291	0.645	1.27
A31	4	2.00	1.414	0.707	1.39
A32	4	1.75	0.957	0.479	0.94
A33	4	1.00	0.000	0.000	
A34	4	1.50	1.000	0.500	0.98
A35	4	1.25	0.500	0.250	0.49

Responses A14-A35 are from AP physics teachers only.

Section B: High School Physics Teacher Survey Data

Question	Number	(a)	(b)	(c)	(d)	(e)
B1	90	20	67	2	1	0
B2	88	37	43	7	1	0
B3	85	23	44	14	4	0
B4	86	24	59	2	1	0
B5	45	0	17	25	3	0
B6	84	33	36	14	1	0
B7	88	34	25	13	12	4
B8	96	30	34	20	11	1
B9	94	7	30	27	15	15
B10	92	14	25	43	9	1
B11	96	21	35	20	17	3
B12	4	0	0	1	3	0
B13	4	0	0	0	2	2
B14	5	1	1	1	2	0
B15	5	0	1	1	3	0
B16	5	5	0	0	0	0
B17	5	0	2	3	0	0
B18	5	4	0	1	0	0
B19	5	0	2	3	0	0
B20	5	2	3	0	0	0
B21	5	5	0	0	0	0
B22	5	3	2	0	0	0
B23	5	0	1	4	0	0
B24	5	0	2	2	1	0
B25	5	0	1	0	3	1
B26	4	2	1	0	1	0
B27	4	0	2	0	1	1
B28	5	1	3	1	0	0
B29	5	0	0	1	0	4
B30	5	1	0	1	2	1

Responses B12-B30 are from AP physics teachers only

Section B: High School Physics Teacher Survey Statistics

Question	Number	Mean Response	Standard Deviation	Standard Error	Confidence Level @ 95%
B1	90	1.82	0.670	0.0538	0.11
B2	88	1.68	0.794	0.0715	0.14
B3	85	1.99	0.546	0.0861	0.17
B4	86	1.77	0.596	0.0589	0.12
B5	45	2.69	0.757	0.0889	0.17
B6	84	1.80	1.215	0.0826	0.16
B7	88	2.17	1.029	0.1295	0.25
B8	96	2.16	0.738	0.1051	0.21
B9	94	3.01	0.907	0.1233	0.24
B10	92	2.54	1.113	0.0945	0.19
B11	96	2.44	0.500	0.1136	0.22
B12	4	3.75	0.837	0.2500	0.49
B13	4	4.80	1.304	0.3742	0.73
B14	5	2.80	0.894	0.5831	1.14
B15	5	3.40	0.000	0.4000	0.78
B16	5	1.00	0.548	0.0000	
B17	5	2.60	0.894	0.2449	0.48
B18	5	1.40	0.548	0.4000	0.78
B19	5	2.60	0.548	0.2449	0.48
B20	5	1.60	0.000	0.2449	0.48
B21	5	1.00	0.548	0.0000	
B22	5	1.40	0.447	0.2449	0.48
B23	5	2.80	0.837	0.2000	0.39
B24	5	2.80	1.095	0.3742	0.73
B25	5	3.80	2.168	0.4899	0.96
B26	4	2.80	1.789	0.9695	1.90
B27	4	3.80	0.707	0.8000	1.57
B28	5	2.00	0.894	0.3162	0.62
B29	5	4.60	1.517	0.4000	0.78
B30	5	3.40		0.6782	1.33

Responses B12-B30 are from AP physics teachers only

Section C: Teacher Free Response

Teacher (AP)

1. AP physics students need 6 periods a week, each 50 minutes

2. If the Dept. wants the AP program in schools, then it must be willing to pay the cost of extra time, lab assistants, etc.

3. As you know, there are some great physics teachers in our province who have backgrounds in the Arts and Humanities, and not in science. Having a background is only a small part of being an AP physics teacher.

   Our present 3204 course has been designed, and rightly so, for our "average" clientele. If there are enough "gifted" students in a school, an "A" [accelerated] designation may be implemented into the program. If enough students are interested, at a higher level and wish to pursue Physics at University, then an AP course may be introduced. The accredited courses are designed to "channel" students into AP physics, and furthermore, AP physics will "bridge the gap" between high school and university.

   High school students should be encouraged to participate in higher level and challenging courses, not only because they receive advanced standing, but also because courses demand critical thinking, hard work, and commitment. In particular, an AP program challenges in a particular area such as Physics, and enables these people to develop extra knowledge and problem solving skills. Moreover, for those who have a particular interest in Physics, they may become aware that "physics may be a philosophy of life" and hopefully many of these students will reach the level of "responsibleness" which is so conspicuously absent in contemporary society

Teachers (non-AP)

4. High school - more topics should be covered, e.g Thermal Energy & Fluids Kinematics & Dynamics should be covered in one year not part 1st year and part 2nd year.

5 I'm not certain as to the quantity of courses at MUN are essential for any course in high school. I'm not certain as to the content of Advanced Placement Physics but I believe that the content of 2204 and 3204 could be more rigorous.

6 My understanding is that AP physics is first year university, so it does not prepare for 1st year physics I'm not sure I see the relevance of this study.

7 There ought to be increased communication amongst physics teachers across the province.

8. First year (university) would cover (the necessary background to teach physics in) high school!

9 I disagree with AP courses in that they draw resources including teacher prep time, and class time from average students in each course. AP should NOT be taught unless extra resources (including teacher time) are provided.

Develop some method of allowing high level students to (a) graduate early, (b) attend high level classes at MUN or community colleges.

10. AP physics & University physics: my ans‹ ers related to these questions are general in that I am not familiar with the exact syllabus of the course.

11. First, AP physics is not appropriate to most rural schools mainly because of size (class size and course restrictions). Second, The new program provides a good-reasonable amount of curriculum for the top 1/2 of the class. Third, physics requires the students to use their math skills. It is of primary importance to develop their math skills and secondly important to apply it to an AP physics program.

12. AP courses, in general, appear to be geared to a small percentage of high school students (because of combination of exceptional ability & strong work ethic/discipline required by students). I have serious doubts that it will ever become a part of the program of small to medium sized high schools. Declining enrollments & the last NLTA collective agreement will place great pressures on high schools throughout NF. to maintain their present programs. Thus a move to introduction of AP courses is not likely to occur without Special funding now given to projects such as Stem~Net.

13. I currently use computer interface technology in my computer labs. I strongly encourage the use of such technology, both in high school and at the university level. Computer technology makes physics more meaningful and relevant to the students. It also heightens their interest in physics in general.

14. The high school physics program is fine for the average student. I don't feel it prepares the student for university, but I also don't feel that this is the purpose of the course. Many students are not bound for university or colleges and we have to meet their needs as well. AP physics needs to be more widely promoted for university prep.

15. I have only taught high school physics and Physics AP [C]. I found that for the AP course I would not have finished with the average high school physics student. I was fortunate to have been working independently with an exceptional student. I have only taught maybe 6 students in 14 years who could have been successful in this program.

16. A minor in physics would be adequate if the appropriate courses are completed. A Major in physics is preferred.

Having been thrust into a situation where I was needed to teach physics with only two university courses, I can say that while the attempts to teach were notable, my knowledge was so severely lacking that students suffered.

Teachers should be required to have at least a minor in order to be allowed to teach the courses.

17. I'll be able to answer this when I see a copy of the curriculum for the new Maritime provinces initiative. I have no experience with AP curriculum, so I can't comment.

18. I feel the issue with physics is the combination of intellect, critical thinking and effort (time) required. Many students in my experience are used to memorizing and bluffing, neither of which are much help in physics. Physics will improve (success wise) only when students realize and accept that the course requires thought and consistent application and accept this task.

A number of students have indicated to me, on dropping the course, "it required too much work - I wanted to coast."

19 The number of physics courses (to teach physics) is not really relevant. Many university physics courses rarely touch the high school physics program.

As well, in my experience at least, many teachers with limited numbers of courses in a subject area spend more time in seeing the material is presented in an understandable fashion.

20 There are too many students participating (or lack of it) in physics courses that are not academically equipped. Also, students enroll in physics 2204, manage to pass, and then believe they can do the same in physics 3204. The gap between 2204 & 3204 means they end up failing. Also, teaching in a school where there is no physics lab and non-existent equipment makes life difficult.

21 The high school program in itself does not encourage critical thinking skills. As well the course content is not covered in depth, probably due to the level of math students have in high school. However, as a physics teacher with a background in the area, I try to extend beyond the actual course objectives. I would think that the background of the teacher would have a large influence on how the course is taught.

In terms of the AP physics I believe there is tremendous need for it, especially for those students who plan to pursue physics related careers. It offers the challenge that could tax the average student in P3204.

22. Why don't the Department of education and MUN physics dept. get together and bridge the gap between high school and university physics. I wonder how many first year physics professors & lecturers really know the high school curriculum. How many also make the assumption that the average high school physics student upon entering first year MUN physics courses knows <u>all</u> of the high school program. Some overlap (review) or redundancy is needed in the first year MUN courses.

23. With some rare exceptions I would feel that a regular course that sweeps across all areas would be sufficient. It should include omitted topics of heat, buoyancy, circular motion, & friction.

Labs are rarely well equipped and it seriously hinders easy & efficient use of labs to coincide with course material. Teacher (full-time) don't have sufficient prep time to adequately prepare these and as a result student effort and attitudes towards labs deteriorate noticeably.

24. I feel often the problem is not the relevance of high school physics to the high school or university system. Often poor student results is a result of expectation, work, and effort.

Advanced Placement physics should be offered for the gifted few. Often teachers can not be made available to teach such courses because of scheduling problems.

25. I think that many physics teachers would like to offer AP physics but the major problem is time. In a school like mine I'd probably get 3-4 students each year and I would never get an adequate time allotment for an AP course apart from the regular 3204 course. I'd end up having both groups together with a subsequent increase in work load (I already teach 6 science courses).

26. If physics is to be advanced in this province, some very critical problems must be addressed: (1) We need qualified physics teachers, i.e. people with extensive backgrounds in physics. (2) We need the proper lab facilities and materials to do the course properly.

These problems have existed for decades in our school system and the present direction of education in our province will do nothing to alleviate these problems.

27. The present high school physics program should be adequate preparation for university physics (both in depth and number of topics covered). AP physics, however, would be a valuable addition for the academically stronger (not necessarily 'gifted') student.

The relationship of university to school labs is difficult to assess. Though we do, I suggest, a greater number (of labs), the time would probably would not be as great I proportion nor would there be the same depth of treatment.

In your demographic information, should number of years teaching physics not have been of importance?

28. The new high school physics program is, in my opinion, much better than the old one & gives students a much better learning experience.

I do think that there needs to be more emphasis placed on getting quality science teachers in the junior high grades. The poor background in science which the junior high teachers have tends to give the students an equally poor background. Many who take physics in grade 10 thus find it difficult, & most opt to wait until grade 11 to start physics. This tends to rule out many possible candidates for the AP physics.

29 Currently the high school physics program deals with two courses, Physics 2204 and 3204, for students. I have found that some canable students are not prepared for physics by previous science courses and hence take some time to become adjusted. I would wish there to be a physics 1204 course as a starting point rather than an Advanced placement as an endpoint.

30. This is my first year teaching high school physics so I expect my lab time to go higher (up to 10-20%) and my prep time to go a little lower as years go by.

31. I am not up to date on first year Physics courses at MUN.

32. Too much emphasis is placed on a high school having AP physics. I think politics gets in the way and you have schools offering it just to get the better students and therefore more scholarships, etc.
Physics in school should be there for the average student to prepare him/her for the world we live in; certainly not have the responsibility of getting them through university physics.

33. I think that there is a need but the course cannot be carried out unless sufficient lab apparatus are available.

34. I would like a more general approach to physics including some historical events and background of some physicists. math background for Level I physics students is not sufficient to comfortably do some portions of 2204! e.g. Solving Doppler effect equation for Vs, and Lens equations.

35. I teach in a small school, therefore, chances of offering Advanced Placement physics is small. I am not familiar with the Advanced Placement physics program.

36. Concerning 3204, it is a step in the right direction in bridging the gap between high school and University/Trade School. It is by far the most difficult science course being offered today (ignoring AP).

37. High school physics is an important course not only for university bound courses but for all courses requiring a technology background (Cabot, Marine, etc.).

Advanced Placement is a good program but with the amount of time needed for preparation, the actual number of students involved (esp. in smaller schools), and the amount of lab materials required it is hard to justify. It would be a good course to offer by distance education with regional sites for lab work. This would work well for the St. John's regional area.

38. The present physics program could be more than enough if introductory calculus was done in high school in conjunction with the physics program.

39. See no purpose to AP physics & do not believe any public funds should be allocated to implementing the program.

40. AP should not be introduced on a wide spread basis. It should be used only to enhance physics study for very good students. I see no need to propel students quickly through their education. The concept of giving students a broader education should be maintained.

41. I am not familiar with any actual AP Physics in High school.

42. All schools should have equipment necessary for activities & some extra for demonstrations. For the age and maturity level of level I & II students, we need to show them concrete links between physics phenomena and practical applications. These demonstrations should be packaged by people knowledgeable in area and made available to all physics teachers. Also, modularize lessons.

43. Our school is a feeder school for eight communities and we loose many days of school due to poor weather and icy road conditions. Rightly or wrongly, under these conditions the labs are the first to be sacrificed as the struggle mounts to complete the course and offer a decent review. (This year, up to this point in time, we have missed 15.5 days of school).

I was appalled at the fact that the Provincial Government introduced a new physics course with not one red cent going to the purchase of lab equipment. Their actions speak loudly as to the Departments view of "lab priority".

44. More effort should be placed in offering seminars on teaching AP physics and high school physics. I believe the need and request is there.

45. Better labs are needed. More time should be allocated for in-school study (> 1-40 minute period for day. each topic needs to be expanded (e.g. motion - include circular motion).

46. I think it would make the transition from high school physics (AP) to university physics much easier.

47. High school physics can help students to think critically if the subject is taught appropriately - and thus would be more adequate preparation for students in 1st year university courses.

48. High school teachers should be made more aware of changes to relevant courses at the University (i.e. what is expected of a high school physics student entering MUN?).

49. I am answering questions based on my attendance at MUN 1965-1969 on the material that was in the degree program then, and on what I think is contained in AP physics?

50. Lack of students in small schools would be a fraction is availability of the course being offered. Here our average physics 3204 class is less than 10 students of which approximately 1/2 will enter post-secondary education.

51. I think the Dept. of education should consider having 3 levels of physics at the high school level. Students could do one course a year, e.g. Physics 1204, physics 2204, and physics 3204. Advanced placement Physics could then be a 4th option. The amount of material cannot be adequately covered in two courses.

52. High school physics teachers in smaller schools have to teach many other subjects and can't have an extensive background in each. Interest in the subject as well as a teacher who is willing to research and take advantage of resources available is a good alternative to an expertise in the subject.

53. I am not very familiar with the AP physics, but there is no doubt that it would benefit the academically gifted student. However, I teach in a small school where if we get to offer physics every two or three years it is considered a great achievement A growing number of Newfoundland schools are loosing enrollment, and thus fewer students, which makes it even harder to offer advanced courses due to lack of numbers. Therefore I consider your proposal of offering AP physics on schools in Newfoundland a noble, but essentially impractical endeavor for most schools in the province. I like the new physics program and so do most students and I feel that it prepares them fairly well for university.

54. I would be interested in some form of communication/liaison between the instructors in high school and those in our local university (or tech college) ... it would give us a better indication of the effect of the crossover. Right now, "we're" only as good as the PUBLIC EXAM Results!!!

I'm afraid I had to omit several of the AP questions, as I am not familiar with the course.

55. I understand that the purpose of AP physics was to better prepare students for university physics with its rigorous standards. However, I strongly believe that it is not the material covered that determines the success of a 1st year student, but rather their work/study habits.

If anything, high school needs to stop spoon-feeding its students. 1st year university students are suddenly free of the confines of their parents' rules/regulations and they no longer have to worry about the teacher calling home when the work isn't being done. This sudden freedom leads to failing grades. If it was just the content that was causing all the problems, how come many students without AP physics are successful in first year physics?

56. The Advanced Placement course offers the hard-working student (with some aptitude) an opportunity to study a greater range of topics. Without the name of "AP", I am sure that most administrations/boards would not allot a ratio of (10-15) students in a class. A third level physics course would be more practical than AP, but would administrators consider this as a necessity for gifted students.

57. Since lab work is such an important component of university physics we need an emphasis on this which includes involvement in independent investigations or science fairs. Computers and interfaces should also be introduced to physics students for more accurate experimentation.

58. Advanced Placement can only be properly offered if time is allotted for the teacher. It is not possible or reasonable to expect a high school physics teacher to simply take on Advanced Placement physics in place of P3204. There must be adequate non-teaching time provided. Essentially administrators and the Dept. have to come to grips with this problem. Essentially, the expectation presently is to merely teach AP physics as another course. If one were at MUN a full load would be 9 periods/week.

59. I am a strong believer in more challenging courses for our students. In smaller schools, of say less than 150 students per grade, it is going to be difficult to find a class of 18+ students to take the AP courses. Our board has a policy of not streaming students and there must be at least 18 students selecting a course before it will be offered

60. The transition from high-school to university would be made much easier if students were more able to handle the math. My basic problem was that you really couldn't challenge some of the class because they couldn't handle the math. However, I felt the students at "School X" were being much better prepared for university based on the fact that they had the chance to do calculus and statistics. I don't really think advanced physics is necessary, maybe if enough time was spent on task to cover the whole course would be sufficient.

61. Our school is very small. The best alternative for us would be distance education.

62. In general I agree with Advanced Placement courses but for very limited numbers of students. Labs would need to be much better equipped and access to information and resources (especially human resources) would have to be much better. I am presently teaching only the 3204 course but I am finding it difficult to squeeze in all the content in the time allocated.

63. I find the high school physics to be my favorite course to teach. the students seem to enjoy the course, especially the relationships to everyday lives.

I have not seen the requirements for Advanced Placement Physics so I can not comment on it.

Section A: Physics Professor Survey Data

Question	Number	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
A1	16	1	4	3	6	2
A2	11	5	4	2	0	0
A3	11	3	4	3	1	0
A4	11	2	6	1	2	0
A5	11	2	4	3	0	2
A6	9	1	4	2	1	1
A7	9	0	5	1	1	2
A8	7	1	0	3	1	2
A9	12	6	3	3	0	0
A10	13	4	2	2	2	3
A11	15	11	3	1	0	0
A12	9	3	4	2	0	0
A13	12	1	3	3	2	3
A14	14	0	4	6	1	3
A15	13	4	2	3	3	1
A16	12	5	5	1	0	1
A17	11	4	5	1	0	1

Section A: Physics Professor Survey Statistics

Question	Number	Mean Response	Standard Deviation	Standard Error	Confidence Level @ 95%
A1	16	3.19	0.911	0.228	0.45
A2	11	2.18	0.405	0.122	0.24
A3	11	2.45	0.688	0.207	0.41
A4	11	2.45	0.820	0.247	0.48
A5	11	2.64	0.809	0.244	0.48
A6	9	2.67	0.866	0.289	0.57
A7	9	2.78	0.972	0.324	0.63
A8	7	3.29	0.756	0.286	0.56
A9	12	2.25	0.452	0.131	0.26
A10	13	2.92	0.954	0.265	0.52
A11	15	2.07	0.258	0.067	0.13
A12	9	2.22	0.441	0.147	0.29
A13	12	3.08	0.900	0.260	0.51
A14	14	3.00	0.784	0.210	0.41
A15	13	2.85	0.899	0.249	0.49
A16	12	2.25	0.622	0.179	0.35
A17	11	2.07	0.267	0.071	0.14

Section B: Physics Professor Survey Data

Question	Number	# of (a)	# of (b)	# of (c)	# of (d)	# of (e)
B1	15	1	6	6	2	0
B2	15	0	0	0	12	3
B3	12	0	0	1	3	8
B4	16	0	0	2	1	13
B5	7	1	3	3	0	0
B6	7	3	2	2	0	0
B7	5	0	2	3	0	0
B8	7	1	3	3	0	0
B9	7	0	2	4	1	0
B10	14	0	1	6	6	1
B11	14	0	0	1	12	1
B12	15	0	2	3	8	2
B13	8	1	2	0	4	1
B14	13	1	2	3	4	3
B15	7	2	3	1	0	1

Section B: Physics Professor Survey Statistics

Question	Number	Mean Response	Standard Deviation	Standard Error	Confidence Level @ 95%
B1	15	2.60	0.828	0.214	0.42
B2	15	4.20	0.414	0.107	0.21
B3	12	4.58	0.669	0.193	0.38
B4	16	4.69	0.704	0.176	0.35
B5	7	2.43	0.535	0.202	0.40
B6	7	2.29	0.488	0.184	0.36
B7	5	2.60	0.548	0.245	0.48
B8	7	2.43	0.535	0.202	0.40
B9	7	2.86	0.690	0.261	0.51
B10	14	3.50	0.760	0.203	0.40
B11	14	4.00	0.392	0.105	0.21
B12	15	3.67	0.900	0.232	0.46
B13	8	3.25	1.389	0.491	0.96
B14	13	3.46	1.266	0.351	0.69
B15	7	2.43	0.787	0.297	0.58

<u>Section C: Physics Professor Free Response</u>

1. I would strongly recommend that anyone thinking of taking university physics (either 1200 or 1050) take AP physics, but **<u>NOT</u>** as a <u>substitute</u>. It is very difficult to imagine anyone who had completed AP physics going straight into 2nd year university physics courses and doing only a fair job. There's too big a gap between high school and university - not sure on which side - so university courses as too big a scale.

2. I have little knowledge of the Advanced Placement physics program in Newfoundland & Labrador. I know only of one such student, and that students did very well in our second year physics courses. I don't feel that I can comment in a constructive way on the topic of high school physics or Advanced Placement physics I knew of only one Advanced Placement student and this knowledge was not "first hand."

3. There is relentless pressure to raise the standards of 1st. year physics & math courses at university (i.e. Memorial) in order to achieve a favorable comparison with other parts of the country, and to permit completion of degrees in correspondingly comparable times. The high school courses must also raise the standards closer to the AP level. We must look forward to the day when the AP level will be the standard for grade 12.

4. Until recently, we did not know who among our students had taken AP physics You may be getting a lot of guessing here (from other surveys). That is why I neglected to answer many questions - so should most of us.

   AP has the potential to provide challenge to students and a 'competitive' physics stream as an alternative to usual high school and to MUN first year. This independent alternative should be pursued - syllabus should not be set by MUN physics.

   (AP physics teachers should have at least a) honors in physics.

   There have only been three such students (AP). One did very well, one did reasonably, ~ 70, and the other crashed on all courses at MUN.

5. I am unable to answer many of the questions as I know little about the AP syllabus. With more information I might be better able to answer your questions. Some of the stats on how AP students performs should be available from the registrar?? or the department (of Education). Also the question - did they perform better because of AP physics - is a difficult question to answer definitely.

6 I am glad to see AP physics in high schools. I wish now that it was there when I went through. I find that people do not have a good grasp on physics when they enter university except for the people who have completed AP physics or who had good majors in regular physics.

7 I'm really not sure what is being taught in AP physics.

8 As you can tell from the responses, I am not familiar with the performance of AP students. I teach Physics 1200 & 1201 and personally would not encounter AP students since (I believe) they bypass these courses and do Physics 2050.

9. I would prefer high school students taking physics in last year of high school, 1 year break is taking big toll.

10. I am unable to answer the questions referring to Advanced placement physics; I have essentially no knowledge of it. I have no way to know if any students I have taught have done AP, though I suspect that they are very few - likely none. (Some question simply that first year university students might have done AP - is this not a contradiction?). Perhaps someone in the school system , or from the Department of Education , could inform us in the University about these programs. Otherwise I could not evaluate them, nor can I suggest changes.

I am sorry not to have been able to help you. The principle need for high school physics is to promote it in all schools, with both levels offered in each, and to ensure suitable preparation of physics teachers in content, not methodology.

11. I think that the relationship between AP and first year physics is an important topic to study and I will be interested to hear what you find. The subject is complicated because the relationship between high school physics and university physics is evolving. Because of circumstances here, Physics 1200/1201 has been positioned somewhere between the traditional high school and 1st year levels (although this view is probably not shared by all my colleagues). The level of first year physics is a matter for current debate in the department.

We do not have a good way to identify AP students at this time using student records. We can see if a particular student got a transfer credit but it is more difficult to generate a list of such students. I guess the registrar can do this if asked. As far as I am aware, students with an AP credit go into 1050/1052 or into 2050. the comparison with 1200/1201 students is thus a bit trickier.

12. Only B.Ed., B.Sc. (physics) teachers should be eligible to teach High school physics.

Appendix E

Physics Syllabus

High School Physics 2204

1. *Introduction*

1.1. Historical Perspective
1.2. Units and Measurement
1.3. Physical and Mathematical Relationships
1.4. Describing Motion
1.5. The Concept and Measurement of Force

2. *Mechanical Energy*

2.1. Work
2.2. Power
2.3. Potential Energy
2.4. Kinetic Energy
2.5. Conservation of Energy
2.6. History, Society and Careers

3. *Wave Energy*

3.1. Vibrations
3.2. Waves
3.3. Sound
3.4. History, Society and Careers

4. *Light*

4.1. Light Production and Transmission
4.2. Reflection in Plane Mirrors
4.3. Reflection in Curved Mirrors
4.4. Refraction of Light
4.5. Refraction by Lenses
4.6. The Nature of Light
4.7. History, Society and Careers

5. ***Elective (Select ONE of the following elective topics)***

5.1. Energy Considerations in House Design and Construction
5.2. The Physics of Music
5.3 The Physics of Photography
5.4 Laser Physics

Note. Adapted from *Physics 2204 Curriculum Guide* (p. 6), by the Department of Education, Division of Program Development, 1991, St. John's: Government of Newfoundland and Labrador.

High School Physics 3204

1. ***Vector Kinematics***

- 1.1. Uniform Motion: Definitions and Graphs
- 1.2. Accelerated Motion: Definitions and Graphs
- 1.3. Uniform Acceleration: An Algebraic Treatment
- 1.4. Relative Velocities
- 1.5. History, Society, and Careers

2. ***Dynamics***

- 2.1. Concepts of Force
- 2.2. Newton's Laws of Motion
- 2.3. Forces in Nature
- 2.4. Momentum and Impulse
- 2.5 Conservation of Linear Momentum
- 2.6. History, Society, and Careers

3. ***Electrostatics***

- 3.1. Electrostatics
- 3.2. Coulomb's Law
- 3.3. Electric Fields
- 3.4. Electric Potential
- 3.5. History, Society, and Careers

4. ***Current Electricity***

- 4.1. Electric Current, Energy, and Electromotive Force
- 4.2. Kirchoff's Circuit Rules
- 4.3. Current-Voltage Relationship for Simple Circuit Elements
- 4.4. Electrical Resistance and Series & Parallel Circuits
- 4.5. Power in Electric Circuits
- 4.6. History, Society, and Careers

5. ***Magnetism, Electromagnetism, and Electromagnetic Induction***
   - 5.1. Magnetism
   - 5.2 Moving Charges and Magnetic Fields - Electromagnetism
   - 5.3. Electromagnetic Induction
   - 5.4 History, Society, and Careers

6. ***Elective (Select ONE of the following elective topics)***
   - 6.1. The Physics of Oceanography
   - 6.2. The Physics of Astronomy
   - 6.3. Nuclear Physics
   - 6.4. Electronics

Note. Adapted from *Physics 3204 Curriculum Guide* (p. 6), by the Department of Education, Division of Program Development, 1991, St. John's: Government of Newfoundland and Labrador.

Advanced Placement Physics B

I. MECHANICS

A. *Kinematics*

1. Vectors, vector algebra, components of vectors, and coordinate systems
2. Displacement, velocity, and acceleration
3. Motion in one dimension
4. Motion in two dimensions
   a) Projectile Motion
   b) Uniform Circular Motion

B. *Newton's Laws of Motion (including friction and centripetal force)*

1. Static Equilibrium (First Law)
2. Dynamics of a single particle (Second Law)
3. Systems of two or more bodies (Third Law)

C. *Work Energy and Power*

1. Work and the Work-Energy Theorem
2. Conservative Forces and potential energy
3. Conservation of Energy
4. Power

D. *Systems of particles, and Linear Momentum*

1. Center of Mass
2. Impulse and Momentum
3. Conservation of Momentum
   a) in one dimension
   b) in two dimensions

E. *Rotation*

1. Torque and Rotational Statics
2. Moment of Inertia
3. Conservation of Angular Momentum

F. ***Oscillations and gravitation***

1. Simple Harmonic Motion (dynamics and Energy relationships)
2. Mass on a spring
3. Pendulum and other oscillations
4. Newton's Law of Gravity
5. Orbits of Planets
    a) Circular
    b) General

II. HEAT, KINETIC THEORY & THERMODYNAMICS

A. ***Temperature and Heat***

1. Mechanical Equivalent of Heat
2. Specific and Latent Heat (including Calorimetry)
3. Other (including heat transfer and thermal expansion)

B. ***Kinetic Theory and Thermodynamics***

1. Ideal Gases
    a) Kinetic Model
    b) Ideal Gas Law
2. Laws of Thermodynamics
    a) First Law (including processes on P-V diagrams)
    b) Second Law (including Heat Engines)

III. ELECTRICITY AND MAGNETISM

A. ***Electrostatics***

1. Charge, field, and potential
2. Coulomb's Law and field and potential of point charges
3. Fields and potentials of other charged distributions
    a) Planar
    b) Spherical symmetry
    c) Cylindrical symmetry
4. Gauss's Law

B. ***Conductors, Capacitors, and Dielectrics***

1. Electrostatics with conductors
2. Capacitors
    a) Parallel plated
    b) Spherical and cylindrical
3. Dielectrics

C. ***Electric Circuits***

1. Current, resistance, and power
2. Steady-state direct current circuits with batteries and resistors only
3. Capacitors in circuits (RC circuits)
    a) Steady state
    b) Transients in RC circuits

D. ***Magnetostatics***

1. Forces on moving charges in magnetic fields
2. Forces on current-carrying wires in magnetic fields
3. Fields of long current-carrying wires
4. Biot-Savart and Ampere's Law

E. ***Electromagnetism***

1. Electromagnetic induction
2. Inductance (including LR and LC circuits)
3. Maxwell's Equations

IV. WAVES & OPTICS

A. ***Wave motion***

1. Properties of travelling waves
2. Properties of Standing Waves
3. Doppler Effect
4. Superposition
5. Interference and Diffraction
6. Dispersion of Light and the Electromagnetic Spectrum

B. ***Geometric Optics***

1. Reflection and Refraction
2. Mirrors
3. Lenses

V. MODERN PHYSICS

A. Atomic Physics and Quantum Effects

1. Alpha particle scattering and the Rutherford model
2. Photons and the photoelectric effect
3. Bohr Model and energy levels
4. Wave-Particle Duality
5. Other topics

B. Nuclear Physics

1. Radioactivity and half-life
2. Nuclear Reactions (including conservation of mass number and charge)
3. Other topics

C. Special Relativity

1. Postulates of Special Relativity
2. Space and time effects
3. Mass and energy effects

VI. MISCELLANEOUS

1. Identification of vectors and scalars
2. Vector mathematics
3. Graphical presentation of data, and graphs of functions.
4. Questions that overlap several topical areas
5. History of physics

Note. Adapted from *Advanced Placement Course Description Physics B, Physics C* (p. 9-14), by The College Board, 1992, Princeton, New Jersey: The College Board.

Physics 1200 (Memorial University)

1. Introduction & Mathematical Concepts

1.1. Nature of physics
1.2. Units
1.3. The role of units in problem solving.
1.4. Trigonometry
1.5. Scalars and vectors
1.6. Vector addition and subtraction
1.7. Vector components
1.8. Addition of vectors by means of vector components

2. Kinematics in One Dimension

2.1. Displacement
2.2. Speed and velocity
2.3. Acceleration
2.4. Equations of kinematics for constant acceleration
2.5. Applications of the equations of kinematics
2.6. Freely falling bodies
2.7. Graphical analysis of velocity & acceleration for linear motion

3. Kinematics in Two Dimensions

3.1. Displacement, velocity, & acceleration
3.2. Equations of kinematics in two dimensions
3.3. Projectile motion
3.4. Relative velocity

4. ***Forces & Newton's Laws of Motion***
    4 1 The concepts of force and mass
    4 2 Newton's First Law of Motion
    4 3 Newton's Second Law of Motion
    4 4 The vector nature of Newton's Second Law of Motion
    4 5 Newton's Third Law of Motion
    4 6. The gravitational Force
    4 7. Weight
    4 8. The normal force
    4 9 Static & kinetic frictional forces
    4 10 The tension force
    4 11. Equilibrium applications of Newton's Laws of Motion
    4 12 Non equilibrium applications of Newton's Laws of Motion

5. ***Dynamics of Uniform Circular Motion***
    5.1. Uniform circular motion
    5 2. Centripetal acceleration
    5 3 Centripetal force
    5 4 Banked curves
    5.5 Satellites in circular orbits
    5.6. Apparent weightlessness and artificial gravity
    5 7. Vertical circular motion

6. ***Work & Energy***
    6 1 Work
    6.2. The Work-Energy Theorem
    6.3 Gravitational potential energy
    6.4. Conservative forces & non conservative forces
    6 5. The conservation of mechanical energy
    6 6. Non conservative forces and the Work-Energy Theorem
    6.7. Power
    6 8. Other forms of energy & the conservation of energy

7. ***Impulse & Momentum***
   7.1. The Impulse-Momentum Theorem
   7.2. The principle of conservation of linear momentum
   7.3. Collisions in one dimension
   7.4. Collisions in two dimensions
   7.5. Rocket propulsion

8. ***Rotational Dynamics***
   8.1. The effects of forces and torques on the momentum of rigid bodies
   8.2. Rigid objects in equilibrium
   8.3. Center of gravity

9. ***Fluids***
   9.1. Mass and density
   9.2. Pressure
   9.3. The relation between pressure and depth in static fluid
   9.4. Pressure gauges
   9.5. Pascal's principle
   9.6. Archemedes' Principle

Note. Adapted from *Physics, 2nd ed.* (p. xxiii-xxv), by J.D. Cutnell., & K.W. Johnson, 1992, Toronto John Wiley & Sons.

Physics 1201 (Memorial University)

(Adapted from the table of contents of Cutnell & Johnson's Physics, Second Edition)

1. Elasticity & Simple Harmonic Motion

1.1. The Ideal Spring & Simple Harmonic Motion
1.2. Simple Harmonic Motion & the Reference Circle
1.3. Energy & Simple Harmonic Motion

2. Waves & Sound

2.1. The Nature of Waves
2.2. Periodic Waves
2.3. The Speed of a Wave on a String
2.4. The Mathematical Description of a Wave
2.5. The Nature of Sound
2.6. The Speed of Sound
2.7. Sound Intensity
2.8. Decibels
2.9. Applications of Sound
2.10. The Doppler Effect
2.11. The Sensitivity of the Human Ear

3. The Principle of Linear Superposition & Interference Phenomena

3.1. The Principle of Linear Superposition
3.2. Constructive & Destructive Interference of Sound Waves
3.3. Diffraction
3.4. Beats
3.5. Transverse Standing Waves
3.6. Longitudinal Standing Waves
3.7. Complex Sound Waves

4. ***Electric Forces & Electric Fields***
   - 4.1. The Origin of Electricity
   - 4.2. Charged Objects & the Electric Forces That They Exert
   - 4.3. Conductors & Insulators
   - 4.4. Charging By Contact & Induction
   - 4.5. Coulomb's Law
   - 4.6. The Electric Field
   - 4.7. Electric Field Lines
   - 4.8. The Electric Field Inside a Conductor: Shielding
   - 4.9. Copiers & Computer Printers

5. ***Electric Potential Energy & the Electric Potential***
   - 5.1. Potential Energy
   - 5.2. The Electric Potential Difference
   - 5.3. The Electric Potential Difference Created by Point Charges
   - 5.4. Equipotential Surfaces & Their Relationship to the Electric Field
   - 5.5. Capacitors & Dielectrics
   - 5.6. Medical Applications of Electric Potential Differences

6. ***Electric Circuits***
   - 6.1. Electromotive Force & Current
   - 6.2. Ohm's Law
   - 6.3. Resistance & Resistivity
   - 6.4. Electric Power
   - 6.5. Alternating Current
   - 6.6. Series Wiring
   - 6.7. Parallel Wiring
   - 6.8. Circuits Wired Partially in Series & Partially in Parallel
   - 6.9. Internal Resistance
   - 6.10. Kirchhoff's Laws
   - 6.11. The Measurement of Current, Voltage, & Resistance
   - 6.12. Safety & the Physiological Effects of Current

7. ***Magnetic Forces & Magnetic Fields***
    7.1. Magnetic Fields
    7.2. The Force That a Magnetic Field Exerts on a Moving Charge
    7.3. The Motion of a Charged Particle in a Moving Field
    7.4. The Mass Spectrometer
    7.5. The Hall Effect
    7.6. The Force on a Current in a Magnetic Field
    7.7. The Torque on a Current-Carrying Wire
    7.8. Magnetic Fields Produced by Currents
    7.9. Magnetic Materials
    7.10. Operational Definitions of the Ampere and the Coulomb

8. ***Electromagnetic Induction***
    8.1. Induced Emf and Induced Current
    8.2. Motional Emf
    8.3. Magnetic Flux
    8.4. Faraday's Law of Electromagnetic Induction
    8.5. Lenz's Law
    8.6. Applications of Electromagnetic Induction to the Reproduction of Sound
    8.7. The Electric Generator
    8.8. Mutual Inductance and Self-Inductance
    8.9. Transformers

9. ***The Reflection of Light: Mirrors***
    9.1. Wave Fronts & Waves
    9.2. The Reflection of Light
    9.3. The Formation of Images by a Plane Mirror
    9.4. Spherical Mirrors
    9.5. The Formation of Images by Spherical Mirrors
    9.6. The Mirror Equation and the Magnification Equation

10. *The Refraction of Light: Lenses & Optical Instruments*

10.1. The Index of Refraction
10.2. Snell's Law & the Refraction of Light
10.3. Total Internal Reflection
10.4. The Dispersion of Light: Prisms & Rainbows
10.5. Lenses
10.6. The Formation of Images by Lenses
10.7. The Thin-Lens Equation & the Magnification Equation
10.8. Lenses in Combination
10.9. The Human Eye
10.10. Lens Aberrations

Note. Adapted from *Physics, 2nd ed.* (p. xxiv-xxviii), by J.D. Cutnell., & K.W. Johnson, 1992, Toronto: John Wiley & Sons.