ANALYZING THE CORRELATION BETWEEN PRE-INSTRUCTION MATHEMATICS SKILL AND EXAM RESULTS IN AN INTRODUCTORY PHYSICS COURSE OF ENGINEERING STUDENTS AT SURANAREE UNIVERSITY OF TECHNOLOGY

META POPANAO

A Thesis Submitted in Partial Fulfillment of the Requirements for the

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การวิเคราะห์สหสัมพันธ์ระหว่างทักษะคณิตศาสตร์ก่อนเรียน และผลการสอบในรายวิชาฟิสิกส์เบื้องต้นของนักศึกษาวิศวกรรม มหาวิทยาลัยเทคโนโลยีสุรนารี

นายเมธา โพธิ์พะเนาว์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
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Suranaree University of Technology has approved this thesis submitted in partial fulfillment of the requirement for a Master's Degree.

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เมธา โพธิ์พะเนาว์ : การวิเคราะห์สหสัมพันธ์ระหว่างทักษะคณิตศาสตร์ก่อนเรียน และผลการสอบในรายวิชาฟิสิกส์เบื้องต้นของนักศึกษาวิศวกรรมศาสตร์ มหาวิทยาลัยเทคโนโลยีสุรนารี
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คำสำคัญ: สหสัมพันธ์, การวิเคราะห์แบบทดสอบ, ทักษะการแก้ปัญหาฟิสิกส์

รายวิชาฟิสิกส์เบื้องต้น ณ มหาวิทยาลัยเทคโนโลยีสุรนารี (มทส.) มีนักศึกษาราว 200 ถึง 300 คนต่อห้อง นักศึกษาแต่ละคนมีแนวทางการเรียนรู้ต่างกัน ในทางอุดมคตินั้นบทเรียนต่าง ๆ จะถูกออกแบบมาเพื่อตอบสนองรูปแบบการเรียนรู้ที่ต่างกันของแต่ละคนได้ ซึ่งการออกแบบบทเรียนนี้จะยิ่งยากขึ้นหากผู้สอนหนึ่งคนต้องรับผิดชอบสอนนักศึกษาในจำนวนมาก เพื่อให้การออกแบบบทเรียนง่ายขึ้น เป้าหมายของวิทยานิพนธ์นี้คือการหาสหสัมพันธ์ระหว่างผลการสอบคณิตศาสตร์ก่อนเรียนของนักศึกษา และผลการสอบวิชาฟิสิกส์เบื้องต้น โดยต้องการหาว่าเนื้อหาใดในคณิตศาสตร์ที่ส่งผลต่อความสามารถในการแก้ปัญหาฟิสิกส์ในหัวข้อต่าง ๆ การศึกษานี้ได้รวบรวมคะแนนสอบคณิตศาสตร์ก่อนเรียนและผลสอบรายวิชาฟิสิกส์ 1 จากนักศึกษาวิศวกรรมศาสตร์ ชั้นปีที่ 1 ที่ลงทะเบียนในรายวิชาฟิสิกส์ 1 ในภาคการศึกษาที่ 1 และ 2 ประจำปีการศึกษา 2563 และได้จัดหมวดหมู่ข้อสอบแต่ละข้อในข้อสอบคณิตศาสตร์และฟิสิกส์เพื่อนำมาหาค่าสหสัมพันธ์ ผลการศึกษาพบว่า หัวข้อพีชคณิตมีค่าสหสัมพันธ์สูงที่สุดจากสามหัวข้อ ตามมาด้วยเรขาคณิต และแคลคูลัส ตามลำดับ เมื่อเทียบกับนักศึกษากลุ่มที่คะแนนสอบอยู่ในเกณฑ์ต่ำกว่า และ กลุ่มที่สูงกว่าแล้ว ค่าสหสัมพันธ์เหล่านี้จะสูงกว่าอย่างเห็นได้ชัดสำหรับนักศึกษาที่ผลการสอบคณิตศาสตร์ไม่สูง ผลการศึกษานี้ยืนยันได้ว่าคณิตศาสตร์เป็นเครื่องมือที่ใช้ทำนายได้ว่านักศึกษาจะล้มเหลวในการเรียนได้ดีกว่าการทำนายความสำเร็จ ผลการทดลองยังทำให้สังเกตได้ถึงความแตกต่างระหว่างเพศหากใช้การทดสอบที (t-test) ในการเปรียบเทียบค่าเฉลี่ยของคะแนน และความแตกต่างนี้ลดลงหากนักศึกษาได้มีประสบการณ์ในรายวิชาที่เกี่ยวกับคณิตศาสตร์ในระดับมหาวิทยาลัยมาแล้ว 1 ภาคการศึกษา

สาขาวิชาฟิสิกส์ ลายมือชื่อนักศึกษา____________

ปีการศึกษา 2565 ลายมือชื่ออาจารย์ที่ปรึกษา____________

META POPANAO : ANALYZING THE CORRELATION BETWEEN PRE-INSTRUCTION MATHEMATICS SKILL AND EXAM RESULTS IN AN INTRODUCTORY PHYSICS COURSE OF ENGINEERING STUDENTS AT SURANAREE UNIVERSITY OF TECHNOLOGY. THESIS ADVISOR : ASST. PROF. MICHAEL F. SMITH, Ph.D. 60 PP.

Keyword: Correlation, Test analysis, Physics problem solving skill

An introductory physics class in Suranaree University of Technology (SUT) has around 200 to 300 students. Individual students have different learning styles. Ideally, the lessons would be tailor-made for each of them. The lessons design would be harder if an instructor has a lot of students in their responsibility. With a hope to make the lessons design easier, the goal of this thesis is to correlate student's pre-instruction mathematics test results and their introductory physics exam results to find that which particular mathematics skill would impact the student's physics problem-solving in specific areas of introductory physics. We collected the pre-instruction mathematics test results and physics 1 exam results of the first-year engineering student in the first and the second trimester of year 2020 and categorizing the items in mathematics test and physics exams to find the correlation. It is found that algebra has the strongest correlation, out of 3 topics, on most physics topics followed by geometry and calculus respectively. The correlation between students' mathematics and physics score appears to be more pronounced when their mathematics scores are lower, compared to hen their math score are higher. This confirms that mathematics skill is a better predictor of failure in physics more than a predictor of success. The gender gap is also observed when comparing mean of score between genders using t-test. This gap is lessened when the students have experience in university mathematics course for one trimester.

School of Physics | Student's Signature_______________

Academic Year 2022 | Advisor's Signature_______________

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CHAPTER I

INTRODUCTION

The main goals of introductory physics courses are to guide students to i) understand physics concepts and ii) learn to apply them to relevant problems. Because individuals have different learning styles, some students will find that the course presentation does not suit them and will struggle with the physics material. Ideally, lessons would be tailored to each of them. But this is often a practical impossibility because of class sizes and limited resources. The typical number of first-year engineering students at Suranaree University of Technology (SUT) is around 2000 students. When they take Physics I, either in the first or the second group, the students are distributed into several sections of 200 to 300 students. It is challenging to develop effective teaching strategies that might achieve the course goals.

Many studies have shown that pre-instruction mathematical skill and student performance in introductory physics classes have positive correlation (Hudson et al., 1977; Hudson et al., 1981; Hudson et al., 1982; Meltzer 2002). It is not surprising that aptitudes for mathematics and physics are correlated; however, a detailed picture of how a knowledge of a particular concept in mathematics impacts the student's ability to learn to solve problems in specific areas of introductory physics would be helpful in crafting physics instruction. That is, if we understood which mathematical skills are vital for acquiring a certain physics problem-solving skill, then we could design the physics course with such connections in mind. This may help provide some of the benefits of an individualized education to SUT physics in spite of limited resources and time constraints. It is reasonable to suppose that insight gained into the case of SUT students will be of interest to the general physics education community.

For this thesis work, we are interested in investigating correlations between first year SUT engineering students' pre-instruction mathematics knowledge and their physics 1 course performance. These are the research questions of our study:

1) Which pre-instruction mathematics topics do SUT students struggle with the most?

2) For which mathematics topics if any, is the prior knowledge of students a reliable predictor of physics course performance?

3) Is there an observable gender gap in the following: pre-instruction mathematics knowledge, physics exam performance, or the correlation between the two?

In 2020, just prior to the shutdown of in-person classes imposed by Covid restrictions, SUT physics instructors administered mathematics tests to two groups of incoming first-year engineering students before they began their university physics courses. The first and the second group took the introductory physics course in the first and second trimester respectively. With these test results, as well as the physics exam results, we did the corresponding statistical analyses to address the above questions.

1.1 Literature Review

It is not surprising that mathematics knowledge is necessary for those who want to learn physics, as physics is a quantitative study of nature. Certainly, those who struggle with mathematics are expected to have a hard time solving physics problems (Redish, 2006; Sidhu, 2006). Many studies suggest that the relationship between university students understanding of mathematics and physics is complex, since students need more than mathematical skills to effectively learn physics (Sweller, 1998; Ince, 2018; Franestian et al., 2020). Within the body of literature, there are two common approaches to study this connection. The first is to consider the correlation between pre-instruction mathematics knowledge and students' final grade in a physics course. The second is to consider the correlation between pre-instruction mathematics knowledge and students' learning gain in a physics course.

In a study at the University of Houston, the researchers investigated the relationship between pre-instruction trigonometry and algebra knowledge and physics performance (Hudson et al., 1976). They had their 194 students took a pre-instruction 30-minute mathematics test. The exam consisted of 18 questions, all related to algebra and trigonometry, and they found that Pearson product moment correlation between the test scores and the final physics grades is positive but weak, meaning that the final grade tends to be slightly higher with the mathematics test score. A few years later, a similar result was found for 913 students, who completed the same course (Hudson et al., 1981). The number of mathematical questions, in this latter work, was increased to 28. The researchers concluded that the pre-instruction mathematics knowledge alone did not guarantee success in physics. In addition, they found that score of the mathematics pre-test did not predict the students' drop-out rate. Later work by the same group investigated the combined effect of students' mathematical skill and operational reasoning on success in physics (Hudson et al., 1982). By having another group of students take an additional test of formal operational reasoning. A stepwise multiple regression analysis was used to determine the combined effect and it was found that the correlation of the combined effect on students' success in physics was significantly stronger than mathematics alone.

As mentioned above, another approach to study the connection is to look for correlation between students' scores on a mathematics test taken before a physics course and the students' learning gain in physics over the duration of the course. The learning gain is defined as the relative change in grades obtained in same test that administered as pre-test and post-test. The idea is that previous knowledge in mathematics may affect students' ability to improve their understanding of physics. In Meltzer's work (Meltzer, 2002), the students took a mathematics test and a test on the physics of electricity on the first day of class (this physics test is termed the pre-test). The scores were compared to their final examination grades in this electricity course. It was found that the pre-test physics score did not significantly correlate with the normalized learning gain, the ratio between the different between pre-test score and post-test score on the same test and the maximum different. However, the mathematics score did correlate with the normalized learning gain. Similar results were obtained in the research from University of New England (Buick, 2007).

Kim and Pak reported that solving 300-2,900 quantitative problems did not help students comprehend physics concepts (Kim et al., 2002). On the other hand, the work by Turşucu and co-workers showed that students with pre-existing algebraic skills have an advantage in physics problem-solving (Turşucu et al., 2020).

Researchers from the University of Port Harcourt, Nigeria, studied the effect of the instructional strategies, gender, and mathematics abilities of 200 students in senior secondary school on the normalized learning gain (Charles-Ogan et al., 2017). They found that there were significant correlations between instructional strategy and gain, and between mathematical ability and the normalized learning gain.

To gain more insight into the correlation of students' mathematical skills with their learning of physics, one may try to investigate the students' reasoning processes during problem solving. Yeatts and Hundhausen (Yeatts et al., 1992) reported that students struggled at transferring their knowledge from calculus to physics. The researchers from Kansas State University also investigated the students' knowledge transfer from calculus to physics by asking the students to solve electromagnetic problems that require calculus operation and describe what steps they made (Cui, 2006). They found that, although students were able to solve calculus problems, they were often unsure if they needed to apply calculus in a given problem. Later, from the same department, another group of researchers developed a so-called conceptual blending framework to investigate the student deficiencies when they solved electromagnetic problems (Hu et al., 2013). It was discovered that students were unable to blend their mathematics and physics knowledge to set up integrals. They discussed several types of so-called blends and possible strategies to change poor blends into productive blends. Additional work on students' difficulties in applying mathematics to physics has been done elsewhere (Nguyen et al., 2011a; Nguyen et al., 2011b; Wilcox et al., 2013; Bollen et al., 2015).

1.2 The Outline of Thesis

The next parts of this thesis are organized as follows. In Chapter II and III, we report the results and discussion of SUT students' performance on pre-instruction mathematics tests and their physics exams respectively. The results and discussion related to the correlation between the mathematics test scores and the physics exam scores are presented in Chapter IV. The conclusion is given in Chapter V. We provide all the questions of the mathematics tests and physics exam in the Appendix.

1.3 Methodology

This thesis can be divided into 4 steps.

1.3.1 Estimate the Validity and Reliability of the Exams

The results from the exams will be taken seriously if and only if the exams is valid and reliable. The validity and reliability of the mathematics tests physics exams will be mentioned in Chapter III and Chapter IV respectively.

1.3.2 Categorize the Exam

Mathematics tests will be categorized into 3 categories including algebra, geometry, and calculus. This categorization for each item is judged by the experts, the researchers. Physics exams will be categorized into 11 categories based on the lesson in class.

1.3.3 Analyze the Students' Performance

To analyze the students' performance, the average score of the students in both trimesters will be compared category wise.

1.3.4 Calculate the Pairwise Correlation between Categories

The correlation between mathematics and physics categories will be calculated using Pearson's product moment correlation. The correlation will be mentioned in Chapter V.

CHAPTER II

PRE-INSTRUCTION MATHEMATICS TEST RESULTS

In this chapter we present the overall pre-instruction test results and detailed itemized analyses for the test questions. We give details on validity and reliability of each item in the test as well as those for the test as a whole.

2.1 Overall Test Results

In the first trimester of academic year 2020 at SUT, 1,392 first-year engineering students enrolled in the Physics I course. Because of the limited classroom capability, they were separated into 7 sections of different classrooms and different instructors. Of these, 1,280 students took the pre-instruction mathematics test, which was administered in the first class for each section. In the second trimester, 658 students enrolled in the course. They were separated into 6 sections, and 531 of them took a similar test. It should be noted here that the students were distributed into many sections, each of which contain 200 to 300 students. The students in both trimesters were the university newcomer. They were separated by the registration department into two trimesters only because of the limited classroom. The enrolled trimester and the section were also randomly chosen by the registration department. With this registration policy, the students in the first trimester did not have any university experience while the second trimester students had experienced a university course for one trimester including mathematics involved subjects. Their difference in mathematical experience is, more or less, expected to have an impact on mathematics test results.

In the subsequent parts of this thesis, the first-year students in the first trimester and the second trimester will be referred as the first group and the second group respectively. There are no restrictions or prior conditions as to which semester students may choose to enroll in Physics I, so the two groups are ostensibly equivalent upon entering SUT. The questions in both mathematics tests are displayed in the Appendix. Originally, there were 34 multiple-choice mathematics questions in each test. Of these, 31 questions were common to both tests (though the question order, and item number, were not always identical). We analyzed the results only for the 31 common questions, and henceforth will not discuss the other questions. We divide our 31 mathematics questions into 3 groups according to topic: geometry, algebra, and calculus.

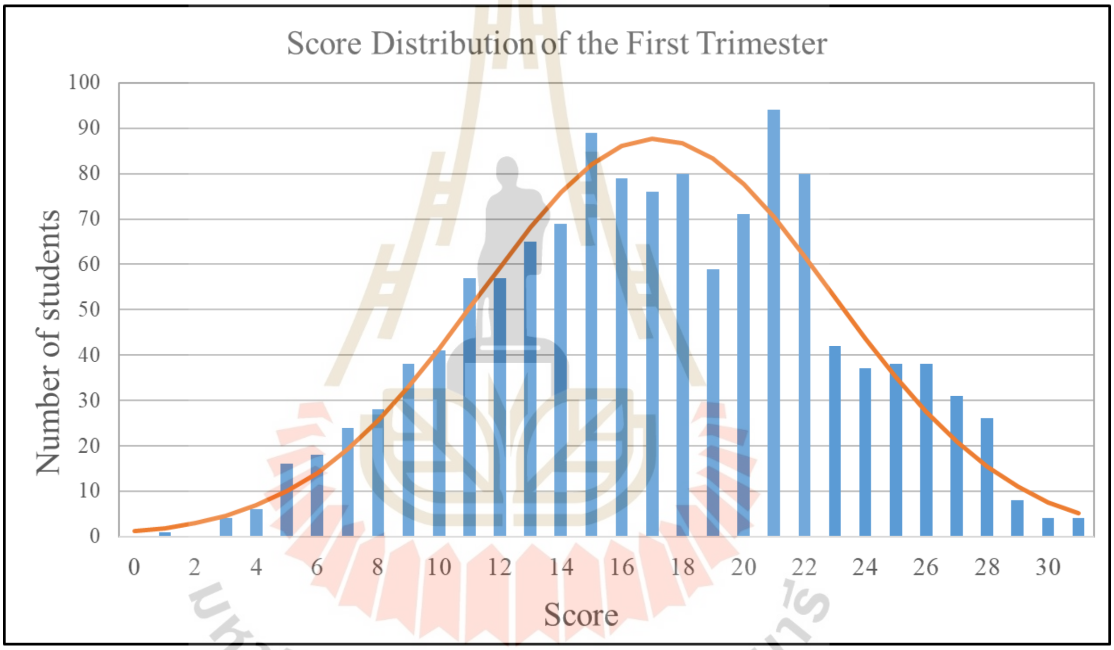


Figure 1 The mathematics pre-instruction score distribution of the first group of students. The horizontal axis is the score, and the vertical axis is the frequency. The mean is 17.13, the standard deviation is 5.82, and the median is 17. The orange line is the normal distribution curve of the same mean and standard deviation.

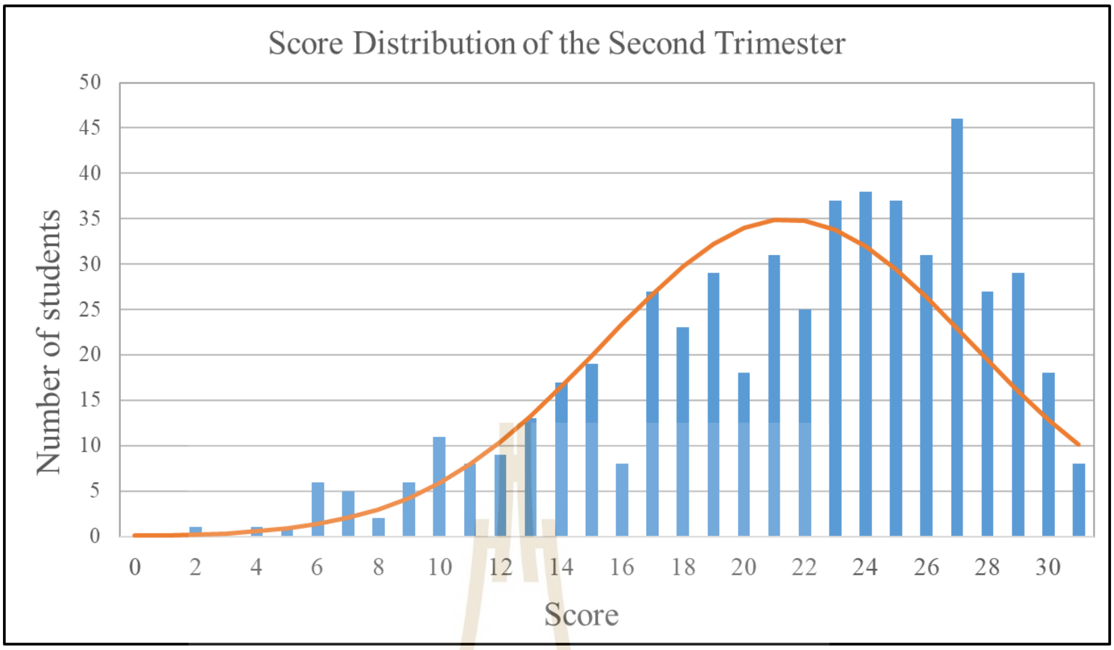


Figure 2 The mathematics pre-instruction score distribution of the second group of students. The horizontal axis is the score, and the vertical axis is the frequency. The mean is 21.44, the standard deviation is 6.06, and the median is 23. The orange line is the normal distribution curve of the same mean and standard deviation.

Table 1 The number of students in each group who enrolled the Physics 1 class and who took the pre-instruction mathematics tests.

	Number of first-year students in the 1st group	Number of first-year students in the 2nd group
The enrolled	1,392	658
Those who took the mathematics test	1,280	531

The first group of students had an average score of 17.13 out of 31 with a standard deviation of 5.82 and median of 17. The score distribution is shown in figure 1. It is close to a normal distribution, represented by the orange line in the figure. The second group of students had an average score of 21.44 with a standard deviation of 6.06, and the median of 23. The score distribution is shown in the figure 2. It is left-skewed. Indeed, it appears that many students in the second group would have scored more than 31 if the distribution was unbounded. By conventional criteria, this difference of the average scores is extremely statistically significant, i.e., the second group did better for the pre-instruction mathematics test by 4.31 points at 0.05 significant level (The average score and error is 17.13±0.2 for group 1 and 21.44±0.3 for group 2).

Table 2 The average scores, standard deviations, and medians of the two groups of students.

Statistical quantities	1st group of students			2nd group of students		
	All	Female	Male	All	Female	Male
Number of students	1,280	640	640	531	264	267
Average score (out of 31)	17.13	16.58	17.69	21.44	21.26	21.61
Standard deviation	5.82	5.65	5.94	6.06	6.09	6.05
Median	17	16	18	23	22	23

Since entering students were randomly selected to enroll Physics 1 course in the first or the second trimester, it is reasonable to assume that the two groups of students would have similar average mathematical knowledge when they entered SUT. A plausible cause of the difference in the average test scores between the two groups may be the fact that the second group of the students took Calculus 1 in the first trimester, before they took Physics 1 in the second trimester, whereas the first group took both Calculus 1 and Physics 1 at the same time. This difference provides an unplanned, but simply understood, variation between groups that we will take advantage of in our discussion below. This difference in a way could indicate that the content in the pre-instruction mathematics test is valid. The reliability and the validity of the test will be discussed in the next section.

2.2 Validity and Reliability of the Test

The results of a test should only be taken seriously if the test has both reliability and validity. A test has reliability if it yields similar results when administered in similar situations (for example, if we gave our test to two groups of SUT students that had the same average knowledge and ability, average test scores should be the same.) Validity of a test is its capability to evaluate the property of interest from the test takers (Colton D, 2007; Dimitrov D M, 2012).

There are several ways to define validity, with corresponding methods for establishing the validity of a given test. For instance, we could have a group of experts who have experience in the field to rate each item in the test according to how well it covers the content that it is supposed to assess (Rassouli, 2009). This aspect of validity is referred to as "content validity". It is typically measured repeatedly during the test development process until the average validity rating reaches a desired value. We did not do this for our mathematics test. There are two other well-known measures test validity that can be determined after confirming that a test is reliable. One is called "criterion-related validity". The evidence for criterion-related validity is that the result from a test can be used to predict performance in an independent test. In our case, if we compare the test result of each individual student to their final grade, the trend of the result should be the same if our test is to be regarded as valid. The second is called "construct-related validity". A construct is some individual characteristic that we assume that can be used to explain the test result (Considine et al., 2005). Mathematical experience, reading comprehension skill, honesty and anxiety are some examples of constructs relevant to physics tests. In our case, we have two groups of students. The second group took Calculus before taking Physics 1 and its average score of the mathematics test is higher; so, we can claim that our test has construct validity.

The reliability of a test is easier to establish. In the following subsections of this section, we report the statistical indices that give insight into the reliability of our mathematics test. We give the definition of these indices (Engelhardt, 2009) and apply criteria according to the classical test theory to indicate if the items in the test and if the whole test are reliable or not. The indices are Kuder-Richardson's Reliability index (r_{test}) and Ferguson's delta (δ). These two are the reliability indices calculating for the whole test. They are affected by the reliability of each item, or each question, in the test as well. The reliability of each item is represented by the difficulty index (P), the discrimination index (D), and the Point Biserial Index (PBI). These indices may be evaluated for many reasons. In this thesis, the main reason is to ensure that the whole test can gives the reliable read for students' mathematical knowledge. Another reason for investigating these indices is to help improve items that show poor quality.

2.2.1 Item Difficulty Index

The first index to consider is the difficulty index (P).

$$P = \frac{N_i}{N}. \tag{2.1}$$

N_i is the numbers of students answering the i^{th} item correctly and N is the number of the total test takers. The difficulty index of each item is therefore the fraction of students, who answer the item correctly. A higher value indicates an easier item. If the difficulty index of an item is around 0.5, the item is deemed the highest reliability. Consider a normal distribution for a given item: if $P =$ 0.5 then the mean is located at the middle of the range of possible scores, leaving maximum space for the wings of the distribution and thus the best chance to reliably distinguish between two students of different ability who lie on those wings.

The difficulty index of all 31 questions or items in the mathematics tests are shown in figure 3 (for the first group of the students) and 2.4 (for the second group).

In our work we interpret that for the difficulty index of an item more than 0.8, we consider it to be too easy. For the value less than 0.2, we consider it to be too difficult. From the results shown in figure 3, most items are neither too difficult nor too easy. All 31 items are used in our mathematics-physics score correlation analysis, because as will be seen in the later subsections Fergusons' delta and Kuder-Richardson's reliability index indicate that the whole mathematics test is reliable. It should be acknowledged that the higher P values for the second group reflects the left skew of its distribution.

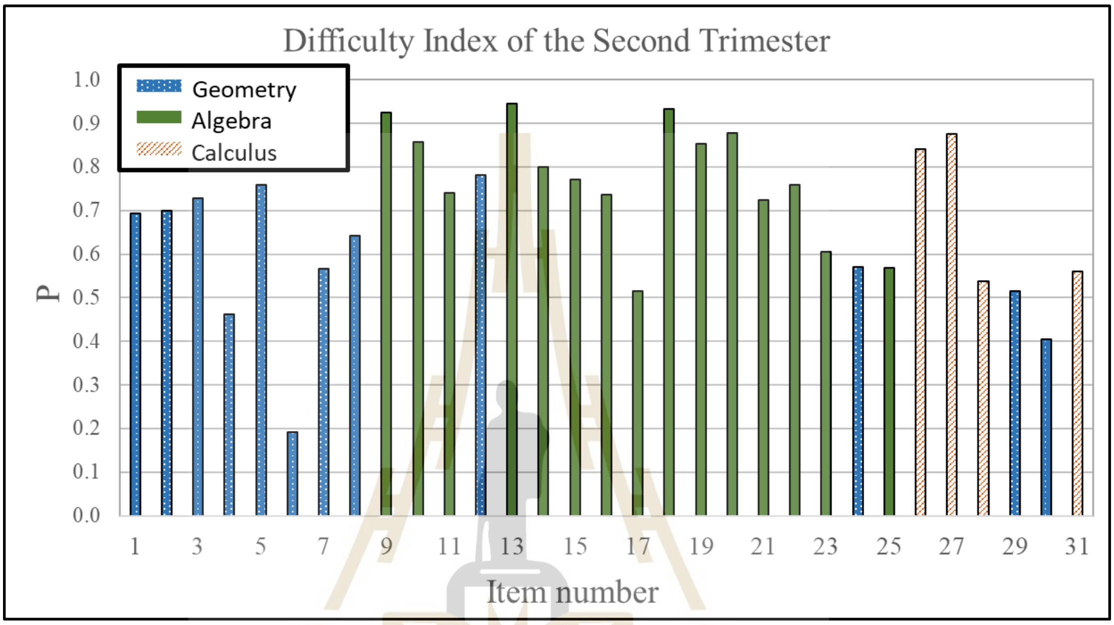


Figure 3 Difficulty index (P) of each item in the mathematics test in the first group. There are 12 geometry items indicated by dotted bar, 15 algebra items by solid bar and 4 calculus items by stripped bar.

The mathematics items were categorized into three topics: algebra, geometry, and calculus. The items that need students to find the value of unknown variables in mathematic cal expressions are categorized as algebra. The items that require the knowledge of shapes, lines, point or the position on the graph are categorized as geometry. The items that involve differentiation, integration and identifying graph of a given function are categorized as calculus. Although some items may involve more than one topic, we assigned a single category for each item based on the central point of focus, according to our judgement. Accordingly, we have 15 algebra items, 12 geometry items and 4 calculus items in both group mathematics tests. The item number for the same question in different groups may not be the same, as can be seen in figure 3 and figure 4.

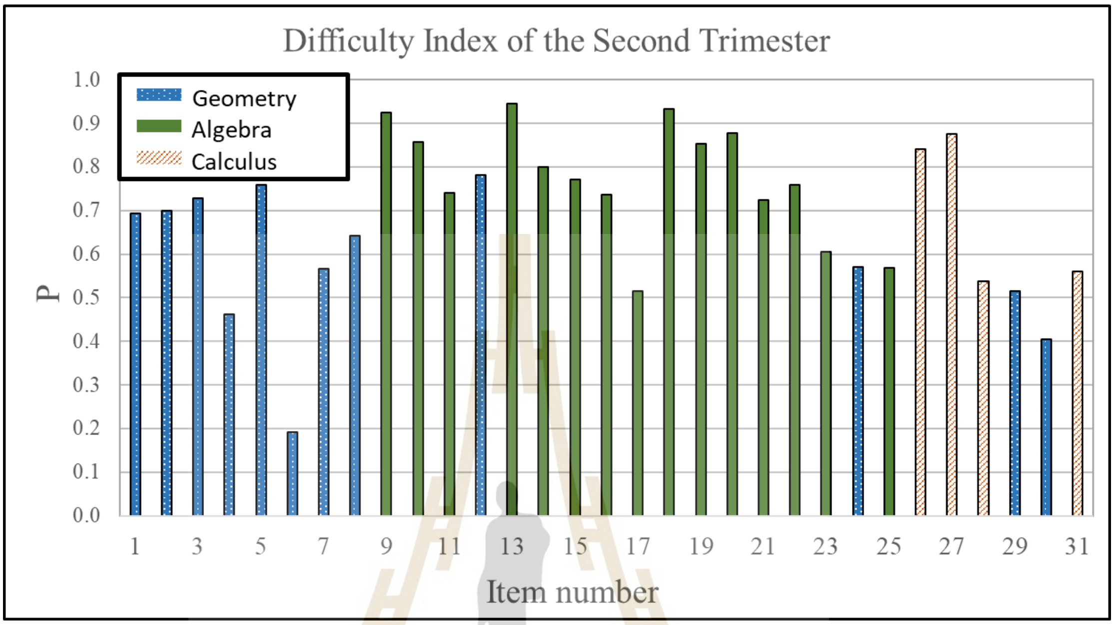


Figure 4 Difficulty index (P) of each item in the mathematics test in the second group. There are 12 geometry items indicated by dotted bar, 15 algebra items by solid bar and 4 calculus items by stripped bar. The order of these items is not exactly the same as those in the first group.

In table 3, we show the averages of difficulty indices for male, female and all students for algebra, geometry, calculus, and all mathematics topics in both trimesters.

The results in table 3 indicate that on average all students in the first group have the most difficulty with geometry with $P = 0.438$. The second most difficult mathematics topic for them is calculus with $P = 0.536$. The least difficult topic is algebra with $P = 0.649$. Even though the second group does better in all mathematics topics, the trend for each topic is the same as the first group with $P = 0.560$, 0.703 and 0.774 for geometry, calculus, and algebra, respectively. At 0.05 degree of significance, the average difficulty indices for all mathematics topics of the students in the second group are found to be higher than those in the first group.

As for the difference in difficulty indices of the two genders, we can see that male students in the first group have higher average score than female students. If we compare using the t-test, males did significantly better than females in geometry and algebra. But for the students in the second group there is no significant difference. This may indicate that Calculus 1 at SUT helps reduce the knowledge gender gap in geometry and algebra among incoming students.

Table 3 The average difficulty of male and female students from both groups for each mathematics category and for the whole test.

	1^{st} group			2^{nd} group		
	Female	Male	Overall	Female	Male	Overall
Number of students	640	640	1280	264	267	531
Average difficulty for algebra	0.639	0.659	0.649	0.766	0.782	0.774
Average difficulty for geometry	0.409	0.467	0.438	0.555	0.565	0.560
Average difficulty for calculus	0.522	0.550	0.536	0.700	0.707	0.703
Average difficulty index for the whole test	0.535	0.571	0.553	0.686	0.697	0.692

2.2.2 Item Discrimination Index

The next index to consider is the discrimination index (D). The students are first divided into a high-performing (HP) group, whose total test score was in the fourth (highest) quartile, and a low-performing (LP) group with total test scores in the first (lowest) quartile. If there are a total of N students who took the test, then the HP and LP groups each contain N/4 students by definition. With these groups established, the discrimination index of each item on the test is defined as

$$D = \frac{N_H - N_L}{N/4}. \tag{2.2}$$

where N_H is the number of HP group members that correctly answered the item while N_L is the number of LP members that did. The value of D varies between a maximum of $D = +1$, occurring when every HP member answers correctly while no LP member does, and a minimum of $D = -1$, when all LP and no HP members correctly answer the item. Clearly, D measures the extent to which a given item differentiates HP and LP members, and thus how well the results of this item are consistent with the results of the test as a whole. A discrimination index of more than 0.3 is usually regarded as a reliable item. Negative values for the discrimination index suggest a problem with the item. Since its results contrast the test total, any item with a negative D value clearly reduces the reliability of the test overall.

The discrimination index of each item in the mathematics test for both groups of the students is shown in figure 5 and figure 6. There are no negative values to be found among any of the items on our test. Item number 6 has a D value that falls below the (somewhat arbitrary) cutoff of $D = 0.3$, but every other item clears this threshold.

2.2.3 Point Biserial Index

The last item reliability index that we consider is the Point Biserial Index (PBI). It combines the previous two indices into a single measure of reliability, constructed as a weighted average. The PBI of an item is related to its difficulty index P as shown in the following equation.

$$PBI = \frac{\bar{x}_1 - \bar{x}_0}{\sigma_x} \sqrt{P(1-P)}. \tag{2.3}$$

In the prefactor on the right side, $\bar{x}_1$ and x_0 are respectively the average total score of those who answer the item correctly, and the average total score of those who answer the item incorrectly, while σ_x is the standard deviation of the total score. So, the PBI is a measure of the item's ability to distinguish high-performers from low-performers. The square root appearing on the right side is a weight factor that assigns

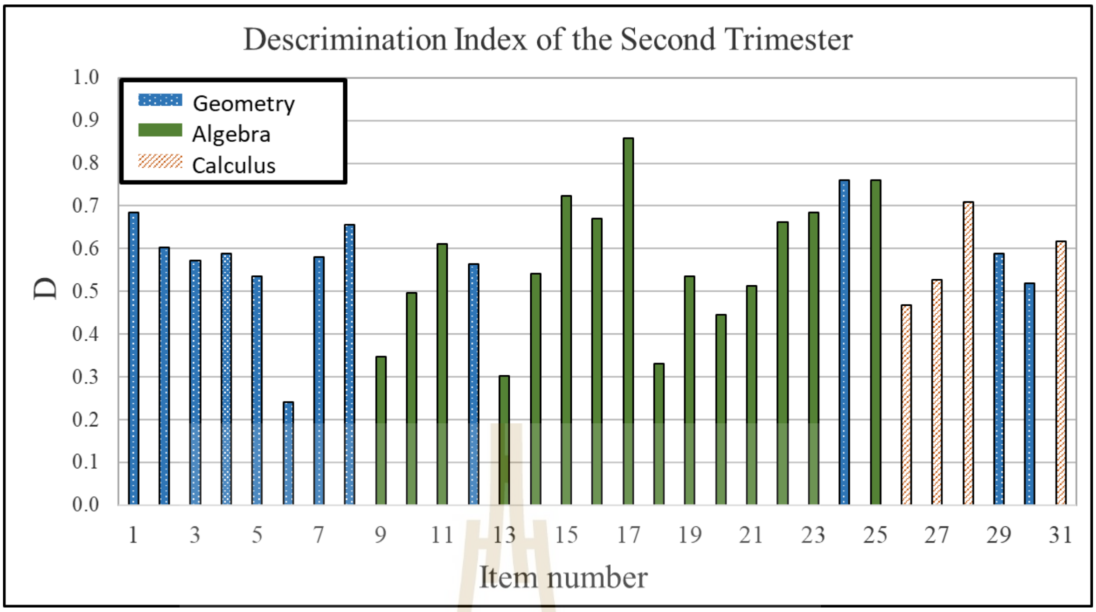


Figure 5 Discrimination indices (D) of each item in the first groups mathematics test.

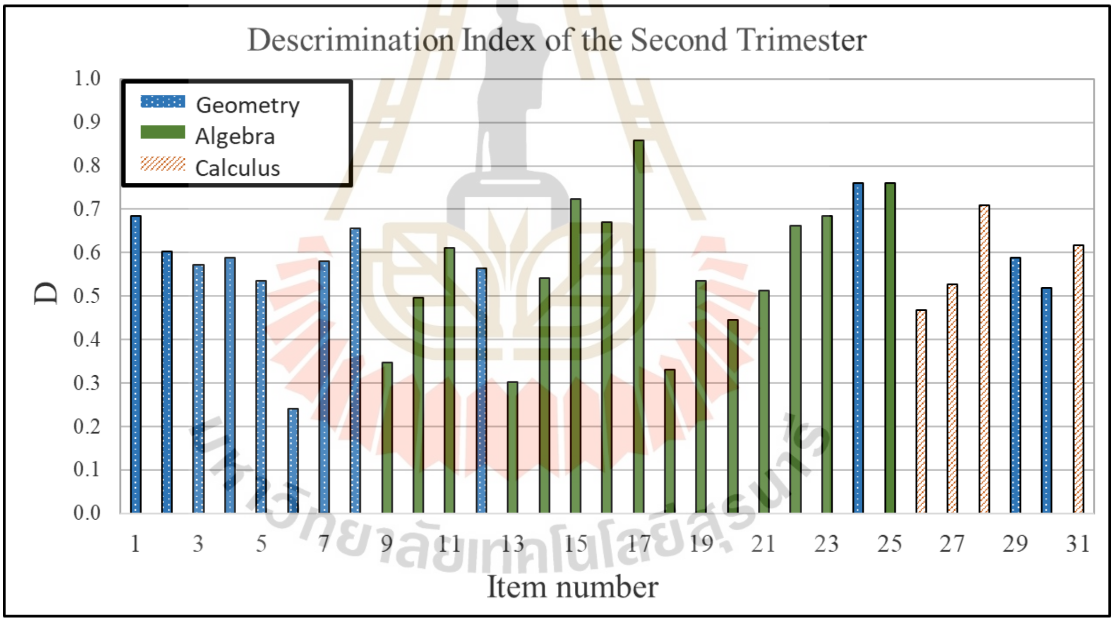


Figure 6 Discrimination indices (D) of each item in the second groups mathematics test.

most weight to items with the optimal P value (the weight is maximal when $P = 0.5$). Items of excessively low or high difficulty indices are given less weight (both $P = 1$ and $P = 0$ items have zero weight). Items with a $PBI > 0.2$ are considered reliable. PBI of the mathematics test are shown in figure 7 and figure 8.

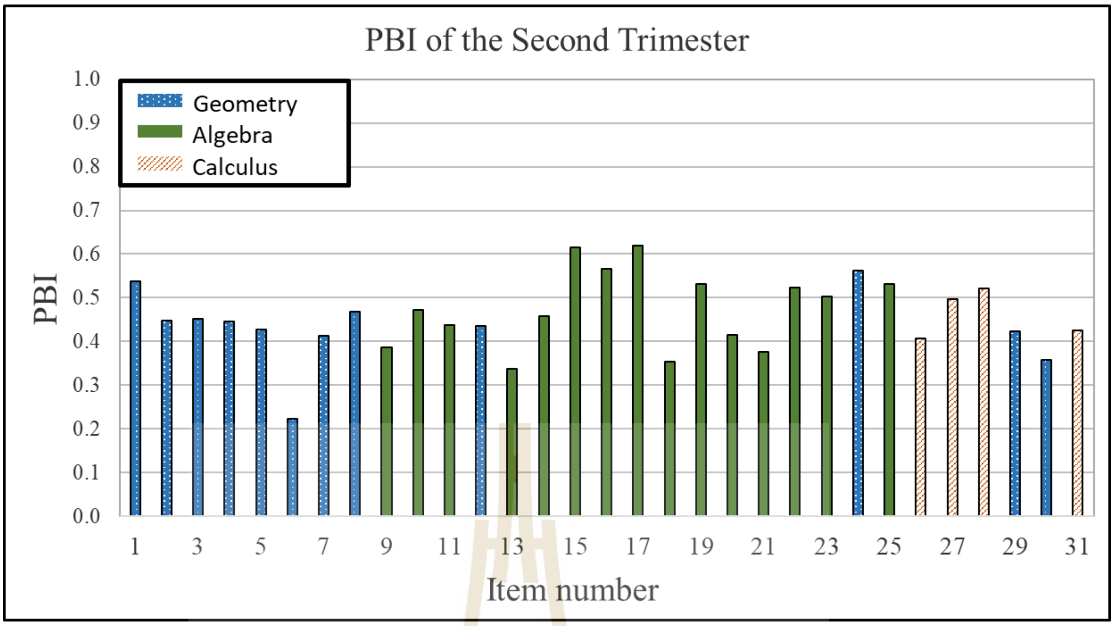


Figure 7 Point Biserial Indices (PBI) of each item in the first groups mathematics test.

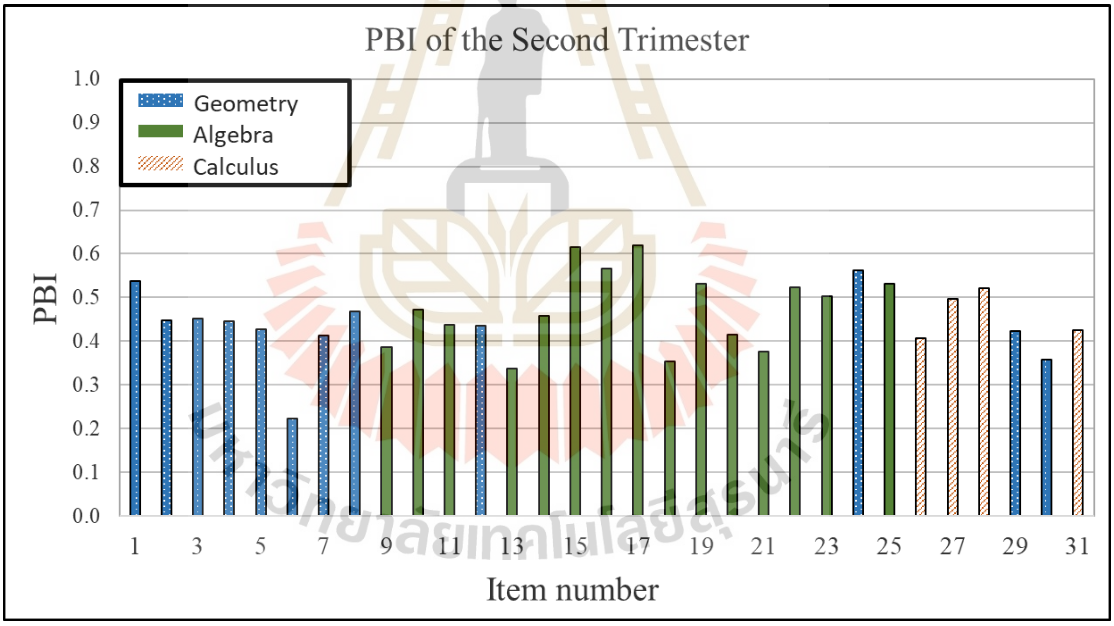


Figure 8 Point Biserial Indices (PBI) of each item in the second groups mathematics test.

2.2.4 Reliability of the Whole Test

Finally, we assess the reliability of the test as a whole. The two reliability indices used for this end are the Kuder-Richardson Reliability index and Ferguson's Delta. They are effectively averages over item reliability values.

The Kuder-Richardson Reliability Index (KR-20) is written as

$$r_{test} = \frac{K}{K-1}\left(1 - \frac{\sum_{i=1}^{K} P_i(1-P_i)}{\sigma_x^2}\right). \tag{2.4}$$

where K and P_i are the number of the items in the test, and difficulty index of the i^{th} item, respectively. The factor in front of the parentheses approaches one in the limit of a very long test. To understand the role of the expression in parentheses, consider first the simple case where half the class gets each item correct, $P_i = 0.5$ for every item i. The summation above is then equal to $K/4$. If the test is reliable then the same half of the class (those with more knowledge or ability) should get each item correct, which means half the class will get a test score of K, the other half will get a score of zero and the average will be $K/2$. The variance is then found to be $\sigma^2 = K^2/4$ and thus $r_{test} = 1$. In a terribly unreliable test, a student's ability would be uncorrelated with their probability of correctly answering each item. Effectively, each student would flip a coin for each item, and get the right answer with 50 percent probability. In a long test $K \gg 1$ every student would get a score that was very close to $K/2$, and the variance, from the central limit theorem would be $\sigma^2 = K/4$ giving $r_{test} = 0$. In the more general case, the same reasoning holds. Here, we use the guideline that for a value of r_{test} greater than 0.8, the test is considered reliable.

Table 4 The overall reliability of the mathematics tests.

Reliability index	1st group mathematics test	2nd group mathematics test
KR-20	0.84	0.85
Ferguson's delta	0.98	0.98

The discrimination index of the whole test determined by Ferguson's delta (δ). It is calculated by dividing the number of different answers in the test by the maximum possible different answers. It written as

$$\delta = \frac{N^2 - \sum_{i=0}^{K} f_i^2}{N^2 - N^2/(K+1)} \ , \tag{2.5}$$

where f_i is the number of students who get the score of i (where i. has a value between 0 and K). In the extreme case that every student got the same score the numerator will go to zero. This means the test cannot distinguish the ability of the students at all. If the distribution of students' score is uniform ($f_0 = f_1 = f_2 = \cdots = f_K = \frac{N}{K+1}$), Ferguson's delta is equal to 1. If the value of δ is more than 0.9, the test's discrimination power is considered acceptable.

As shown in table 4, both KR-20 and Ferguson's delta of the mathematics tests for both groups of students are reliable.

2.3 Conclusions

According to all the indices, the pre-instruction mathematics tests in both groups are reliable and valid. The students from both groups struggled most with geometry. Both did best in algebra. The students in the second group have significantly higher average score. This result may be because the second group took Physics 1 after taking Calculus 1 whereas the first group took both in the same trimester. This result may also be used as evidence of the construct validity of the test.

By comparing the average score of male and female of the first group students, we see the gender gap in geometry and algebra. However, this gap disappears for the students in the second group. With the assumption that when entering SUT the two groups of students on average are similar in mathematical knowledge level, this result may suggest that studying at SUT for one trimester helps improve their mathematical knowledge and reduce the gender gap.

CHAPTER III

PHYSICS EXAMINATION RESULTS

In the previous chapter we analyzed the pre-instruction mathematics tests, here we do the same for the physics examinations. Details about the exam content, including a breakdown of the validity and reliability of test items, and exam results, including a comparison between test groups and genders, is provided in this chapter. The correlations between mathematics and physics results will be studied in Chapter IV.

There were two physics exams in each trimester: the midterm and final exam. The results in this thesis are the analyses of first-year students' answers to multiple-choice questions in the exams. It is a practical necessity (to avoid cheating) that the examinations in the two semesters must be slightly different. In the first trimester, there were 29 questions on the midterm and 51 questions in the final. In the second trimester, there were 30 questions on the midterm and 50 on the final. Many of the 80 questions done by one group were similar to those done by the other, and 32 were identified by instructors as being substantively identical (the same question with different numerical values). These 32 questions, common to the two groups, will be a focus of our later analysis. But, in this section, we will give results for the examinations as a whole.

All physics questions were put into one of the following 10 categories: one-dimensional (1D) motion, two-dimensional (2D) motion, Newton's laws of motion, work and energy, momentum, rotation kinematics, torque, angular momentum, oscillations, waves, and fluid mechanics. We should note that there may be a few questions that are put into more than one category. All the questions are included in the Appendix.

Table 5 shows the number of the enrolled first-year students and the smaller number of students who took both midterm and final exam for each group (students who dropped the course after the midterm being excluded).

Table 5 Number of first-year students in each group who enrolled and who took both midterm and final physics exams in Physics 1 class.

	Number of first-year students in the 1st group	Number of first-year students in the 2nd group
The enrolled	1,392	658
Those who took **both** midterm and final exam	1,352	591

3.1 Overall Physics Exam Results

The average score of the first group of students is 38.09 out of 80 with a median of 36 and standard deviation equal to 14.15. The score distribution of the group is shown in figure 9. The orange curve represents the normal distribution with the same average and the standard deviation.

The average score of the second group is 34.18 with a median of 31 and standard deviation equal to 13.76. The score distribution of the second group is shown in figure 10. The normal distribution with the same mean and standard deviation is shown in the figure but, to the eye, the measured distribution appears better described as a sum of two normal distributions with averages around 27 and 53.

Because all 80 questions in each group are not the same, the level of difficulty of each exam is slightly different. As will be seen in the next section, when we report the reliability indices of each exam, the overall physics exam of the second group is more difficult. For the 32 questions common to both groups, the second group performed slightly better. So, it was clearly a difference in exams, not in the groups themselves, that resulted in the second group having a higher average exam score overall.

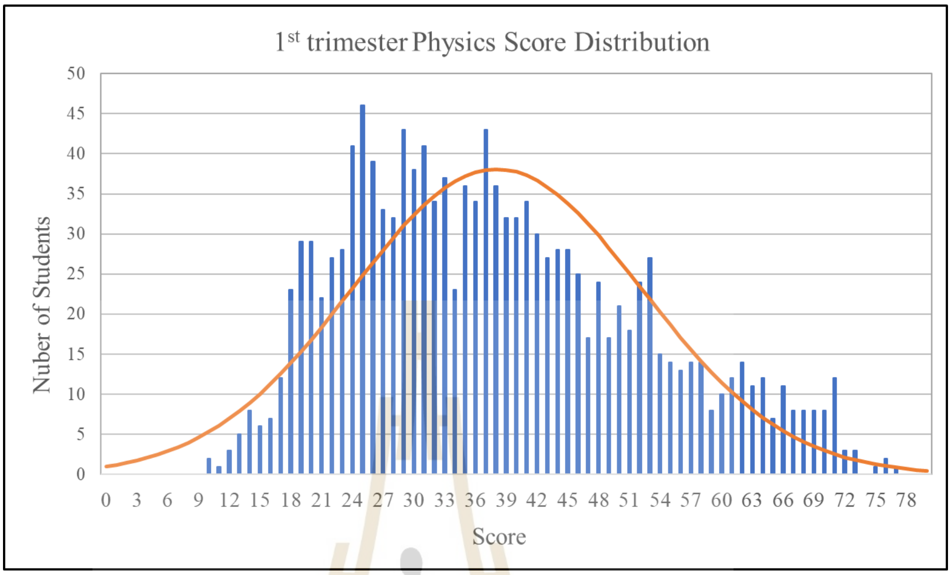


Figure 9 The physics exam score distribution of the 1,351 students in the first group. The horizontal axis is the score, and the vertical axis is the students' frequency. The mean of this graph is 38.09 and the standard deviation is 14.15. The orange line is the normal curve plotting with the mean and standard deviation.

If we consider only the average score for the 32 common items, the average score of the first group is 14.15 with a standard deviation of 5.90 and those of the second group are 15.20 and 6.23. A t-test indicates that the average score of the second group is significantly higher with a 0.05 significant level. This result may be expected. From previous work (Hudson et al., 1977; Hudson et al., 1981; Hudson et al., 1982) it was shown that those who perform better at mathematics tend to perform better at physics exams, and our second group performed better at the pre-instruction mathematics test, as shown in the previous chapter.

3.2 Validity and Reliability of the Physics Exam

Since the exams in this work were made by several experienced physics lecturers and were designed to evaluate the students' performance and assign their respective grades, the exams have content validity. The reliability of the exams is examined according to the classical test theory (Engelhardt, 2009), like what was done for the mathematics pre-instruction test in the last chapter.

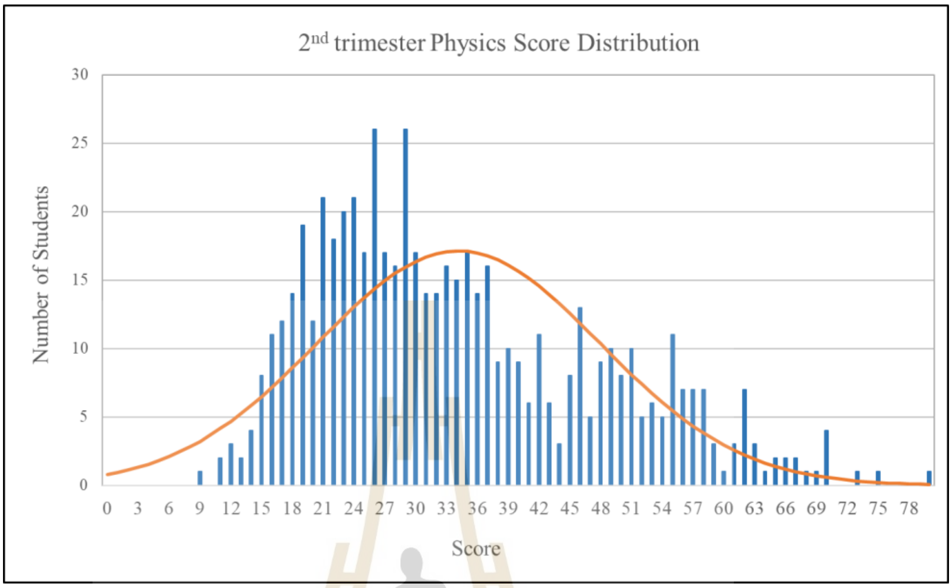


Figure 10 The physics exam score distribution of the 591 students in the second group. The horizontal axis is the score, and the vertical axis is the students' frequency. The mean of this graph is 34.18 and the standard deviation is 13.76. The orange line is the normal curve plotting with the mean and standard deviation.

3.2.1 Difficulty Index and Its Indication

For the reader to see the whole picture of the difficulty index for each of the 80 items for both groups of the students, we present its value as a function of the item number in figure 11 and figure 12. It should be noted that questions with the same item number in both figures are not the same questions. The 80 items are simply ordered as they appeared in the course, including both midterm and final exams. It is clear that the majority of items fall within the desirable range of $0.2 < P < 0.8$, such that they are neither too hard nor too easy to reliably assess students.

Table 6 is a detailed breakdown of all examination items for the first and second group, labeled by item number. From this table we can see the difficulty index and subject category of any item for either semester.

Table 6 Average scores, standard deviations, and medians of students' physics exam score.

Statistics quantities	1st group of students			2nd group of students		
	All	Female	Male	All	Female	Male
Number of students	**1351**	665	686	**591**	295	296
Average score **(out of 80)**	**38.08**	35.67	40.42	**34.18**	32.71	35.64
SD	**14.15**	12.88	14.92	**13.76**	13.00	14.36
Median	**36**	34	38	**31**	29	33.5
Average score **(out of 32)**	**14.15**	13.97	15.81	**15.20**	14.14	15.04
SD	**5.80**	5.31	6.12	**6.23**	5.74	6.32
Median	**14**	13	15	**14**	13	15

In figure 13, we show the difficulty indices for the 32 items common to both groups. The first group (solid bars) and the second group (patterned bars) are juxtaposed for comparison. As noted above, the average score in these 32 questions was higher for the second group. In more detail, there were 15 items in which group 1 scored significantly higher (i.e. higher by a margin greater than the statistical error indicated), 5 items in which both groups performed equally, and 12 in which group 2 outperformed group 1.

Here we consider a couple of example items in which group 2 fared worse, though performing better overall on the exam, Table 8 displays the questions corresponding to these items and the percentage of students who answered correctly in both groups. Additionally, it indicates the percentage of students who chose the most popular incorrect option in the second group.

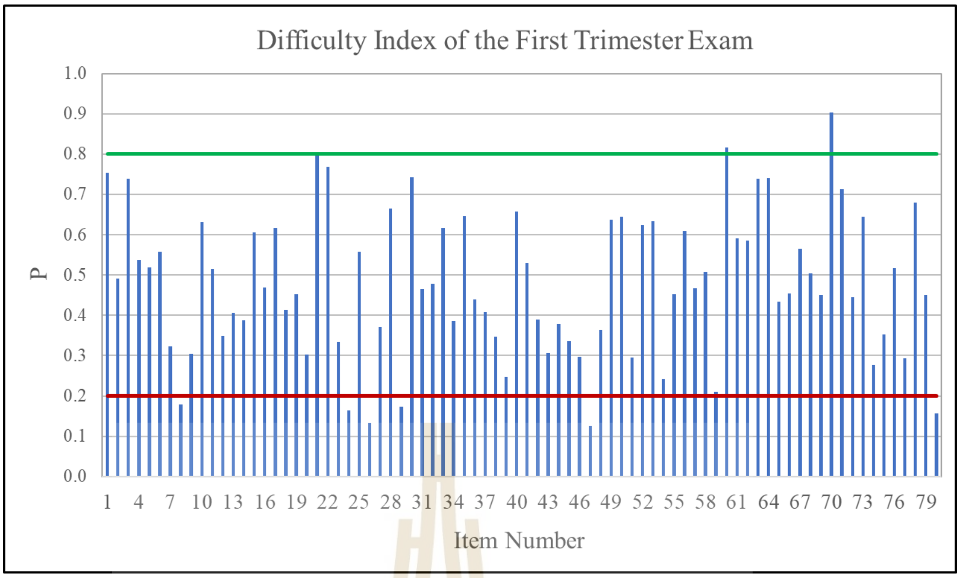


Figure 11 Difficulty index (P) of each item in the first group. The items, whose P's is higher than the upper line (0.8), are deemed too easy. Those lower than the lower line (0.2) are deemed too hard.

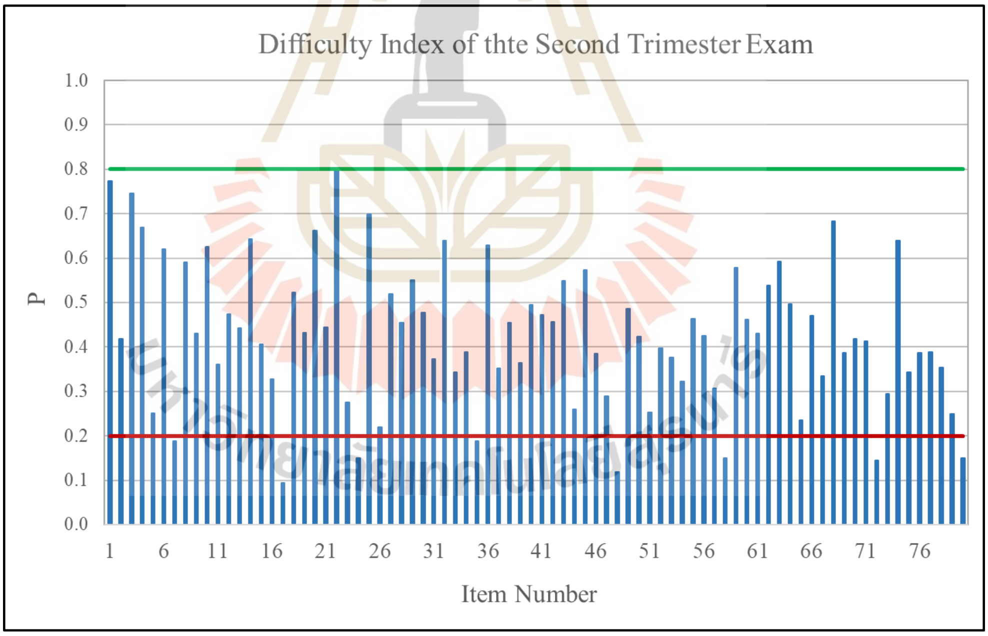


Figure 12 Difficulty index (P) of each item in the second group. The items, whose P's is higher than the upper line (0.8), are deemed too easy. Those lower than the red lower (0.2) are deemed too hard.

Table 7 The item no.'s in each the physics category and difficulty level (based on the difficulty index P) from both groups physics exams.

Physics topic	Item no. # with ...					
	P>0.8 (Easy)		P<0.2 (Difficult)		0.2< P <0.8	
	Group 1	Group 2	Group 1	Group 2	Group 1	Group 2
1D motion	-	-	8	7	1,2,3,4,5,20	1,2,3,4,5,6
2D motion	-	-	-	-	6,7,12,13, 14,30,31,32	8,9,10,11, 12,13,31,32 33
Newton's laws of motion	-	22	24	17,24	8,9,10,15, 16,19,22,23	14,15,16,18 19,23,65
Work & energy	-	-	26	-	11,17,18,25 33,41,42,59	20,21,25,26 37,38
Momentum	-	-	29	-	27,28	27,28,29,30
Rotation kinematics			-	48	34,35,36,37 38,39,41,42 ,43	34,35,37,38 39,47
Torque		-	47	-	38,40,44,45 46	36,40,41,42 43,44,45
Angular Momentum	-	-	47	-	48	46
Oscillations	-	-	-	58	49,50,51,52 53,54,55,56 57,58,59	49,50,51,52 53,54,55,56 57
Waves	60,70	-	-	72	61,62,63,64 65,66,67,68 ,69,71,72	59,60,61,62 63,64,65,66 ,67,68,69,7 0,71,73
Fluid mechanics			80	80	73,74,75,76 ,77,78,79	74,75,76,77 ,78,79

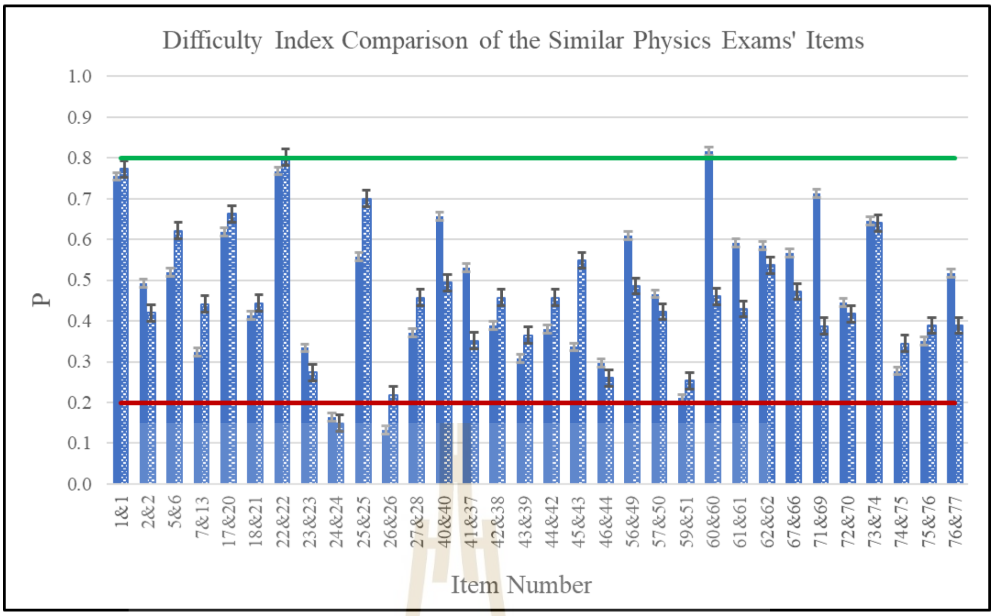


Figure 13 Difficulty index comparison of the 32 similar items in the 1^{st} & 2^{nd} groups exams. The first group items are indicated by the solid bar and the second group items are indicated by the patterned bar. The error bars are calculated by taking the standard deviation of each items score divided by the number of the students.

For the first pair of the questions 81% of students in the first group answered correctly, while only 46% of students in the second group answered correctly. Among those in the second group who answered incorrectly 23% were apparently confused by a name-change of variables—i.e. merely using z instead of the more familiar x as the position variable for a 1D wave seemed to throw them. This suggests that students may struggle with replacing familiar quantities with unfamiliar variables (Nguyen et al., 2011). Surprisingly, better mathematical knowledge among the second group of students did not appear to improve their ability to do this. To address this issue, instructors may need to provide students with more examples of this type of problem to help them improve.

Table 8 the questions related to the 2-paired similar items of the two groups and the percentage of students who answered correctly. The highest percentage of students who chose an incorrect answer in the second group is also shown.

Group 1	Group 2
#60 คลื่นฮาร์มอนิกมีสมการเป็น $y(x,t) = 0.50\cos(\frac{\pi}{4}x - 2\pi t)$ โดยที่ x มีหน่วยเป็น m และ t มีหน่วยเป็น s 31. คลื่นนี้มีทิศทางการเคลื่อนที่อย่างไร 1) ไปทาง $+y$ 2) ไปทาง $+x$ 3) ไปทาง $-y$ 4) ไปทาง $-x$ 5) ไปทาง $+z$ A harmonic wave has a wave function $y(x,t) = 0.50\cos(\pi x/4 - 2\pi t)$, where x and t have the units of m and s respectively. 31. In which direction is this wave moving? 1) +y 2) +x 3) -y 4) -x 5) +z **81% of students answered 2)**	#60 คลื่นกลมีฟังก์ชั่นคลื่นตามสมการ $y(z,t) = 0.2\sin(0.5\pi z - 4\pi t)$ โดยที่ทุกปริมาณในสมการมีหน่วยใ ระบบ SI 30. คลื่นนี้เคลื่อนที่ไปในทิศทางใด (แนะนำ: โปรดสังเกตตัวแปรในสมการให้ดี) (1) $+x$ (2) $-x$ (3) $+y$ (4) $-z$ (5) $+z$ A harmonic wave has a wave function $y(z,t) = 0.2\sin(0.5\pi z - 4\pi t)$, where every quantity in the equation is in SI units. 30. In which direction is this wave moving? (Hint: notice carefully of the variables in the equation.) 1) +x 2) -x 3) +y 4) -z 5) +z **46% of students answered 5)** **23% of students answered 1)**
#71 **จงใช้ข้อมูลต่อไปนี้ตอบคำถามข้อ 42. – 43.** รถโฆษณา A เปิดเสียงรบกวนชาวบ้านที่ความถี่ 660 Hz และกำลังวิ่งไปทางขวาด้วยความเร็ว 20 m/s คุณตำรวจ O ยืนนิ่งอยู่ข้า ถนน ทางด้านหลังของรถโฆษณา A รถกระบะ B วิ่งตามรถโฆษณา A ด้วยความเร็ว 20 m/s เท่ากันกับ A และรถ C กำลังวิ่งสวา ทางมา ด้วยอัตราเร็ว 10 m/s กำหนดให้อัตราเร็วของเสียงในอากาศเป็น 350 m/s  42. ใครจะได้ยินเสียงที่มีความถี่ต่ำสุด 1) คนขับรถ A 2) คนขับรถ B 3) คนขับรถ C 4) คุณตำรวจ O 5) ทุกคนได้ยินเสียงความถี่เท่ากันหมด Use the following info to answer question 42. – 43. An advertisement car A is annoyingly giving out sound of frequency 660 Hz and moving with speed 20 m/s to the right. A police officer O is standing still. Following behind car A with speed 20 m/s is pick-up truck B. Car C is moving towards car A in the opposite direction with speed 10 m/s. Given speed of sound to be 350 m/s. 42. Who hears sound with the lowest frequency? 1) Car A driver 2) Car B driver 3) Car C driver 4) Police officer O 5) Everyone **70% of students answered 4)**	#69 **จงใช้ข้อมูลต่อไปนี้ตอบคำถามข้อ 39. – 40.** รถโฆษณา A เปิดเสียงรบกวนชาวบ้านที่ความถี่ 800 Hz และกำลังวิ่งไปทางขวาด้วยความเร็ว 50 m/s คุณตำรวจ O ยืนอยู่นิ่งข้างถนนทางด้านหลังของรถโฆษณา A รถกระบะ B วิ่งตามรถโฆษณา A ด้วยความเร็ว 50 m/s เท่ากัน และรถกระบะ C กำลังวิ่งสวนทางมาด้วยอัตราเร็ว 10 m/s กำหนดให้อัตราเร็วของเสียงในอากาศเท่ากับ 350 m/s 39. ใครจะได้ยินเสียงความถี่สูงที่สุด (1) คนขับรถ A (2) คนขับรถ B (3) คนขับรถ C (4) คุณตำรวจ O (5) ทุกคนได้ยินเสียงความถี่เท่ากัน  Use the following info to answer question 39. – 40. An advertisement car A is annoyingly giving out sound of frequency 800 Hz and moving with speed 50 m/s to the right. A police officer O is standing still. Following behind car A with speed 50 m/s is pick-up truck B. Car C is moving towards car A in the opposite direction with speed 10 m/s. Given speed of sound to be 350 m/s. 42. Who hears sound with the highest frequency? 1) Car A driver 2) Car B driver 3) Car C driver 4) Police officer O 5) Everyone **39% of students answered 3)** **29% of students answered 2)**

For the second pair of the questions which were about Doppler's effect (see table 8), 70% of students in the first group answered correctly, while only 39% of students in the second group answered correctly. The setup of the two questions was essentially the same but in the second group the question asked for the highest, rather than lowest, apparent frequency. A considerable 29% of students chose a wrong answer, that of an observer with no relative motion to the source, that did not distract many students in the first semester. This result puzzles us.

In table 9, we present the average difficulty index, which we calculated based both on all 80 items and of the common subset of 32 items. The table also includes average difficulty indices for the students in group 1 and 2, including: 1) as a whole and divided by gender, 2) divided by physics topic category, and 3) separated into conceptual and numerical items.

From the results we can see that the three topics the students struggled with most in the first group are angular momentum ($P = 0.219$), torque ($P = 0.336$) and rotation kinematics ($P = 0.373$), while for those in the second group are rotation kinematics ($P = 0.309$), fluid mechanics ($P = 0.359$) and oscillation ($P = 0.360$).

Table 9 Average difficulty index of each physics topic. The average difficulty of female and male are also shown in the table. The highlighted cells indicate the average difficult indices **are not** significantly different.

	1st group			2nd group		
	Female	Male	All	Female	Male	All
Number of students	665	686	1,351	295	296	591
Average difficulty index for all 80 items	0.446	0.505	0.476	**0.409**	**0.446**	0.427
Average difficulty index for 32 similar items	0.437	0.494	0.466	0.462	0.488	0.475
Average difficulty index for 1D Motion items	0.450	0.504	0.478	0.494	0.553	0.523
Average difficulty index for 2D Motion items	0.436	0.490	0.463	0.431	0.519	0.475
Average difficulty index for Newton's laws of motion items	0.430	0.515	0.473	0.358	0.419	0.389
Average difficulty index for work & energy items	0.409	0.470	0.440	**0.459**	**0.485**	0.472
Average difficulty index for momentum items	0.376	0.428	0.402	**0.481**	**0.520**	0.501
Average difficulty index for rotation kinematics items	0.373	0.459	0.417	**0.292**	**0.325**	0.309
Average difficulty index for torque items	0.336	0.431	0.384	**0.475**	**0.506**	0.491
Average difficulty index for angular momentum items	0.219	0.260	0.140	**0.371**	**0.400**	0.385
Average difficulty index for oscillation items	0.448	0.516	0.482	**0.346**	**0.374**	0.360
Average difficulty index for wave items	0.590	0.621	0.606	**0.427**	**0.436**	0.431
Average difficulty index for fluid mechanics	0.394	0.444	0.420	**0.359**	**0.359**	0.359
Average difficulty index for all numerical items	0.419	0.483	0.451	**0.404**	**0.439**	0.421
Average difficulty index for all conceptual items	0.482	0.526	0.504	0.425	0.470	0.448
Average difficulty index for similar numerical items	0.453	0.517	0.486	**0.466**	**0.489**	0.477
Average difficulty index for similar conceptual items	0.518	0.576	0.547	**0.501**	**0.516**	0.508

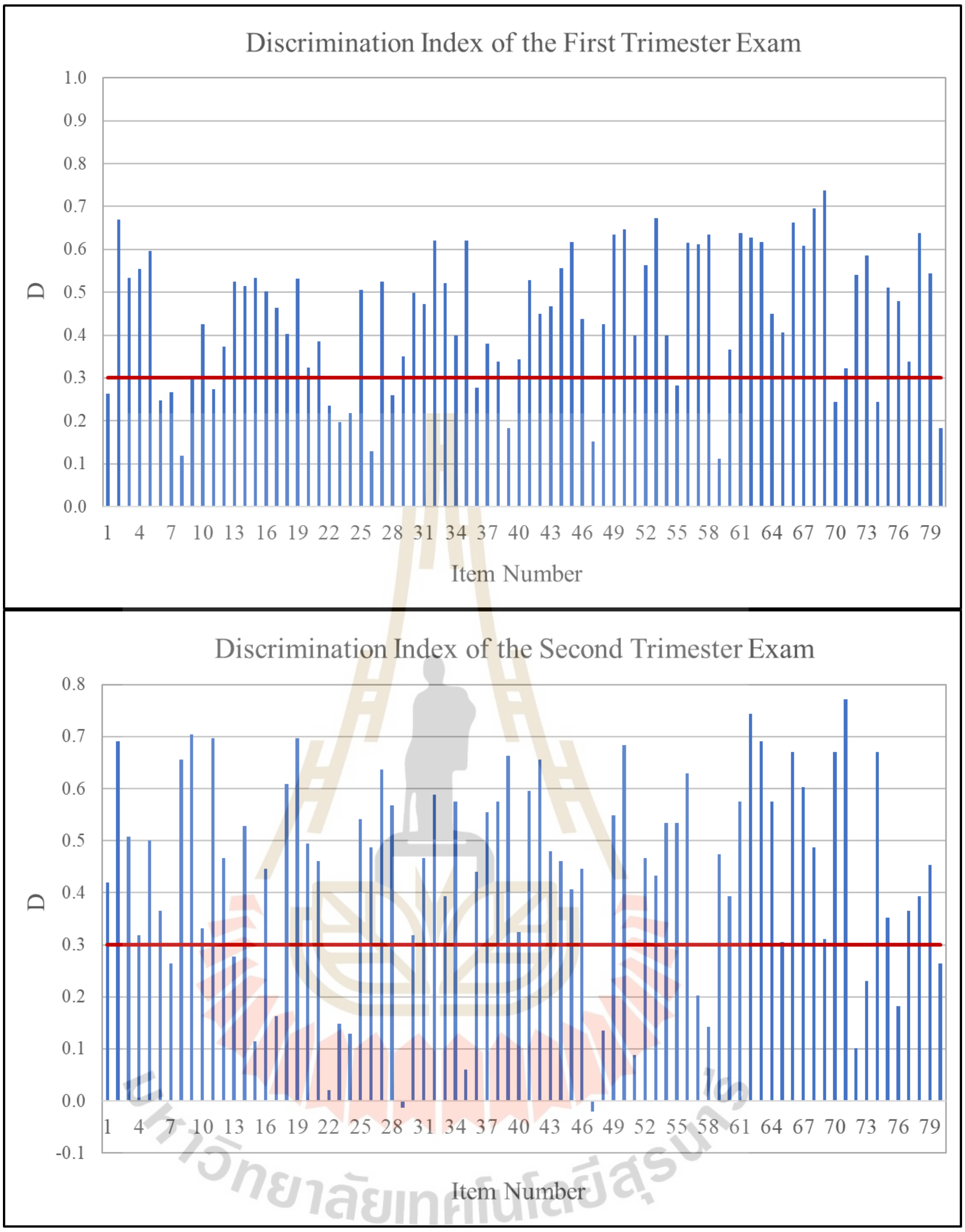
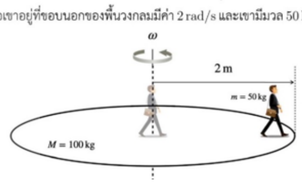


Figure 14 Discrimination indices (D) of each item in the first groups (upper) and the second group (lower) physics exams.

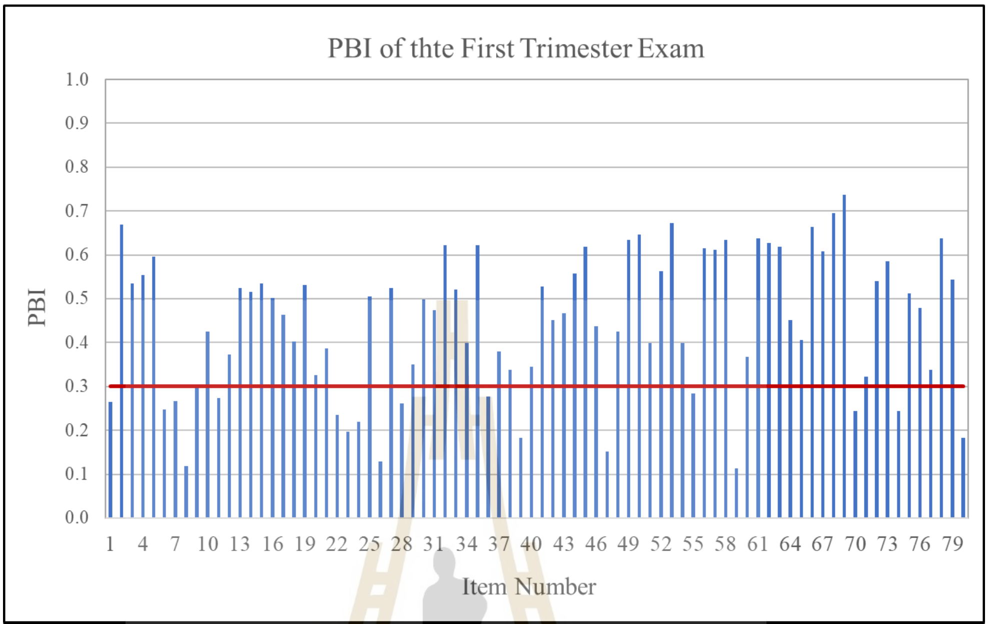
When we consider gender gap, in the first group, at 0.05 degree of significance male students did better than female students in their overall score. As for the physics topics, males did better than females at all topics. In the second group, the gender gap was reduced significantly. The orange-highlighted cells indicate those categories for which there were no significant differences in the average difficulty index.

Table 10 Two physics exam questions in the second group that have negative discrimination indices.

<table>
<tr><th>Group 1</th><th>Group 2</th></tr>
<tr><td>29. รถยนต์มวล 1,500 kg วิ่งมาด้วยอัตราเร็ว 20 m/s เกิดอุบัติเหตุพุ่งเข้าชนรถจักรยานยนต์ที่จอดอยู่นิ่งแล้วลไป โมเมนตัมรวมของรถยนต์และรถจักรยานยนต์หลังชนกันมีค่าเท่าใด
1) 15,000 kg m/s
2) 30,000 kg m/s
3) 35,000 kg m/s
4) 40,000 kg m/s
5) ข้อมูลไม่เพียงพอ</td><td>17. ชายคนหนึ่งยืนอยู่บนพื้นที่มีลักษณะเป็นแผ่นกลมหมุนรอบแกนที่ผ่านจุดศูนย์กลางและตั้งฉากกับระนาบของพื้น โดยแผ่นนี้มีมวล 100 kg และมีรัศมี 2 m ถ้าตอนเริ่มต้นชายคนนี้ยืนอยู่ ณ ตำแหน่งจุดศูนย์กลาง จากนั้นเขาเดินช้าๆเป็นเส้นตรงในแนวรัศมีออกไปยังริมด้านนอก จงหาอัตราเร็วเชิงมุมตอนเริ่มต้นของระบบเมื่อทราบว่าอัตราเร็วเชิงมุมเมื่อเขาอยู่ที่ขอบนอกของพื้นวงกลมมีค่า 2 rad/s และเขามีมวล 50 kg
(1) 1 rad/s
(2) 2 rad/s
(3) 3 rad/s
(4) 4 rad/s
(5) 5 rad/s

</td></tr>
<tr><td>29. A car of mass 1500 kg moves at speed 20 m/s and hits a motorcycle that was parking still. After the collision, both moves together with the same velocity. What is the magnitude of the total momentum of both vehicles after the collision?
1) 15000 kg m/s (3.6%)
2) 30000 kg m/s (54.7%) N_H= 81, N_L = 83
3) 35000 kg m/s (6.8%)
4) 40000 kg m/s (1.6%)
5) Not enough info (33.2%)</td><td>17. A man of mass 50 kg is standing on a spinning disc of mass 100 kg and of radius 2 m. Its axis of rotation is perpendicular to the disc and passes through the center of the disc. Initially, the man was at the center of the disc. Then, he walks towards the edge of the disc. If his angular speed at the edge is 2 rad/s, what is the initial angular speed of the system?
1) 1 rad/s (19.3%)
2) 2 rad/s (28.2%)
3) 3 rad/s (12.7%)
4) 4 rad/s (28.9%) N_H= 42, N_L = 45
5) 5 rad/s (9.6%)</td></tr>
</table>

3.2.2 Item Discrimination Index

The discrimination indices of each item are shown in figure 14. There are 18 items in the first and 18 items in the second group that have discrimination index lower than 0.3. The items #29 and #47 in the second group have negative discrimination index.



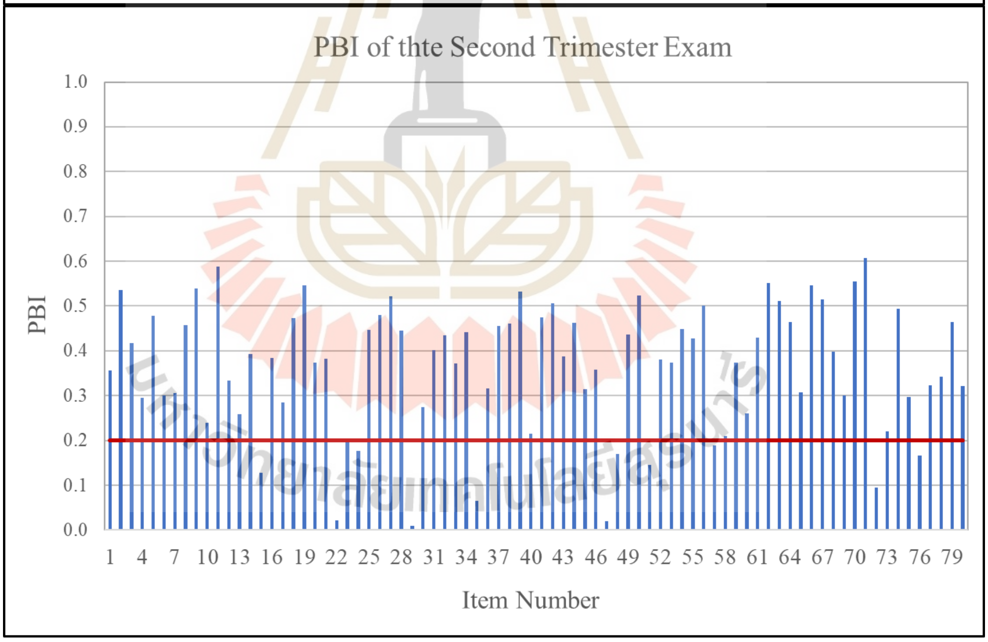


Figure 15 Point Biserial Indices (PBI) of each item in the first groups (upper) and the second group (lower) physics exams.

Table 10 displays the two questions corresponding to these items, #29 on the left and #47 on the right. The number in each bracket is the percentage of students who chose the multiple choice. The values of N_H and N_L are also shown for the correct choice.

3.2.3 Point Biserial Index

The PBI of each item are shown in figure 15. There are 5 items in the first and 12 items in the second group that have lower than 0.2 PBI.

3.2.4 Reliability of the Whole Exam

The reliability of an exam is measured using Kuder-Richardson's reliability index and Ferguson's delta. Both indices of both exams are shown in table 11. Both exams have high reliability.

Table 11 The overall reliability of the physics exams.

Reliability index	1^{st} group	2^{nd} group
KR-20	0.92	0.92
Ferguson's delta	0.99	0.99

3.3 Conclusion

The multiple-choice physics exam questions in both groups are valid and reliable. The average score out of similar 32 items of the students in the second group is higher than that of those in the first group, suggesting that better mathematics knowledge could lead to better physics exam scores. The gender gap is smaller in the second group of the students. The previous literature highlighted that the gender gap is occur due to high school physics education and affective experience (Hazari, 2007). Another work from university of Minnesota also found gender gap between female and male students in pre-test Force Inventory Concept (FCI) but not on the post-test (Docktor, 2008).

CHAPTER IV

CORRELATION OF MATHEMATICS TEST AND PHYSICS EXAM SCORE

In this chapter, we present several measures of correlation between the math test scores and the physics exam scores of the two distinct groups of first-year engineering students at SUT. Specifically, we investigate the overall correlation between the two subjects, as well as correlations between scores on particular mathematics and physics topics.

The statistical correlation coefficient used here, called Pearson's correlation coefficient (r), measures the strength and direction of the linear relationship between two quantitative variables. The value of the coefficient ranges from -1 to 1. A correlation coefficient of -1 indicates a perfectly negative correlation, meaning that as one variable increases, the other variable decreases. A correlation coefficient of 0 indicates no correlation between the two variables, so the variables are linearly independent. A correlation coefficient of 1 indicates a perfectly positive correlation, meaning that as one variable increases, the other variable also increases. The coefficient is calculated using the formula (Schober et al., 2018):

$$r = \frac{\sum_{i=1}^{N}(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\sum_{i=1}^{N}(x_i-\bar{x})^2\sum_{i=1}^{N}(y_i-\bar{y})^2}}. \tag{4.1}$$

N is the number of data points. x_i and y_i are the values of the first and the second variables, with the integer index *i* labeling individual data points , $\bar{x}$ and $\bar{y}$ are the mean values of variable x and y. Note that perfect correlation, with $r = 1$, would occur if $x = y$. That is, a variable is perfectly correlated with itself. On the other hand, if the two variables are independent, then variations from their respective means fluctuate independently and r averages to zero. A maximally negative value 0

$r = -1$ would occur if $x = -y$. The strength of the correlation coefficient can be characterized as follows.

1) Weak correlation: r between 0 and 0.3 (or between 0 and -0.3).

2) Moderate correlation: r between 0.3 and 0.7 (or between -0.3 and -0.7).

3) Strong correlation: r greater than 0.7 (or less than -0.7)

Apart from the Pearson correlation coefficient, the level of significance (p-value) is another important statistic that must be reported. The p-value indicates the likelihood that the result of an experiment occurred by chance (Thiese et al., 2016). If the level of significance is lower than a certain value, we can conclude that the observed correlation is statistically significant (i.e. that it unlikely to be due to chance). Correlations that are far from zero usually have a p-value lower than 0.05. Generally, a p-value of 0.05 is the most commonly used threshold in statistical experiments. It indicates that there is only a 5% chance that the result could have occurred by chance. This number is automatically calculated along with the Pearson correlation coefficient in SPSS.

4.1 Results and Discussion

To determine the correlation between scores, we only included students who had taken both the mathematics test and the physics exam in each group. There were 1,243 such students in the first trimester and 507 in the second trimester. We calculated several pairwise correlations between the mathematics test items and physics exam items and present the results in table 12, for those in the first group and table 13 for the second group.

The correlation between pre-instruction mathematics test scores and physics exam scores for both groups of students falls within the moderate range ($0.3 < r < 0.7$). However, the correlation is twice as strong for the first group of students, who had a lower average mathematics test score. To investigate this observation further, we examined the correlation between math and physics scores within subsets of students in the same trimester.

Table 12 Pearson's correlation coefficients between the categorized physics and mathematics items of the students in the first trimester. All correlated pairs are significant with degree of significancy less than 0.05.

Physics topic items (number of items in brackets)	Pearson's correlation coefficients that were computed between the scores of the items in the first column and those in the rows below (number of items in brackets)			
	All mathematics items (31)	Algebra items (15)	Geometry items (12)	Calculus items (4)
All physics items (80)	**0.662**	0.614	0.515	0.459
1D motion items (7)	0.557	0.516	0.425	0.409
2D motion items (8)	0.497	0.463	0.391	0.332
Newton's laws of motion items (9)	0.440	0.379	0.375	0.320
Work & energy items (9)	0.476	0.435	0.385	0.317
Momentum items (3)	0.364	0.320	0.299	0.269
Rotation kinematics items (9)	0.489	0.423	0.432	0.314
Torque items (6)	0.424	0.356	0.378	0.295
Angular momentum items (2)	0.316	0.278	0.265	0.219
Oscillation items (11)	0.525	0.505	0.391	0.348
Waves items (13)	0.534	0.536	0.357	0.381
Fluid mechanics items (8)	0.510	0.471	0.392	0.369
Numerical items (61)	0.662	0.618	0.510	0.461
Conceptual items (19)	0.511	0.461	0.418	0.347
Similar physics items (32)	**0.619**	0.571	0.483	0.437
Similar numerical items (24)	**0.609**	0.558	0.480	0.428
Similar conceptual items (8)	**0.424**	0.392	0.327	0.308

Table 13 Correlation between physics topics listed in the first column and mathematics topics of the students in the second trimester. Almost all the correlated pairs are significant with degree of significancy less than 0.05.

Physics topic items (number of items in brackets)	Pearson's correlation coefficients that were computed between the scores of the items in the first column and those in the rows below (number of items in brackets)			
	All mathematics items (31)	Algebra items (15)	Geometry items (12)	Calculus items (4)
All physics items (80)	**0.338**	0.368	0.266	0.266
1D motion items (7)	0.225	0.246	0.182	0.179
2D motion items (9)	0.242	0.271	0.178	0.202
Newton's laws of motion items (10)	0.275	0.272	0.262	0.161
Work & energy items (6)	0.240	0.277	0.175	0.228
Momentum items (4)	0.185	0.186	0.153	0.131
Rotation kinematics items (7)	0.172	0.215	0.087	0.138
Torque items (7)	0.193	0.219	0.157	0.152
Angular momentum items (1)	0.177	0.164	0.153	0.168
Oscillation items (10)	0.261	0.284	0.197	0.226
Waves items (15)	0.330	0.361	0.255	0.264
Fluid mechanics items (7)	0.279	0.294	0.233	0.190
Numerical items (62)	0.356	0.385	0.279	0.275
Conceptual items (18)	0.190	0.217	0.153	0.167
Similar physics items (32)	**0.309**	0.344	0.246	0.245
Similar numerical items (24)	**0.314**	0.350	0.245	0.250
Similar conceptual items (8)	**0.123**	0.126	0.086	0.132

In Figure 16, there are two scatter plots that illustrate the relationship between mathematics and physics scores for weak and strong mathematics students based on their mathematics test scores and the common 32 physics exam question scores. The scatter plots are divided by orange lines at the mathematics score of 15 (out of 31), separating the weaker mathematics students on the left from the stronger mathematics students on the right. With a visual inspection, it appears that the average physics score is increasing linearly with mathematics score for weaker students, but this curve flattens so that average physics scores depend less strongly on mathematics scores for the strong students. Moreover, the variance of the data among students with the same mathematics score is clearly larger for the strong students. This implies that mathematics scores are a better predictor of physics scores for students who are weak at mathematics. We can confirm this observation by examining the correlation coefficient values. In the first trimester group of students, the correlation coefficient for weaker mathematics students is 0.504, while the stronger mathematics students have a coefficient of 0.246. Similarly, in the second trimester group, the correlation coefficient for weaker mathematics students is 0.386, and the stronger mathematics students have a coefficient of 0.127. It's worth noting that these values do not take into account students who scored exactly 15 on the mathematics test (73 students from group 1 and 26 students from group 2 scored exactly 15).

It is not difficult to understand why students who are weak in mathematics would show a stronger correlation between their mathematics test scores and physics scores than others. There are presumably many factors, one of which is mathematical knowledge, that determine success in a physics course. But mathematics is likely a crucial factor for those students who are weakest in it, just as the slowest step in a chemical reaction determines the overall rate reaction. That is, for students who are weak in mathematics, their understanding of mathematics likely limits their ability to understand physics. An increase in mathematical knowledge thus results predictably in an increased physics score, i.e. mathematics test scores and physics test scores are strongly correlated. On the other hand, for mathematically strong students it is some other factor, not mathematical knowledge, that limits their physics understanding. So, the correlation between mathematics and physics test scores is understandably weaker.

This argument is consistent with previous research by Hudson et al. (Hudson et al., 1977; Hudson et al., 1981), which found that the correlation between mathematics pre-test score and the final grade in introductory physics predicts failure rather than success. Indeed, students who are weakest in mathematics are likely to fail in physics (the correlation is strong for this group) whereas students who are good in mathematics may or may not succeed in physics (the weaker correlation is less predictive).

Additional findings can be derived from the correlation coefficient values presented in tables 12 and tables 13. Firstly, the mathematics topic that exhibits the strongest correlation coefficient with physics exam scores is algebra. Secondly, the correlation coefficient between numerical physics items and mathematics is higher than that between conceptual items and mathematics.

4.2 Conclusion

In conclusion, we have presented the correlation coefficients between the mathematics test scores and physics exam scores for two groups of students in this chapter. All correlations are positive and moderate in strength. Upon closer inspection, we found that the correlation coefficient for weaker mathematics students is higher than that for stronger mathematics students.

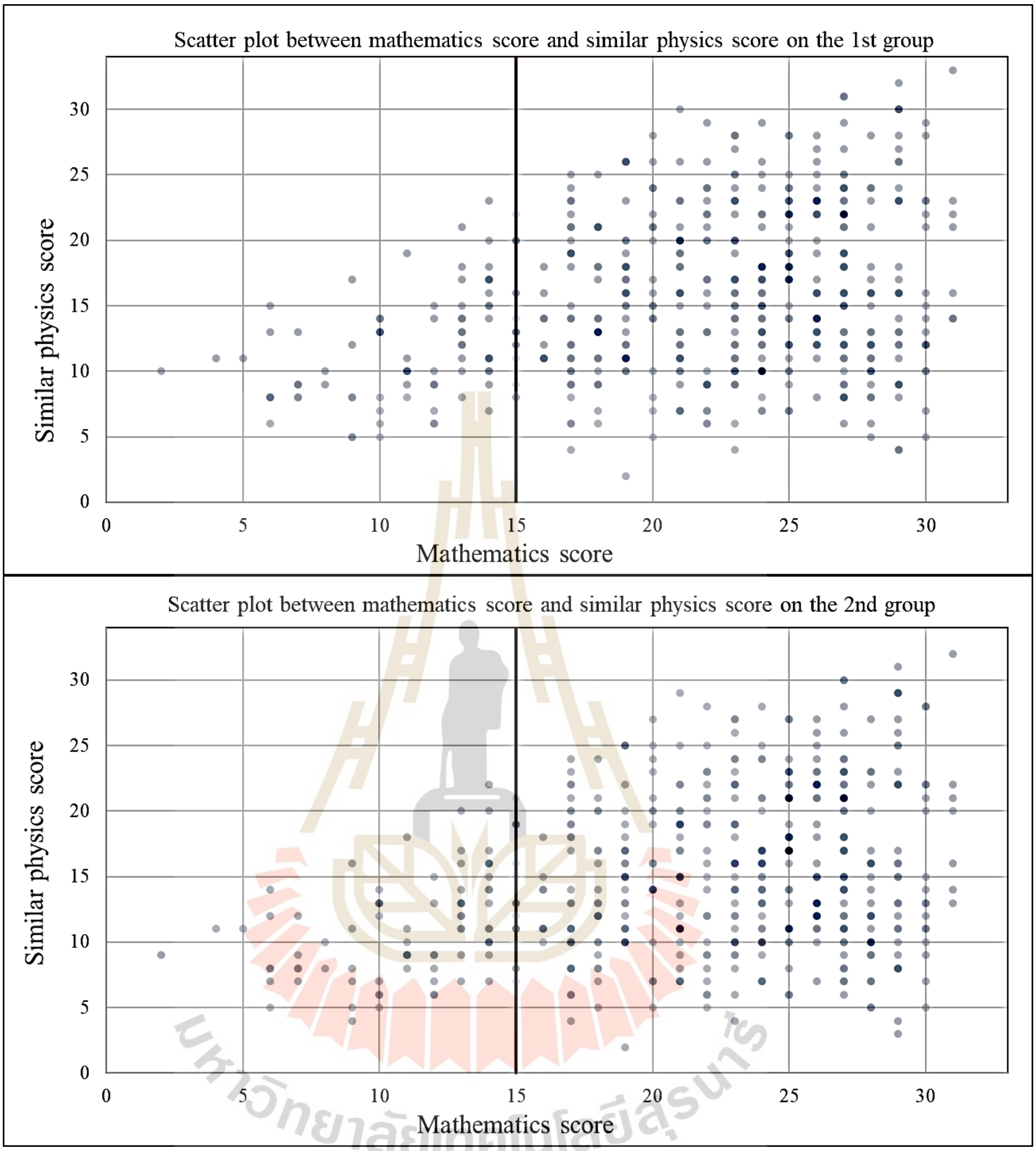


Figure 16 The scatter plots show the relationship between mathematics test scores and common physics exam question scores for two groups of students: the first group of the students in the upper and the second group in the lower panel. Each point on the plot represents at least one student, with the opacity of the point indicating the number of students at that score. The orange line is half of the mathematics score. It is evident that the correlation trend is more pronounced on the left side of the line in both groups.

CHAPTER V

CONCLUSION

In this thesis, we analyzed the pre-instruction mathematics test scores and physics exam scores of first-year engineering students who took Physics I at SUT during the academic year 2020. The students were randomly assigned to two groups: those who took Physics I in the first trimester and those who took it in the second trimester. Both groups took the same pre-instruction mathematics test, consisting of 31 identical questions, in the first class of Physics I. In each trimester, there were two physics exams (midterm and final), and we collected the results of 80 multiple-choice physics questions from each exam and treated them as one physics exam score for that trimester. While none of the physics questions were identical, 32 of them in each trimester were deemed nominally similar.

Our findings indicate that the second group of students was stronger in mathematics, based on their average mathematics test score. This difference may be due to the fact that the second group took the pre-instruction mathematics test after completing SUT Calculus I in the previous trimester, whereas the first group took the mathematics test before completing the course. Additionally, male students in the first group performed significantly better than female students on the mathematics test, while both male and female students in the second group performed equally well.

Regarding the physics exam results, the average score (out of all 80 physics questions) of the first group was higher than that of the second group. This could be due to the higher overall difficulty level of the exam for the second group. However, when considering the similar 32 physics questions, the average score of the second group was higher. Male students in both groups performed better than female students on the physics exam.

We also observed positive and moderately strong correlations between the mathematics test scores and the physics exam scores. However, we found that this correlation was weaker for students who performed better on the mathematics test.

As a suggestion to the lecturers, if the students are not well-groomed in mathematics, the lecturer should give them the mathematical help. It should be also kept in mind that the failure in physics is not necessary be the result of low mathematical skill. So, before the students take physics exams they should pass a necessary mathematical skill test. The failed students should take an extra mathematics course and pass the test before they can enroll physics course. If the students still fail in physics course, the other parameter that affect physics learning should be examine.

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APPENDIX

APPENDIX

MATHEMATICS TEST AND PHYSICS EXAM IN THIS THESIS

Mathematics test used in the 1st and the 2nd trimester are shown in **Figure A-1** to **Figure A-8** in this order

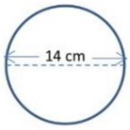
1) 1st trimester mathematics test (**Figure A-1** to **Figure A-4**)

2) 2nd trimester mathematics test (**Figure A-5** to **Figure A-8**)

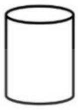
Three items in each test do not exist in the other trimester test. The 1st trimester test does not contain item 21, 30 and 31 that exist in the second trimester test. The 2nd trimester test does not contain item 21, 30 and 32 that exist in the first trimester test. Therefore, the total number of mathematics test in each term are 31

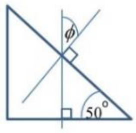
ชื่อ______________________________ รหัสนักศึกษา______________ 1 / 4

1. วงกลมที่มีเส้นผ่านศูนย์กลางยาว 14 cm มี **เส้นรอบวง** ยาวเท่าใด
   1) 616 cm
   2) 308 cm
   3) 154 cm
   4) 88 cm
   5) 44 cm

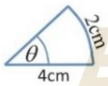


2. พื้นที่ของวงกลมที่มีรัศมี R มีค่าเท่าใด
   1) $\frac{4}{3}\pi R^3$ 2) πR 3) $2\pi R$ 4) πR^2 5) $4\pi R^2$
3. ทรงกระบอกที่มีพื้นที่หน้าตัด 15.0 cm^2 และสูง 20.0 cm มีปริมาตรเท่าใด
   1) 600 cm^3
   2) 450 cm^3
   3) 300 cm^3
   4) 150 cm^3
   5) 75 cm^3

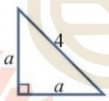




4. จากรูปด้านขวามือนี้ มุม ϕ มีค่าเท่ากับกี่องศา
   1) 50° 2) 40° 3) 30° 4) 45° 5) 25°
5. มุม 20 องศามีค่าเท่ากับกี่เรเดียน
   1) $\frac{\pi}{9}$ 2) 20π 3) 9π 4) $\frac{\pi}{90}$ 5) $\frac{\pi}{18}$
6. มุมθในรูปด้านล่างนี้ มีค่าเท่ากับกี่เรเดียน
   1) 8
   2) 0.5π
   3) 2
   4) 2π
   5) 0.5



7. a ในรูปด้านล่างขวานี้ยาวเท่าใด
   1) $\frac{1}{2}$
   2) $2\sqrt{2}$
   3) $\sqrt{\frac{1}{2}}$
   4) $\sqrt{2}$
   5) 2

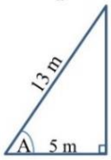


8. $\cos(135^o)$มีค่าเท่าใด
   1) $1/2$ 2) $-1/2$ 3) $1/\sqrt{2}$ 4) $-1/\sqrt{2}$ 5) $\sqrt{3}/2$
9. ข้อใดมีค่าเท่ากับ 0.0000056
   1) 5.6×10^{-3} 2) 5.6×10^{-4} 3) 5.6×10^{-5} 4) 5.6×10^{-6} 5) 5.6×10^{-7}
10. ข้อใดมีค่าเท่ากับ 1.2×10^5
    1) 1200 2) 12000 3) 120000 4) 1200000 5) 12000000
11. $(-2x^2)^3(3x^2)$ มีค่าเท่าใด
    1) $-24x^3$ 2) $-24x^8$ 3) $-6x^8$ 4) $24x^8$ 5) $24x^3$

Figure A-1 Page 1/4 of pre-instruction mathematics test in the first trimester.

ชื่อ______________________________ รหัสนักศึกษา______________ 2 / 4

12. พื้นเอียงหนึ่ง เอียงเป็นมุม A กับแนวระดับ โดยมีด้านตรงข้ามมุมฉากยาว 13 m มีฐานยาว 5 m ดังรูป cos A มีค่าเท่าใด
    1) 13/5
    2) 12/13
    3) 5/13
    4) 12/5
    5) 5/12



13. ถ้า $x = -2$ และ $y = 5$ แล้ว x^3y มีค่าเท่ากับเท่าใด
    1) -30
    2) -40
    3) 30
    4) 40
    5) 12

14. $(t^2 - 3t + 2) - (3t^2 - 5t - 1)$ เท่ากับเท่าใด
    1) $4t^2 - 8t + 1$
    2) $2t^2 + 2t + 3$
    3) $-2t^2 + 2t + 3$
    4) $-2t^2 - 2t - 1$
    5) $-2t^2 - 2t + 3$

15. $2^{-2}9^{\frac{1}{2}}$ มีค่าเท่าใด
    1) 18 2) -18 3) $\frac{3}{4}$ 4) $\frac{1}{18}$ 5) 12

16. $\frac{2.0\times10^{8}}{5.0\times10^{-12}}$ มีค่าเท่ากับเท่าใด
    1) 4.0×10^{19} 2) 4.0×10^{20} 3) 4.0×10^{4} 4) 4.0×10^{-4} 5) 4.0×10^{-5}

17. $(\log_{10} 5) + (\log_{10} 2)$ เท่ากับเท่าใด
    1) 1 2) 10 3) $\log_{10} 25$ 4) $\log_{10} 7$ 5) 0

18. $\frac{5}{6} - \frac{1}{4}$ มีค่าเท่ากับเท่าใด
    1) $\frac{3}{4}$ 2) $\frac{2}{3}$ 3) $\frac{1}{3}$ 4) $\frac{7}{12}$ 5) 2

19. $\frac{\frac{3}{4}}{\frac{2}{3}}$ มีค่าเท่ากับเท่าใด
    1) 2 2) $\frac{1}{3}$ 3) $\frac{9}{4}$ 4) $\frac{9}{8}$ 5) $\frac{1}{2}$

20. ถ้า$7y - 4 = 16 + 3y$ แล้ว y มีค่าเท่ากับเท่าใด
    1) 6/5 2) 2 3) 3 4) 5/6 5) 5

21. ถ้า $\log_b(C^4) = 8$ แล้ว $\log_b\left(\frac{1}{C}\right)$ มีค่าเท่าใด
    1) $\frac{1}{2}$
    2) $\sqrt[4]{8}$
    3) $\frac{1}{\sqrt[4]{8}}$
    4) -2
    5) $-\frac{1}{2}$

22. ถ้า $2^{x-3} = \frac{1}{16}$ แล้ว x มีค่าเท่าใด
    1) 7 2) 5 3) 3 4) 1 5) -1

Figure A-2 Page 2/4 of pre-instruction mathematics test in the first trimester.

ชื่อ________________________________ รหัสนักศึกษา_______________ 3 / 4

23. เส้นรอบรูปสี่เหลี่ยมผืนผ้ารูปหนึ่งยาว 16 cm และเราทราบว่า ด้านยาว ยาวกว่าด้านกว้าง 2.0 cm สี่เหลี่ยมรูปนี้มีพื้นที่กี่ตารางเซนติเมตร

1) 8.0 2) 10 3) 15 4) 16 5) 64

24. $I_1 + I_2 = 5$ และ $2I_1 - I_2 = 7$ ข้อใด คือ ค่าของ I_2

1) 1
2) 2
3) 3
4) 4
5) 5

25. ถ้า $\frac{1}{10} + \frac{1}{15} = \frac{1}{x}$ แล้ว x เท่ากับเท่าใด

1) $\frac{1}{5}$ 2) $\frac{1}{6}$ 3) 5 4) 6 5) $\frac{2}{3}$

26. ถ้า $2x^2 - 5x + 1 = 0$ ข่อใดเป็นคำตอบของสมการนี้ได้

1) $\frac{5+\sqrt{17}}{4}$
2) $\frac{-5+\sqrt{17}}{4}$
3) $\frac{-5-\sqrt{17}}{4}$
4) $\frac{-5+\sqrt{33}}{4}$
5) $\frac{5+\sqrt{33}}{4}$

27. ถ้า $f(x) = -x^3 + 2x^2 + 1$ แล้ว $\frac{df}{dx}$ (หรือ $f'(x)$) มีค่าเท่าใด

1) $-3x^2 + 4$
2) $-3x^2 + 4x$
3) $-3x^2 + 4x + 1$
4) $-3x + 4$
5) $-3x + 1$

28. ถ้า $x(t) = 2t^3 - 3t^2$ แล้ว $\frac{dx}{dt}$ (หรือ $x'(t)$) เมื่อ $t = 2$ มีค่าเท่าใด

1) −12 2) 12 3) 0 4) 6 5) −6

29. ถ้า $f(x) = 3x^2 + 1$แล้ว $\int_1^2 f(x)dx$ มีค่าเท่ากับเท่าใด

1) 4
2) 5
3) 6
4) 7
5) 8

30. เวกเตอร์เส้นประ A ถึง E ตัวใดที่บวกกับเวกเตอร์เส้นทึบ F แล้วได้เวกเตอร์ผลลัพธ์เป็นเวกเตอร์ที่**ชี้ไปทางซ้าย**

1) A
2) B
3) C
4) D
5) E

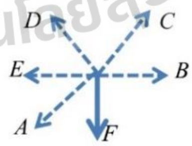
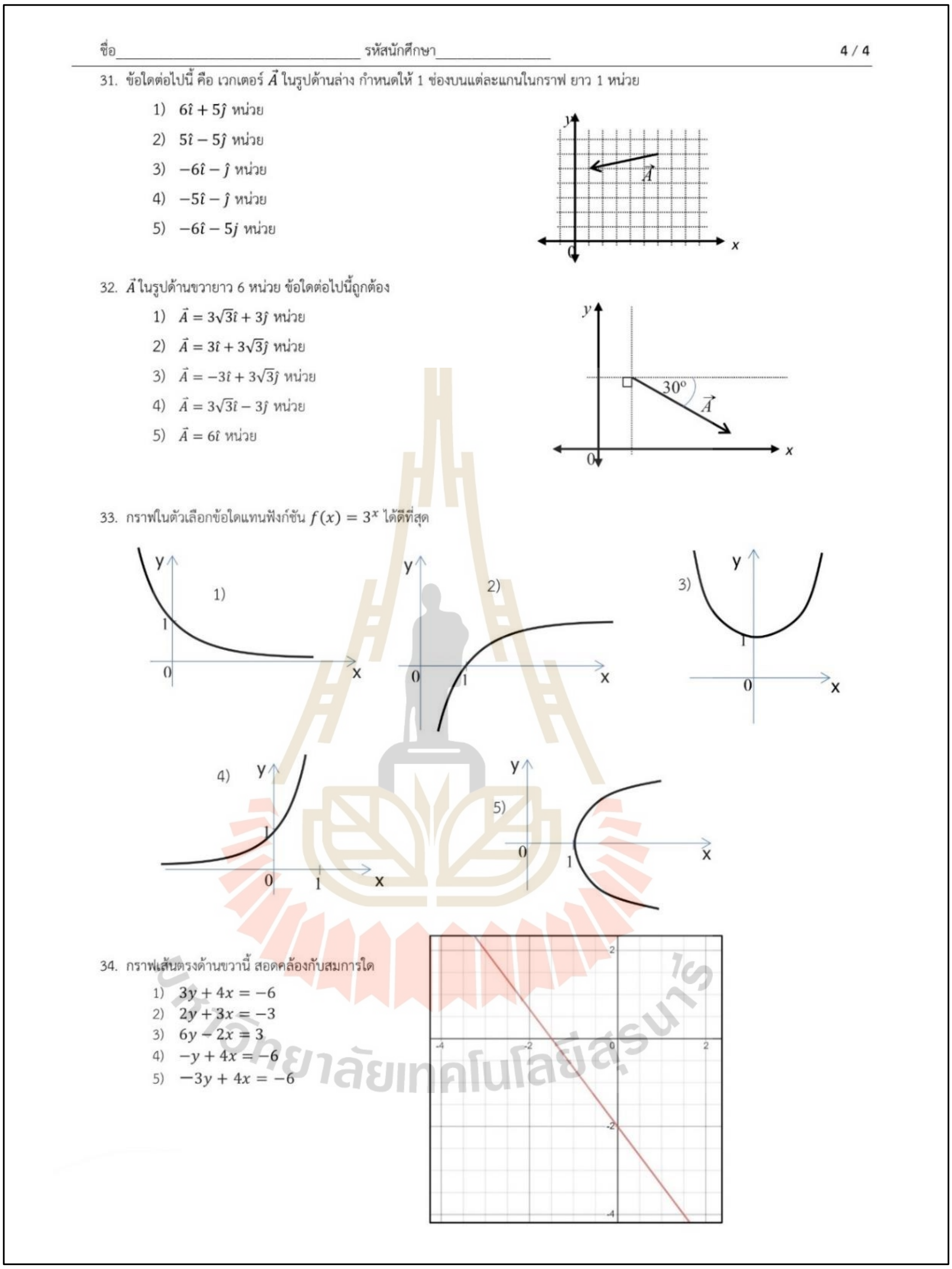


Figure A-3 Page 3/4 of pre-instruction mathematics test in the first trimester.



ชื่อ________________________________ รหัสนักศึกษา_______________ 4 / 4

31. ข้อใดต่อไปนี้ คือ เวกเตอร์ $\vec{A}$ ในรูปด้านล่าง กำหนดให้ 1 ช่องบนแต่ละแกนในกราฟ ยาว 1 หน่วย

1) $6\hat{\imath} + 5\hat{\jmath}$ หน่วย
2) $5\hat{\imath} - 5\hat{\jmath}$ หน่วย
3) $-6\hat{\imath} - \hat{\jmath}$ หน่วย
4) $-5\hat{\imath} - \hat{\jmath}$ หน่วย
5) $-6\hat{\imath} - 5j$ หน่วย

32. $\vec{A}$ ในรูปด้านขวายาว 6 หน่วย ข้อใดต่อไปนี้ถูกต้อง

1) $\vec{A} = 3\sqrt{3}\hat{\imath} + 3\hat{\jmath}$ หน่วย
2) $\vec{A} = 3\hat{\imath} + 3\sqrt{3}\hat{\jmath}$ หน่วย
3) $\vec{A} = -3\hat{\imath} + 3\sqrt{3}\hat{\jmath}$ หน่วย
4) $\vec{A} = 3\sqrt{3}\hat{\imath} - 3\hat{\jmath}$ หน่วย
5) $\vec{A} = 6\hat{\imath}$ หน่วย

33. กราฟในตัวเลือกข้อใดแทนฟังก์ชัน $f(x) = 3^x$ ได้ดีที่สุด

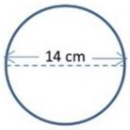
34. กราฟเส้นตรงด้านขวานี้ สอดคล้องกับสมการใด

1) $3y + 4x = -6$
2) $2y + 3x = -3$
3) $6y - 2x = 3$
4) $-y + 4x = -6$
5) $-3y + 4x = -6$

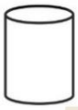
Figure A-4 Page 4/4 of pre-instruction mathematics test in the first trimester.

ชื่อ____________________________รหัสนักศึกษา______________

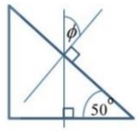
1. วงกลมที่มีเส้นผ่านศูนย์กลางยาว 14 cm มี **เส้นรอบวง** ยาวเท่าใด
   1) 616 cm
   2) 308 cm
   3) 154 cm
   4) 88 cm
   5) 44 cm



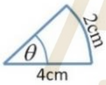
2. พื้นที่ของวงกลมที่มีรัศมี R มีค่าเท่าใด
   1) $\frac{4}{3}\pi R^3$ 2) πR 3) $2\pi R$ 4) πR^2 5) $4\pi R^2$
3. ทรงกระบอกที่มีพื้นที่หน้าตัด 15.0 cm² และสูง 20.0 cm มีปริมาตรเท่าใด
   1) 600 cm³
   2) 450 cm³
   3) 300 cm³
   4) 150 cm³
   5) 75 cm³



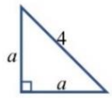
4. พื้นเอียงหนึ่งมีลักษณะดังแสดงในรูปด้านขวา มุม ϕ มีค่าเท่ากับกี่องศา
   1) 50° 2) 40° 3) 30° 4) 45° 5) 25°



5. มุม 20 องศามีค่าเท่ากับกี่เรเดียน
   1) $\frac{\pi}{9}$ 2) 20π 3) 9π 4) $\frac{\pi}{90}$
   5) $\frac{\pi}{18}$
6. มุม θ ในรูปด้านล่างนี้ มีค่าเท่ากับกี่เรเดียน
   1) 8
   2) 0.5π
   3) 2
   4) 2π
   5) 0.5



7. a ในรูปด้านล่างขวานี้ยาวเท่าใด
   1) $\frac{1}{2}$
   2) $2\sqrt{2}$
   3) $\sqrt{\frac{1}{2}}$
   4) $\sqrt{2}$
   5) 2



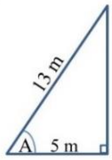
8. $\cos(135^o)$มีค่าเท่าใด
   1) $1/2$ 2) $-1/2$ 3) $1/\sqrt{2}$ 4) $-1/\sqrt{2}$ 5) $\sqrt{3}/2$
9. ข้อใดมีค่าเท่ากับ 0.0000056
   1) 5.6×10^{-3} 2) 5.6×10^{-4} 3) 5.6×10^{-5} 4) 5.6×10^{-6} 5) 5.6×10^{-7}
10. ข้อใดมีค่าเท่ากับ 1.2×10^5
    1) 1200 2) 12000 3) 120000 4) 1200000 5) 12000000
11. $(-2x^2)^3(3x^2)$ มีค่าเท่าใด
    1) $-24x^3$ 2) $-24x^8$ 3) $-6x^8$ 4) $24x^8$ 5) $24x^3$

Figure A-5 Page 1/4 of pre-instruction mathematics test in the second trimester.

ชื่อ________________________________รหัสนักศึกษา______________

12. พื้นเอียงหนึ่ง เอียงเป็นมุม A กับแนวระดับ โดยมีด้านตรงข้ามมุมฉากยาว 13 m มีฐานยาว 5 m ดังรูป cos A มีค่าเท่าใด

   1) 13/5
   2) 12/13
   3) 5/13
   4) 12/5
   5) 5/12



13. ถ้า $x = -2$ และ $y = 5$ แล้ว x^3y มีค่าเท่ากับเท่าใด

   1) -30
   2) -40
   3) 30
   4) 40
   5) 12

14. $(t^2 - 3t + 2) - (3t^2 - 5t - 1)$ เท่ากับเท่าใด

   1) $4t^2 - 8t + 1$
   2) $2t^2 + 2t + 3$
   3) $-2t^2 + 2t + 3$
   4) $-2t^2 - 2t - 1$
   5) $-2t^2 - 2t + 3$

15. $2^{-2}9^{\frac{1}{2}}$ มีค่าเท่าใด

   1) 18   2) -18 3) $\frac{3}{4}$ 4) $\frac{1}{18}$ 5) 12

16. $\frac{2.0\times10^{8}}{5.0\times10^{-12}}$ มีค่าเท่ากับเท่าใด

   1) 4.0×10^{19} 2) 4.0×10^{20} 3) 4.0×10^{4} 4) 4.0×10^{-4} 5) 4.0×10^{-5}

17. $(\log_{10} 5) + (\log_{10} 2)$ เท่ากับเท่าใด

   1) 1   2) 10   3) $\log_{10} 25$ 4) $\log_{10} 7$ 5) 0

18. $\frac{5}{6} - \frac{1}{4}$ มีค่าเท่ากับเท่าใด

   1) $\frac{3}{4}$ 2) $\frac{2}{3}$ 3) $\frac{1}{3}$ 4) $\frac{7}{12}$ 5) 2

19. $\frac{\frac{3}{4}}{\frac{2}{3}}$ มีค่าเท่ากับเท่าใด

   1) 2   2) $\frac{1}{3}$ 3) $\frac{9}{4}$ 4) $\frac{9}{8}$ 5) $\frac{1}{2}$

20. ถ้า $7y - 4 = 16 + 3y$ แล้ว y มีค่าเท่ากับเท่าใด

   6/5   2) 2   3) 3   4) 5/6   5) 5

21. ถ้า $\ln x = \frac{1}{2}$ แล้ว x มีค่าเท่าใด

   1) $\sqrt{10}$
   2) $\frac{1}{\sqrt{e}}$
   3) $\sqrt{e}$
   4) -2^{e}
   5) e^{-2}

Figure A-6 Page 2/4 of pre-instruction mathematics test in the second trimester.

ชื่อ________________________________รหัสนักศึกษา______________

22. $I_1 + I_2 = 5$ และ $2I_1 - I_2 = 7$ ข้อใด คือ ค่าของ I_2

   1) 1
   2) 2
   3) 3
   4) 4
   5) 5

23. ถ้า $2^{x-3} = \frac{1}{16}$ แล้ว x มีค่าเท่าใด

   1) 7   2) 5   3) 3   4) 1   5) -1

24. ถ้า $\frac{1}{10} + \frac{1}{15} = \frac{1}{x}$ แล้ว x เท่ากับเท่าใด

   1) $\frac{1}{5}$
   2) $\frac{1}{6}$
   3) 5
   4) 6
   5) $\frac{2}{3}$

25. เส้นรอบรูปสี่เหลี่ยมผืนผ้ารูปหนึ่งยาว 16 cm และเราทราบว่า ด้านยาว ยาวกว่าด้านกว้าง 2.0 cm สี่เหลี่ยมรูปนี้มีพื้นที่กี่ตารางเซนติเมตร

   1) 8.0   2) 10   3) 15   4) 16   5) 64

26. ถ้า $2x^2 - 5x + 1 = 0$ ข่อใดเป็นคำตอบของสมการนี้ได้

   1) $\frac{5+\sqrt{17}}{4}$
   2) $\frac{-5+\sqrt{17}}{4}$
   3) $\frac{-5-\sqrt{17}}{4}$
   4) $\frac{-5+\sqrt{33}}{4}$
   5) $\frac{5+\sqrt{33}}{4}$

27. ถ้า $f(x) = -x^3 + 2x^2 + 1$ แล้ว $\frac{df}{dx}$ หรือ $f'(x)$ มีค่าเท่าใด

   1) $-3x^2 + 4$
   2) $-3x^2 + 4x$
   3) $-3x^2 + 4x + 1$
   4) $-3x + 4$
   5) $-3x + 1$

28. ถ้า $x(t) = 2t^3 - 3t^2$ แล้ว$\frac{dx}{dt}$ หรือ$x'(t)$ที่ $t = 2$ มีค่าเท่าใด

   1) −12   2) 12   3) 0   4) 6   5) −6

29. ถ้า $f(x) = 3x^2 + 1$แล้ว $\int_1^2 f(x)dx$ มีค่าเท่ากับเท่าใด

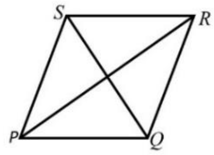
   1) 4
   2) 5
   3) 6
   4) 7
   5) 8

Figure A-7 Page 3/4 of pre-instruction mathematics test in the second trimester.

ชื่อ______________________________รหัสนักศึกษา_____________

30. พิจารณารูปด้านล่างนี้ $PQRS$ เป็นรูปสี่เหลี่ยมด้านขนาน โดยกำหนดให้ $\overrightarrow{PQ}$ หมายถึงเวกเตอร์ที่เริ่มจากจุด P ชี้ไปที่จุด Q เวกเตอร์ที่เป็นผลของ $\overrightarrow{PQ}+\overrightarrow{RS}$ คือข้อใด

1) $\overrightarrow{QS}$
2) $\overrightarrow{SQ}$
3) $\overrightarrow{PR}$
4) $\overrightarrow{RP}$
5) 0

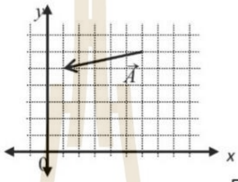


31. จากข้อ 30. เวกเตอร์ที่เป็นผลของ $\overrightarrow{PS}-\overrightarrow{PQ}$ คือข้อใด

1) $\overrightarrow{QS}$ 2) $\overrightarrow{SQ}$ 3) $\overrightarrow{PR}$ 4) $\overrightarrow{RP}$ 5) $\overrightarrow{SR}$

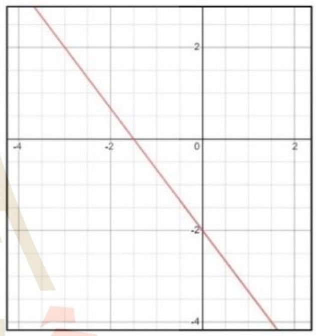
32. ข้อใดต่อไปนี้ คือ เวกเตอร์ $\vec{A}$ ในรูปด้านล่าง กำหนดให้ 1 ช่องบนแต่ละแกนในกราฟ ยาว 1 หน่วย

1) $6\hat{\imath}+5\hat{\jmath}$ หน่วย
2) $5\hat{\imath}-5\hat{\jmath}$ หน่วย
3) $-6\hat{\imath}-\hat{\jmath}$ หน่วย
4) $-5\hat{\imath}-\hat{\jmath}$ หน่วย
5) $-6\hat{\imath}-5j$ หน่วย



33. กราฟเส้นตรงด้านขวานี้ สอดคล้องกับสมการใด

1) $3y+4x=-6$
2) $2y+3x=-3$
3) $6y-2x=3$
4) $-y+4x=-6$
5) $-3y+4x=-6$



34. กราฟในตัวเลือกข้อใดแทนฟังก์ชัน $f(x)=3^x$ ได้ดีที่สุด

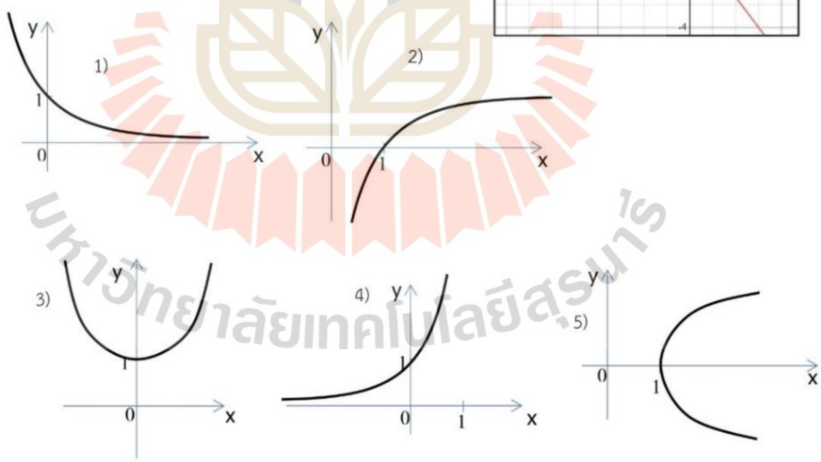


Figure A-8 Page 4/4 of pre-instruction mathematics test in the second trimester.

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