THE USE OF INTERACTIVE LECTURE DEMONSTRATION IN TEACHING HIGH-SCHOOL PHYSICS: MAGNETIC FORCE ON A MOVING CHARGED PARTICLE

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ABSTRACT

This research presented the use of Interactive Lecture Demonstration (ILD) in teaching high-school level on magnetic force on a moving charged particle. The aim of this work was to study grade-12 students' understanding on this physics topic and comparing the effectiveness of ILD method to traditional teaching. The ILD teaching module with the Cathode-ray tube as demonstration set had been developed and administrated to high school students. After the instruction, all sample groups' conceptual understanding were assessed by the Magnetic Force on a moving Charged Particle Test. In year 2014, the results showed that most students had difficulty of indicating the direction and magnitude of the magnetic force. They were unable to apply the right-hand rule. However, the mean score of the ILD classes was significantly better than that of the traditional class. In year 2015, the mean scores of all sample groups decreased and were extremely low compared to the previous year. Overall, the ILD method could enhance understanding of students with the requirement that some members of each group should have a good background in the subject.

In addition, most students lack consistency in answering the same concept questions. However, the number of students who had highest consistency belong to ILD class in 2014.

KEY WORDS: INTERACTIVE LECTURE DEMONSTRATION (ILD) /
MAGNETIC FORCE ON A MOVING CHARGED PARTICLE

66 pages

การใช้วิธีการสอนแบบบรรยายประกอบการสาธิตเชิงปฏิสัมพันธ์ในการสอนฟิสิกส์ระดับมัธยมศึกษาตอนปลาย เรื่องแรงแม่เหล็กที่กระทำต่ออนุภาคที่มีประจุไฟฟ้าที่กำลังเคลื่อนที่

THE USE OF INTERACTIVE LECTURE DEMONSTRATION IN TEACHING HIGH- SCHOOL PHYSICS: MAGNETIC FORCE ON A MOVING CHARGED PARTICLE

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บทคัดย่อ

งานวิจัยนี้นำเสนอวิธีการสอนแบบบรรยายประกอบการสาธิตเชิงปฏิสัมพันธ์(ILD) ในเรื่องแรงแม่เหล็กที่กระทำต่ออนุภาคที่มีประจุไฟฟ้าสำหรับการสอนในระดับมัธยมศึกษาตอนปลาย โดยมีวัตถุประสงค์เพื่อศึกษาความเข้าใจของนักเรียนระดับมัธยมศึกษาปีที่ 6 และเปรียบเทียบประสิทธิภาพการสอนระหว่างวิธีการสอนแบบบรรยายประกอบการสาธิตเชิงปฏิสัมพันธ์(ILD)และวิธีการสอนแบบดั่งเดิม(traditional teaching)

งานวิจัยนี้ได้มีการพัฒนาชุดการเรียนการสอน ILD โดยใช้หลอดรังสีแคโทดเป็นชุดสาธิตประกอบการสอน หลังจากเสร็จสิ้นการเรียน นักเรียนทุกกลุ่มได้รับการทดสอบความเข้าใจหลังเรียนด้วยแบบทดสอบแรงแม่เหล็กที่กระทำต่ออนุภาคที่มีประจุไฟฟ้า พบว่า ในปีการศึกษา 2557 นักเรียนจำนวนมากมีความเข้าใจผิดในการหาทิศทางและขนาดของแรงแม่เหล็กและขาดความชำนาญในการใช้กฎมือขวา อย่างไรก็ตาม คะแนนเฉลี่ยของนักเรียนในห้องเรียนที่สอนแบบบรรยายประกอบการสาธิตเชิงปฏิสัมพันธ์(ILD)สูงกว่าห้องเรียนที่สอนด้วยวิธีแบบดั่งเดิมอย่างมีนัยสำคัญ ในปีการศึกษา 2558 คะแนนเฉลี่ยของนักเรียนแต่ละกลุ่มมีค่าน้อยเมื่อเทียบกับคะแนนเต็มและต่ำกว่าปีที่ผ่านมา การสอนแบบบรรยายประกอบการสาธิตเชิงปฏิสัมพันธ์(ILD)ช่วยพัฒนาความเข้าใจของนักเรียนได้ดี โดยมีเงื่อนไขที่สมาชิกในกลุ่มย่อยจะต้องมีนักเรียนที่มีความรู้พื้นฐานฟิสิกส์เป็นอย่างดีอยู่ในกลุ่ม นอกจากนี้ พบว่านักเรียนส่วนใหญ่ไม่สามารถตอบคำถามที่ทดสอบความเข้าใจในประเด็นเดียวกันได้ อย่างไรก็ตาม ในปีการศึกษา 2557 นักเรียนที่สอนแบบบรรยายประกอบการสาธิตเชิงปฏิสัมพันธ์(ILD) มีจำนวนนักเรียนที่สามารถตอบคำถามที่วัดความเข้าใจในประเด็นเดียวกันได้มากที่สุด

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CHAPTER I

INTRODUCTION

This chapter presents the introduction of this dissertation which consist of the significance of this research on Thai high-school student's understanding in the topic of Magnetic Force on a Moving Charged Particle, the purpose of this study, the research question and the structure of this dissertation.

1.1 Context of the study

Magnetic force on a moving charged particle is commonly taught in high-school and undergraduate levels in the domain of Electricity and Magnetism. Many learners regarded this topic as difficult to understand due to abstract concept (1). Although, the magnetic force on a moving charged particle topic seems to be very simple subtopic with a few detail and most instructor finished this topic in a short time. There are several earlier researches which presented the opposite results to that was expected by many instructors.

Maloney et al. developed the Conceptual Survey of Electricity and Magnetism (CSEM) (2). It was the well-known conceptual test of Electricity and Magnetism. By using this test, they found that students were confused in such physics content. They also found that standard instruction was unsuccessful to improve student's understanding on magnetic force on a moving charged particle.

Furthermore, Thai-students' knowledge in this physics topic was studied by Kaewkhong (2012) (3). He investigated conceptual understanding in the topic of magnetic force on a moving charged particle of the first-year engineering students at University of Phayao who enrolled in an introductory physics course. The result showed that a half of students still lacked conceptual understanding, they could not find the direction of magnetic force by applying the right-hand rule and were confused to find magnitude of magnetic force when the charged magnitude changed.

During the past few decades, physics education research has the aim of study on students' understanding in physics and misunderstanding which is caused by the student or instruction process (4). The founding are very helpful for instructor to prepare their instruction for high effectiveness. There are many researches which found the evidences showing the low effectiveness of student learning with traditional teaching. In traditional teaching, the lecturers always described physics content by talking, gave student the example and showed how to solve problems (5, 6). Knowing students' difficulties, researchers have developed new instruction based on active learning approach that student can realize scientific concept more than transformation and memorizing (7).

One familiar active learn strategy, namely Interactive Lecture Demonstration (ILD was developed from microcomputer-based laboratory tools that establishs an active learning environment in lecture portion of introductory course (Sokoloff & Thornton, 1997) (8, 9). In ILD, the instructor has more interaction with students and students get more chance to discuss their understanding with their peers. Students do not only observe the demonstration, they also are asked to predict individually and allowed to discuss their individual prediction with peers in small group. This step provides a good chance for student conceptual changing. After that the instructor shows the result of the demonstration and have the whole class discuss the conclusion. Additional advantage of ILD teaching method is that it could improve students' understanding with less investment of time and without the prerequisite understanding (10).

Therefore, this study purposes to survey high-school student conceptual understanding and compare effectiveness between ILD method and traditional teaching in the topic of magnetic force on a moving charged particle.

1.2 Purposes of the study

To enhance student conceptual understanding in the topic of magnetic force on a moving charged particle by using Interactive Lecture Demonstration (ILD).

1.3 Research question

Does Interactive Lecture Demonstration (ILD) have effectiveness to enhance high-school student conceptual understanding in the topic of magnetic force on a moving charged particle greater than traditional teaching?

1.4 Expected output

1.4.1 ILD worksheet
1.4.2 Guided worksheet (for Lecture)
1.4.3 The Magnetic Force on a Moving Charged Particle test
1.4.4 Cross Product Model

1.5 Expected outcome

Students who study by Interactive Lecture Demonstration (ILD) have conceptual understanding greater than those who study in the traditional classroom.

1.6 Research structure

This dissertation presents the research data of teaching on Thai high-school student in the topic of Magnetic Force on a Moving Charged Particle based on the Interactive Lecture Demonstration (ILD). This research consists of five main chapters as follow.

Chapter I: Introduction- the background and significance of the study, the objective of this study, the research question, the expected output and outcome.

Chapter II: Literature Reviews- the key concepts of magnetic force on a moving charged particle in high-school and introductory physics level, the research of student's understanding on this physics topic aboard and in Thailand context, and the Conceptual Survey on Electricity and Magnetism.

Chapter III: Teaching Module and Research Methodology--the development of the ILD teaching module, the procedure to teach students with the ILD teaching module and the research methodology.

Chapter IV: Results and Discussion--the presentation of students' responses on the post-test of years 2014 and 2015, the analysis of students answers in each question, the consistency of student's answers in the same concept, the misunderstanding, and the results from interviews.

Chapter V: Conclusions--the answer of research question, the limitation of this study and suggestion for the future work.

CHAPTER II
LITERATURE REVIEWS

This chapter presents the literature reviews starting with summary of the key concept of magnetic force on a moving charged particle in high-school and introductory physics level. The significant researches of student's understanding on this physics topic in foreign countries and Thailand were showed to address student difficulties. The development of Interactive Lecture Demonstration (ILD) as an active learning strategy and the example of using this method on physics course were illustrated. Finally, the Conceptual Survey of Electricity and Magnetism (CSEM) which was used to assess student's understanding in this research was presented.

2.1 The concepts of magnetic force on a moving charged particle

The magnetic force on a moving charged particle is one subtopic in domain of magnetism which had been included in high-school and undergraduate level. The concept of this physics topic will be presented at the level of high-school and introductory physics specifically.

When the particle carrying charge q moves at velocity $\vec{v}$ through the magnetic field $\vec{B}$, the magnetic force $\vec{F}$ acts on the charged particle along the direction that is perpendicular to the plane containing both velocity and magnetic field. The magnitude of the magnetic force on moving charged particle is the product of the magnitude of the charged, the magnitude of the magnetic field and the component of the velocity perpendicular to the magnetic field, which can be written as.

$$F_B = |q| vB \sin\theta \qquad (1)$$

Where θ is the angle between velocity and magnetic field. The direction of the magnetic force can be determined by using the right-hand rule. When appling this rule, the fingers point in the direction of charged particle velocity, the magnetic field comes out of the palm and the fingers curl in the direction of the magnetic field. Therefore, the thumb represents the direction of the magnetic force if the particle is positive charged as shown in Figure 2.1. The direction of the force has to be reversed if the particle is negative charged (11).

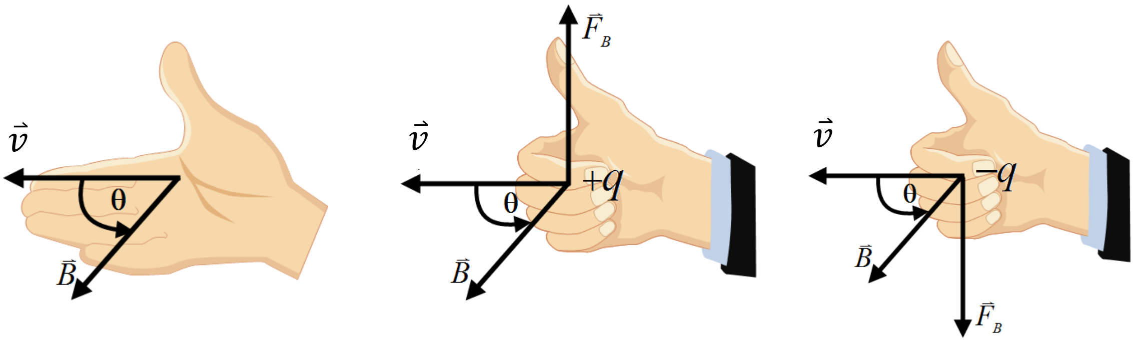


Figure 2.1: Hand orientation of the right-hand rule.

The behavior of the direction of the magnetic force can be summarized in term of the cross product as.

$$\vec{F}_B = q\vec{v} \times \vec{B} \qquad (2)$$

2.2 Research of magnetic force on a moving charged particle

Over the last decade, there were many physics education researches which focused on student’s understanding before and after instruction on many physics topics. These were helpful for teachers in preparing their instruction to achieve high effectiveness. The Magnetic force on a moving charged particle is a subtopic in the domain of Magnetism that many learners regarded as difficult to understand because of its abstract concept. It seem to be a simple topic with a few detail. Most instructors finished their teaching on this topic within one hour.

Maloney, Okuma, Hieggelke and van Heuvelen developed the Conceptual survey to investigate more than 5000 introductory students at different institution in the United State on the domain of Electric and Magnetism. Maloney et al. (2001) presented the students' responses for their conceptual questions before and after instruction, especially in the topic of Magnetic force. After the instruction, 39% of calculus-based students thought that the magnetic force exists whenever the charged particle is placed in magnetic field. They did not consider the fact that the charged particle stayed without moving. For the question that investigated students' understanding on the direction of the force, the results showed that student still confused about the direction. Only 40% could give the correct answer and, interestingly, 30% answered in the opposite direction. In addition, 53% of students still had difficulty in indicating magnitude of magnetic force.

Saglam and Millar (2006) used their diagnostic questions to explore students' understanding of basic ideas in electromagnetism of upper high school in Turkey and England (12). The students' responses presented misunderstandings and inconsistencies on this topic. In the specific question of magnetic force on a moving charged particle, student performance in both samples was surprisingly poor. 47.5% of students answered incorrectly that the force acted on the charged particle was in the direction of a magnetic field line which indicated the lack of understanding that the magnetic force was always perpendicular to the charged velocity and magnetic field. Some interviewed students thought of the north pole of the magnet bar as positive charge and the south pole as negative charge. This was the reason used by student who answered the positive charge move from the north pole to the south pole by the electric force (north pole pushed the charged particle to the south pole).

Scaife and Heckler (2010) studied student's understanding on the direction of the magnetic force on a moving charged particle (13). Their work consisted of many sections that considered the detail of student's understanding on this topic. One of their studies was student performance on different magnetic field representations. The group of 110 calculus-based students at The Ohio State University were asked a week after instruction about the direction of the magnetic force for both the magnetic pole and field line representation as shown in Figure 2.2.

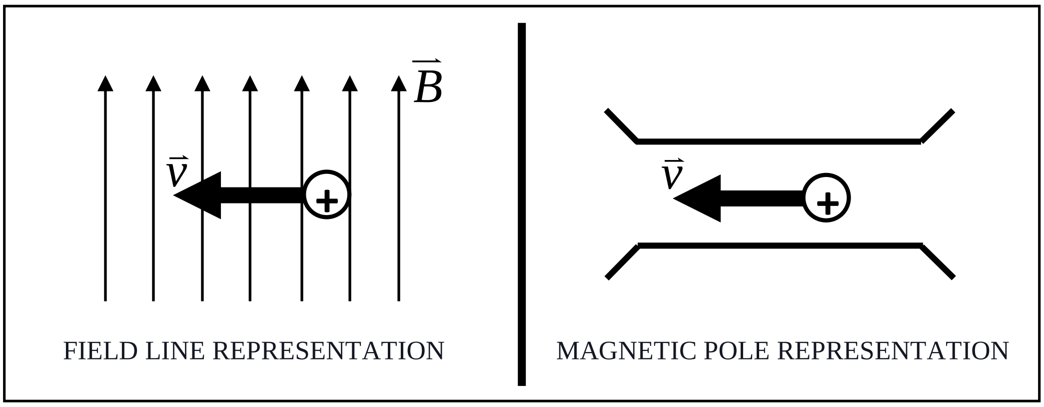


Figure 2.2: Illustrations for the filed line and pole representation question.

There was 47% of students who could answer correctly on the filed line representation. The number dropped to 32% when the field line was changed to magnetic pole representation. The students had difficulties on sign error and though that the magnetic force is parallel to the magnetic field. In addition to this, they studied student consistency of sign error. Another sample group of 174 students were asked the same concept questions about the direction of the magnetic force as shown in Figure 2.3.

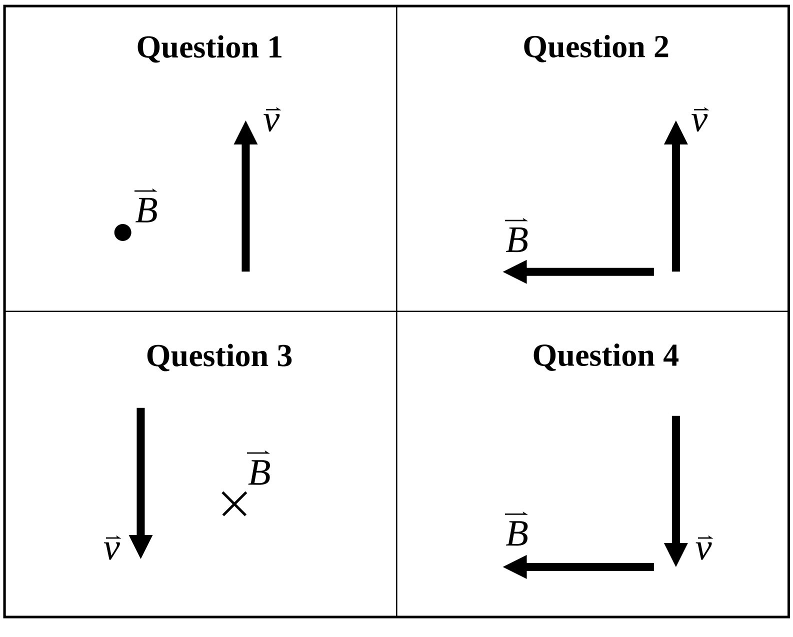


Figure 2.3: Illustrations for the same conceptual question.

One-thirds of students answered correctly, two-thirds answered randomly with sign error and small number of student had consistency on sign error. This indicated that most students answered inconsistency with sign error. Some students were interviewed by think out loud while they solved the question about the direction of the magnetic force on a moving charged particle and generally cross product question. Most of them were able to apply the right-hand rule to find the direction of magnetic force correctly but did not do consistently by using different version of the right-hand rule for different question.

In context of Thai students, the first-year engineering students at University of Phayao who enrolled in an introductory physics course were investigated their conceptual understanding in the topic of magnetic force on a moving charged particle. The students studied this topic by using interactive teaching method which gave them a chance to predict direction and magnitude of magnetic force on a moving charged particle. Instructor revealed correct answer step-by-step based on the right-hand rule with experimental kits. After students finished the instruction, they were asked to indicate the direction and magnitude on charged particle moving in magnetic field. The result of the study showed that about 50% of 214 students still lacked conceptual understanding in how to find the direction of magnetics force by applying the right-hand rule and magnitude of force which relate to charged magnitude. This studying was repeated in 2011 and got the similar result to year 2010.

The percentage of students who had misunderstanding in this topic even after learning this topic from high school and university level was still very high. Therefore, it was interesting to survey high-school students' understanding in the topic of magnetic force on a moving charged particle. The understanding in the high school level may lead to a better chance in learning in the higher level. However, magnetism is rather abstract content so the method which was interactive and can visualize Physics phenomena was required to teach this topic.

2.3 Interactive Lecture Demonstrations (ILD)

Interactive Lecture Demonstration (ILD) is one of the active learning strategies. This method was developed from microcomputer-based laboratory tools which establish an active learning environment in lecture portion of introductory course. After several years of research, Thornton and Sokoloff formalized a procedure of ILD in 1991. The steps of procedure are:

1. Instructor describes the demonstration without display the result on monitor.
2. Students individually predict the result of that demonstration in prediction sheet.
3. Students discuss their individual predictions in small group with their nearest neighbors.
4. Students finally record their individual predictions.
5. Some students' predictions are shown to the class.
6. Students observe demonstration which is shown by instructor.
7. Some students are asked to discuss the result and record it in result sheet.
8. Instructor discusses that different situation but the concept remains the same.

In ILD, there are chances of discussion and interaction between student to student and teacher to student. The using of simple demonstration make students understands that Physics topic by real-time situation. Moreover, the misunderstanding of students will be corrected when they observed demonstration and during discussion. This method is especially useful when applied to the abstract content and complicated forms of mathematical representation such as electricity and magnetism.

Thornton and Sokoloff started to apply ILD in kinematics and dynamics in 1998. The sequences of the ILD that they used to enhance student conceptual understanding were shown in Table 2.1.

Table 2.1: Mechanics Interactive Lecture Demonstration Sequences.

ILD Sequence	Contents
Kinematics 1: Human Motion	Introductory, constant-velocity kinematics using a motion detector to explore walking motions. Relationships between position-time graph and velocity - time graph.
Kinematics 2: Motion with Carts	Kinematics of constant velocity and uniformly accelerated motion using a motion detector to display motion of a low friction cart pushed along by a fan unit. Relationships between velocity and acceleration.
Newton's First and Second laws	Dynamics using a force probe and motion detector to measure forces applied to low-and high-friction carts, and the resulting velocity and acceleration. Relationships among velocity, acceleration, and force.
Newton's Third law	Using two force probes that allows students to examine interaction forces between two objects during fast collisions and when one object is in constant contact with another, pushing or pulling.

The famous conceptual test about this topic which was used to evaluate student conceptual understanding by many researchers is the Force and Motion Conceptual Evaluation (FMCE).

In 1991, the non-calculus general physics class at the University of Oregon was taught by a series of kinematics and dynamics ILD. The comparison of student evaluation of dynamics concepts by using FMCE in traditional teaching (where students listen to lectures, do homework, and take quizzes and exams) and learning in ILD method was shown in Figure 2.4. The vertical axis is the percentage of students answered correctly in each sets of FMCE questions. The first two bars show the evaluation of students' understanding before and after traditional teaching in 1989-90. The last bar shows the evaluation of students who had learning with ILD in 1991.

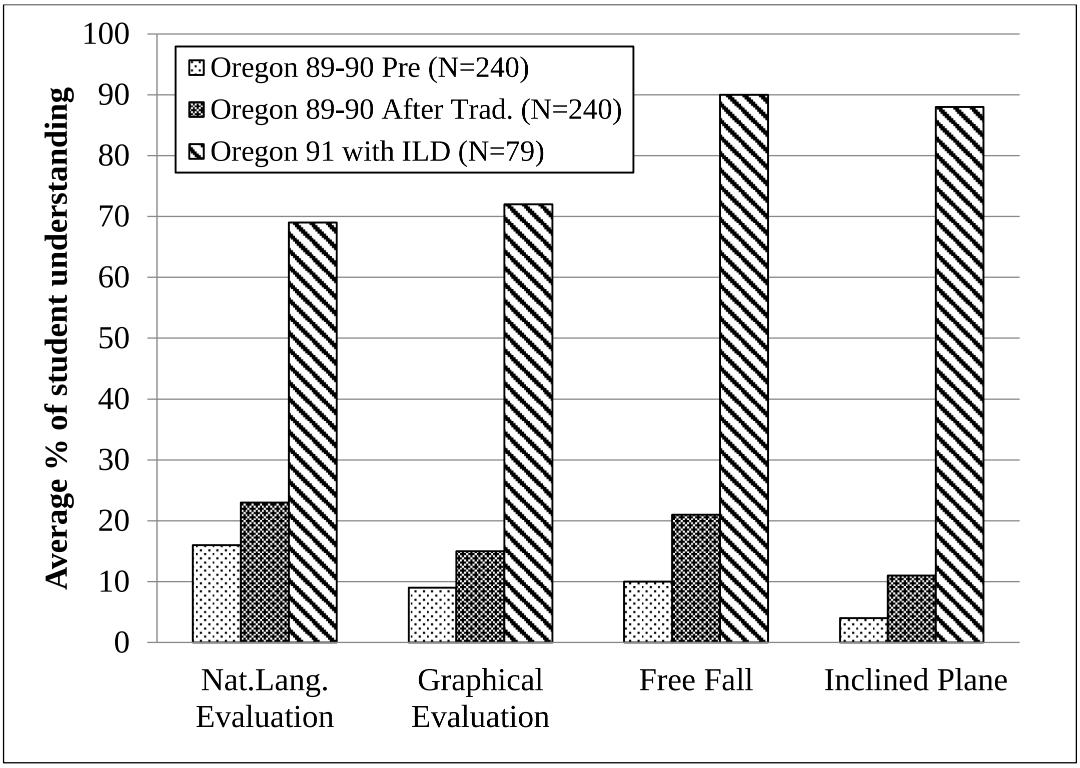


Figure 2.4: Comparison of (Oregon) student learning of dynamics before and after traditional instruction with ILD.

The result showed that the improvement of student learning with traditional teaching was about 7-10% on these dynamics questions. On the other side, the results of the studying in ILD method was clearly higher than traditional teaching.

In addition to this, Loverude (2009) presented the study of ILD on sinking and floating. The students who enrolled in algebra-based introductory physics course at the University of Washington were given the conceptual question on buoyancy (14, 15). The Five Blocks question was used to asked student to sketch the final position of five blocks of identical size and shape but varying mass (the block 1 is the lightest and the block 5 is the heaviest) after all blocks are held approximately halfway down in an equilibrium filled water, then all of them were released and block 2 is barely floating and block 5 rests on the bottom of the tank. The illustration of this question is showed in Figure 2.5.

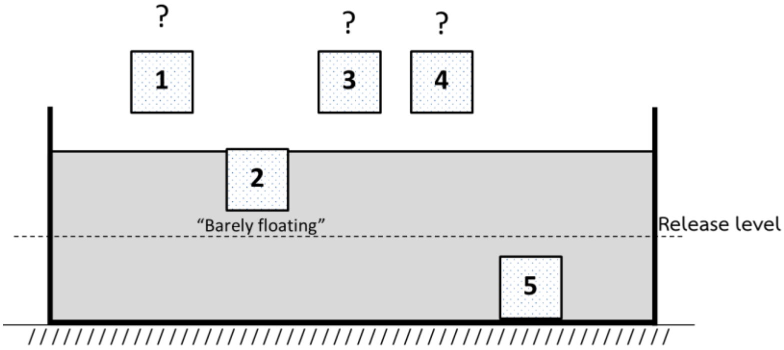


Figure 2.5: The illustration of the Five blocks question.

Only 20% of 371 students could answer correctly and the results at other universities of students' responses on the Five Blocks question were very similar proportions. Heron et al. (2003) (16) presented successful teaching strategies on the Five Blocks question using of the research-based tutorial sequence (17) with 50% of students answered correctly. Over 80% of students got correct answer after learning from the laboratory-based approach in Physics by Inquiry (18). However, both teaching strategies were time consuming and require a good understanding of prerequisite concepts. Therefore, Loverude developed the alternative teaching strategy to improve students' understanding with less investment of time and without the prerequisite understanding.

ILD was applied to teach on this physics topic with the demonstration of a sealed bottle containing metal shots. He described the instruction in a briefly steps as followed.

Part A

1. The instructor showed the first sealed bottle with metal shots inside which floated in the tank of water.
2. Students were asked to individual predict what would happen if two or three of metal shots were removed from the bottle.
3. Students were allowed to discuss the individual prediction of the behavior of the bottle with their peers in small group.
4. The instructor performed the demonstration and asked the students to explain the result.

Part B

1. The instructor brought the second sealed bottle out and set up to be "barely floating" with the appropriate number of metal shots.

2. Then, one of metal shot was added in to the bottle and the students were asked to predict what would happen on the behavior of the bottle.

3. Similar to part A, the students discuss about their individual prediction.

4. The students observed the result of demonstration and the instructor led the whole class discussed the behavior of the bottle.

After the instruction, the Five Blocks question was used to investigate student's understanding. 60-70% of students who were thought by this ILD method could answer correctly. The researcher concluded that this developed instruction was suitable and effective to teach student on buoyancy by the simple demonstration.

The reason for the high scores was that students did not only observe demonstration or real-time Physics phenomena. In ILD, prediction and discussion are important steps that made students exchange their own understanding to their peers and when demonstration was shown, the results from a demonstration set confirm their understanding or correct student misunderstandings immediately. In addition, there was the result of study the use of ILD in different context. Sharma et al. (2010) studied the performance of ILD in the domain of Force and Motion at the University of Sydney (19). The results indicated that the effectiveness of ILD was similar to the originators of this active learning strategy. Therefore, ILD method was of interest to study the effectiveness when it is applied to teach the topic of magnetic force of a moving charged particle.

2.4 The Conceptual Survey of Electricity and Magnetism (CSEM)

Maloney et al. (2001) developed the Conceptual Survey of Electricity and Magnetism to investigate students' understanding in introductory physics course (algebra-based and calculus-based). It consists of 32 multiple choices questions which were extracted from students' response on the open-ended questions. This conceptual survey was divided into 11 sub topics as shown in Table 2.2 with the corresponding question number.

Table 2.2: Conceptual areas and question numbers that address each conceptual area for the CSEM.

Concept	**Question**
1. Charge distribution on conductors/insulators	1, 2, 13
2. Coulomb’s force law	3, 4, 5
3. Electric force and field superposition	6, 8, 9
4. Force caused by an electric field	10, 11, 12, 15, 19, 20
5. Work, electric potential, field and force	11, 16, 17, 18, 19, 20
6. Include charge and electric field	13, 14
7. Magnetic force	21, 22, 25, 27, 31
8. Magnetic field caused by a current	23, 24, 26, 28
9. Magnetic field superposition	23, 28
10. Faraday’s law	29, 30, 31, 32
11. Newton’s third law	4, 5, 7, 24

CHAPTER III

TEACHING MODULE AND REAEARCH METHODOLOGY

This chapter presents a teaching module on the topic of magnetic force on a moving charged particle and research methodology. The teaching module was constructed in order to enhance students' understanding on this physics topic. The teaching module used the Interactive Lecture Demonstration (ILD) as a main strategy. The instructor starts with lecturing the core concepts of magnetic force on a moving charged particle by the help of guided worksheet. There was also an equipment which was constructed to visualize the relationship of physical quantities and the right-hand rules. In addition to basic knowledge, students need to understand the operation of demonstration set in order to ensure that the emergence of students' misconceptions is not result of the demonstration set operating. Then, students would enter to demonstration part which bases on ILD process. The illustration of how to perform the demonstration is presented in this chapter.

The research methodology was applied in order to compare the students' understanding on magnetic force on a moving charged particle from the teaching module classes and the traditional teaching classes. Thai high-school students who generally study this topic in first semester of grade-12 were used as the sample group. A group of students in the same school learning by traditional teaching was used as a control group. The expectation core concept on this topic and duration of the teaching steps are shown in lesson plan. The effectiveness of both teaching strategies are investigated by evaluating responses of all groups of student to the conceptual test.

3.1 Magnetic force on a moving charged particle teaching module

The standard Physics text book developed by the Institute for the Promotion of Teaching Science and Technology (IPST) (20) was analyzed to find the concepts in which the students were expected to know after learning. We then looked for related equipment to demonstrate and appropriate duration to teach this topic. The recommended demonstration in the book was Cathode-ray tube set. Research in physics education have found that lecture and demonstration are methods with low effectiveness. We decided to used ILD to teaching this topic. This method has the characteristic of gaining interaction between teachers and students in lecture class through the use of demonstration. Therefore, the magnetic force on a moving charged particle teaching module was constructed to apply in physics high-school classroom based on ILD method with a reason to enhance students' understanding on this topic. The teaching module consists of 2 parts.

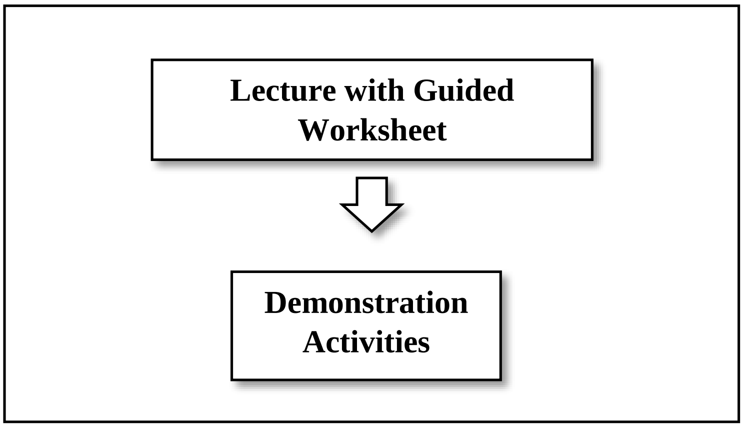


Figure 3.1: Teaching module diagram.

Part 1: Lecture

According to ILD, students must have the core concept of magnetic force on a moving charged particle before they started the demonstration activity.. Students were given lecture on this topic with the use of guided worksheet (Appendix A). The lecture was designed for more interaction between students and instructors than one-way transmission The core concept of this topic was extracted and designed to 5 main lecture steps.

1. To explain student about the situation of a charge moving into magnetic field.
2. To calculate the magnitude of magnetic force.
3. To find the direction of magnetic force by using the right-hand rule.
4. To give some examples on how to find direction of magnetic force.
5. To introduce the Cathode ray tube set.

In year 2014, students were visualized the situation of magnetic force acts on a moving charged particle in magnetic field by using a spherical polymer clay represents a particle and three arrows represents the vectors of velocity, magnetic field and magnetic force. This tool was used in combination with the right-hand rule.

Figure 3.2: Applied tool for representing physical quantities in year 2014.

In year 2015, the additional researches of right-hand rule device were studied (21, 22) and then, the Cross Product Model was developed to help student visualize the relation of those three vectors were used to teach the right-hand rule. This tool as shown in Figure 3.3 consists of three arrows: 1. Green arrow represents the velocity of particle. 2. Yellow arrow represents the magnetic field. 3. Red arrow represents the magnetic force. A translucent board was used to show that the magnetic force are always perpendicular to v-B plane.

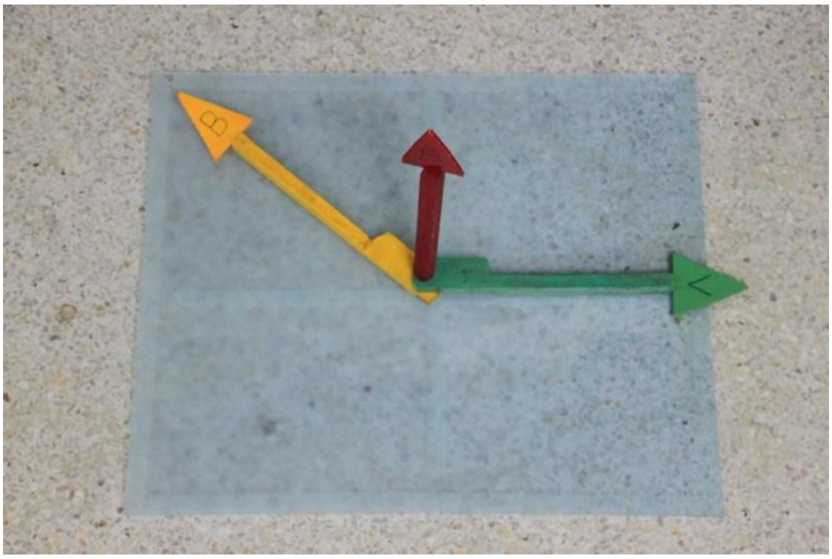


Figure 3.3: Cross Product Model**.**

Part 2: Demonstration activity

After the instructor finished lecture, students were led into the process of demonstration activity. In this part, the process of ILD was used to improve students' understanding in main physics concept. The concepts involved 1.The factor that causes the magnetic force on a moving charged particle. 2. Direction of magnetics force on a moving charged particle, and 3. Magnitude of magnetic force. There are four demonstrations:

The demonstration 1 (D1) is about the trajectory of electron when the given magnetic field was pointing into the page.

The demonstration 2 (D2) is about the direction of magnetic field that causes the electron trajectory to change as indicated in the question.

The demonstration 3 (D3) is about the trajectory of electron when magnitude of the given magnetic field was increased.

The demonstration 4 (D4) is about the trajectory of electron when magnetic field make an acute angel of θ with the velocity of charged particle.

ILD worksheets of each demonstration including the prediction sheets and result sheets are given in Appendix B.

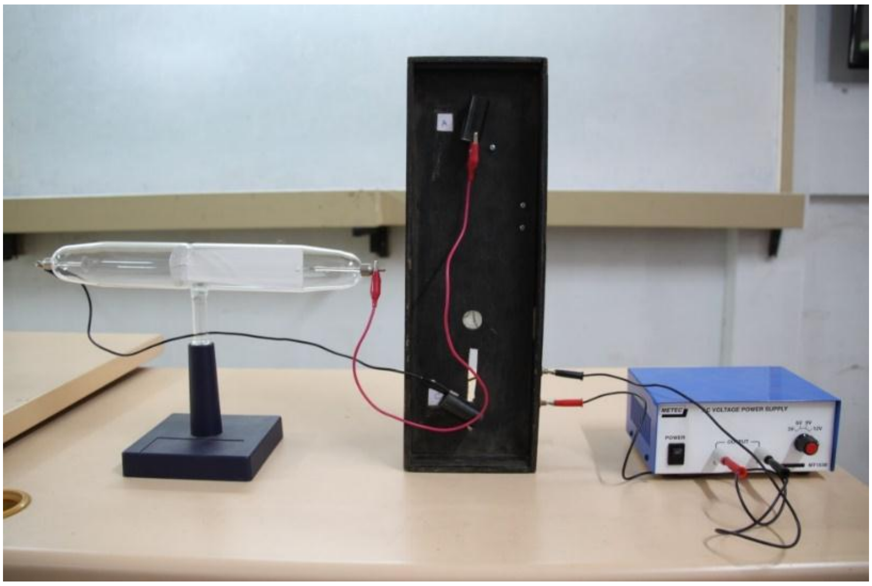


Figure 3.4: The Cathode ray tube set.

To illustrate the process of ILD, demonstration 1(D1) will be discussed in detail. This demonstration asks students to predict the trajectory of electron (Cathode-ray) in the presence of the magnetic field. The steps of using this demonstration are:

I. Students were given D1 ILD worksheet which consists of prediction part and result part.

II. Instructor turn on the Cathode ray tube set without any magnetic field as shown in Figure 3.5.

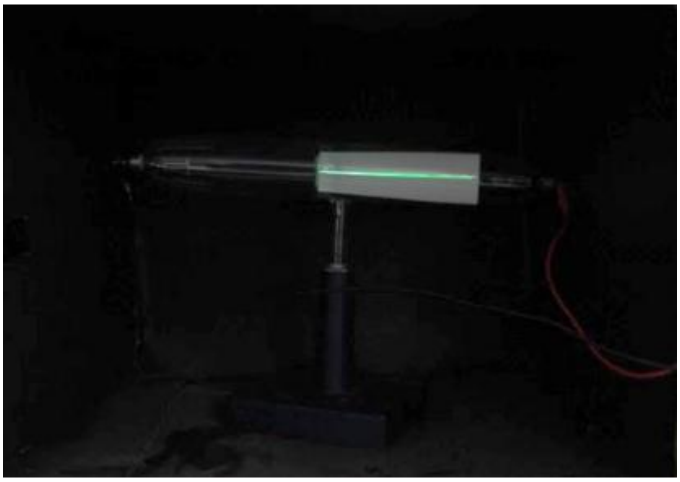


Figure 3.5: Cathode ray without magnetic field.

III. Instructor asked students to predict their individual prediction about the trajectory of electron when magnetic field was given into page.

IV. Students were allowed to discuss the individual prediction with their peer in small group and students can change their prediction.

V. After students got their final prediction, they handed in their prediction. The instructor reflected some students' predictions to the class.

VI. Instructor started to demonstrate the Cathode ray tube set in the presence of the magnetic field by using magnet bar as shown in Figure 3.6.

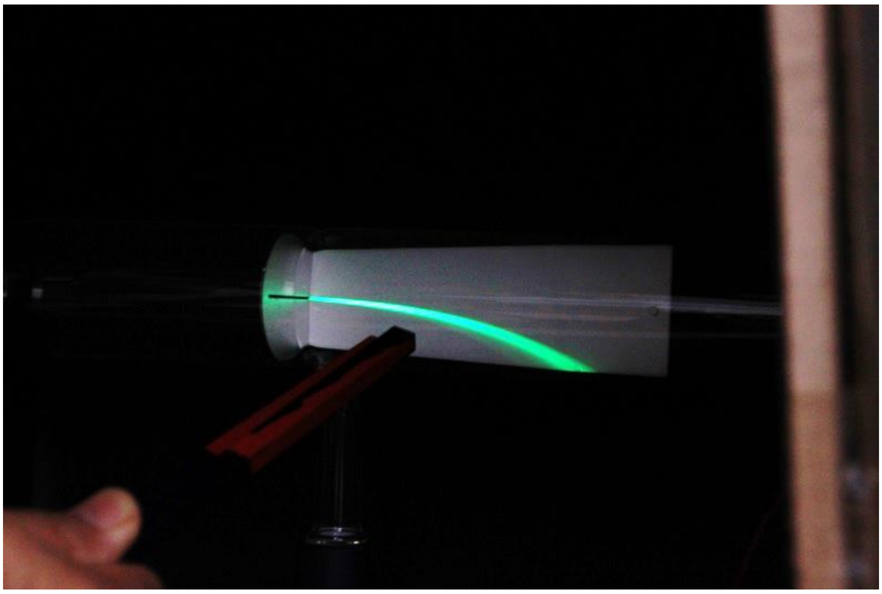


Figure 3.6: Cathode ray with giving magnetic field.

VII. Students observed the real situation and compared with their predictions.

VIII. Instructor led the whole class to reflect the result from demonstration and students recorded the result of the observation in the result part.

In Figure 3.7, video camera was used to visualize demonstration and display on monitor because of the demonstration set was small and difficult to observe from the whole class.

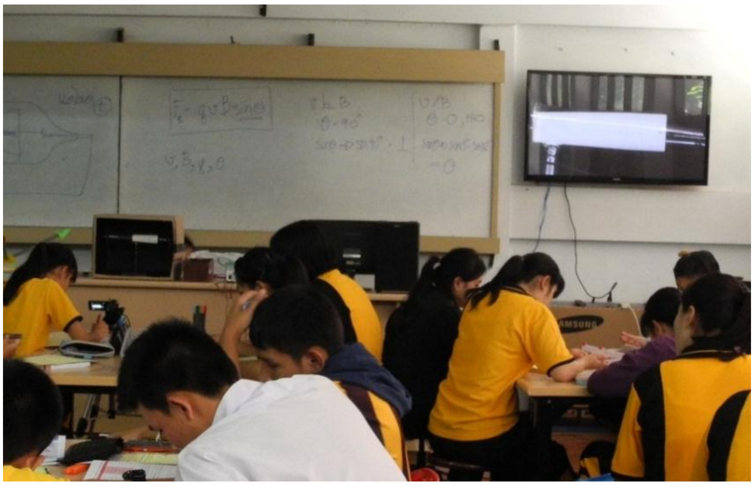


Figure 3.7: Demonstration set was displayed on monitor.

3.2 Research methodology

3.2.1 Sample group

The sample was grade-12 students who enrolled in the physics course at Thabo School in Nongkhai province. In year 2014, there were 3 classrooms which were 2 experimental groups and 1 control group. This research was repeated in year 2015, with 2 experimental groups and 2 control groups. The number of students in each classroom were about 30-40. The details of sample group in this research are shown in Table 3.1.

Table 3.1: Sample group information in year 2014 and 2015.

Year	Room	Teaching Method	Number of students
2014	G1A	ILD	33
	G1B	ILD	40
	G1C	Traditional	37
2015	G2A	ILD	38
	G2B	ILD	41
	G2C	Traditional	43
	G2D	Traditional	37

The background in physics of students were assessed by comparing their midterm exam score and high-school teacher interview. In 2014, G1A had similar background in physics to G1C and both groups had better background in physics than G1B. In 2015, G2C had the highest background in physics followed by G2A. G2B had similar background in physics to G2D but lower than both G2C and G2A. The ability of overall students in 2015 seem quite lower than students in 2014.

3.2.2 Treatments

The treatment was similar in both years (2014 and 2015). The students in control group were taught by traditional teaching with high-school teacher. However, this traditional teaching was performed in the way that the high-school teacher did not only lecture the physics content, the students observed the demonstration set and they were given a chance to predict the result of the demonstration set. (the details of traditional teaching is shown in Appendix D). The experimental group students were taught by using ILD teaching module and this method performed by researcher. All groups were given the same post-test after they finished instruction.

3.2.3 Lesson plans

Topic: Magnetic force on a moving charged particle

Detail: Describe the force on a moving charged particle moving into magnetic field, the magnitude and the direction of magnetic force which relates to the movement of a charge particle.

Time: 1 hour and 30 minutes

Table 3.2: Lesson plan of experimental group.

Step	Task/Topic	Time taken
1	Magnetic force	10 minutes
2	Magnitude of magnetic force	10 minutes
3	Direction of magnetic force	15 minutes
4	Example	10 minutes
5	ILD	40 minutes
6	Conclusion	5 minutes

3.2.4 Student conceptual understanding assessment

After instruction, all sample groups were investigated their conceptual understanding by the Magnetic Force on a Moving Charged Particle Test. This test consists of two parts, the first part has four multiple choice questions (Q1-Q3) which were taken from Conceptual Survey on Electricity and Magnetism (CSEM) (Maloney et al., 2001) and Q4 was new constructed question which had three sub-questions (Q4.1-Q4.3). The second part consists of two newly constructed open-ended questions that were verified by Physics experts (Appendix C). The effectiveness of teaching methods will be analyzed statistically from students' responded to the Magnetic Force on a Moving Charged Particle Test by using mean score.

CHAPTER IV

RESULTS AND DISCUSSION

This chapter presents the results of students' understanding investigation. The Magnetic Force on a Moving Charge Particle Test was used as the assessment tool and it was given to all group of student a week after the instruction. An overview of the evaluation. The mean score of each group was presented Table 4.1 and Table 4.3. The percentage of student with correct answer of each question was shown. In addition, student conceptual consistency was explored by analyzing student answers in the set of questions with the same concept. Students' responses on prediction sheet were categorized to study their performances in demonstration activity. The examples of students' answer were shown to discuss their conceptual understanding on this topic. In order to gain insight in students' concept, some of them were interviewed about how they solve the questions and their opinion on ILD teaching module.

4.1 Results of year 2014

The students' response on the Magnetic Force on a Moving Charged Particle Test in year 2014 of all sample groups were analyzed. The mean scores are shown in Table 4.1.

Table 4.1: Mean scores of students in 2014.

Class	**Mean Score (Full score is 7.0)**	**Standard Error**
G1A (ILD)	3.9	0.3
G1B (ILD)	1.6	0.2
G1C	0.9	0.2

The students in G1A who studied with ILD teaching module got the highest mean score of 3.65 from the full mark of 7.0. This was followed by G12 with the mean score of 1.6. The lowest mean score of 0.92 was belong to G1C. The mean scores of these three groups was significantly different.

Table 4.2 summarizes the topic of each question in the Magnetic Force on a Moving Charge Particle Test.

Table 4.2: Conceptual areas and question numbers that address each conceptual area for the Magnetic Force on a Moving Charged Particle Test.

Question	Topic
1	Charged at rest in a uniform magnetic field
2,5.1,5.2	Direction of a uniform magnetic field
3	Magnitude of magnetic force
4.1,4.2,4.3	Direction of magnetic force on a moving charged particle in a uniform magnetic field

In addition to the mean scores of the whole test, students' response were analyzed in term of each question. The percentage of student answered correctly in each question is shown in Figure 4.1.

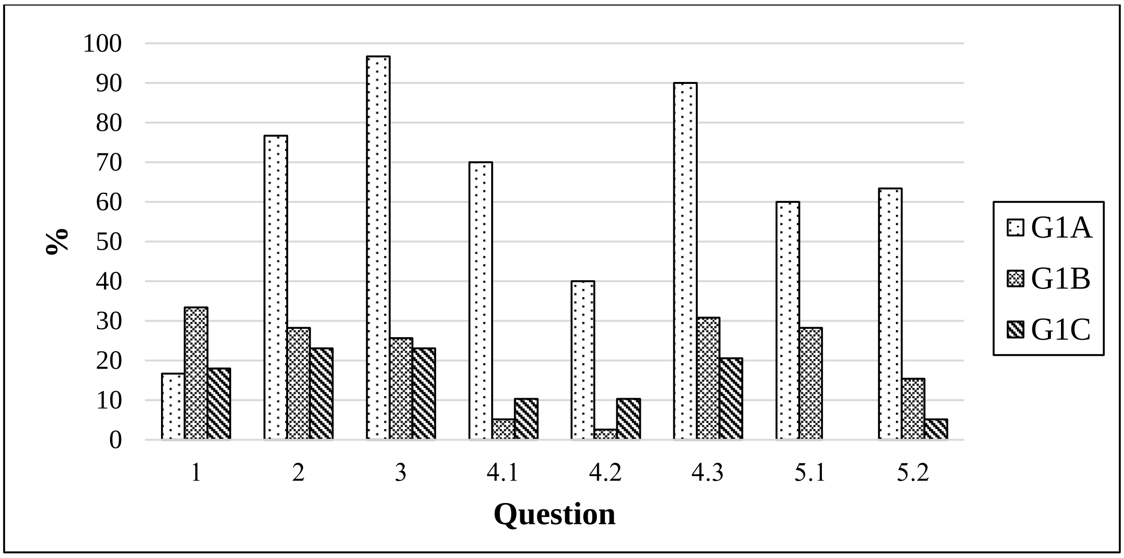


Figure 4.1: Percentage of students answered correctly in each Post-test question of year 2014.

From Figure 4.1, G1A had the highest percentage of students with correct answers in all questions except Question 1. The question that this group answered correctly with highest percentage of 93% belong to Question 3 that asks students to compare the magnitude of magnetic force. There were six questions that G1A students could answer correctly more than 50%. While other groups of students got correct answers lower than half in all questions.

G1B and G1C were quite similar in getting low percentage in all questions. There were very low percentage of G1B and G1C in Question 4.1 and 4.2. The last two bars (5.1 and 5.2) represented the open-ended question, G1C students could make a few correct answer on Question 5.2 and none on Question 5.1.

The comparison of G1A and G1B which both studied ILD teaching module showed that G1A had the higher percentage than G1B in all questions except Question 1. This result indicates that the effectiveness of ILD teaching module depends on some factors such as the ability of students. It was clear that ILD method matched very well G1A students.

Interestingly, the score of G1A students' response on Question 1 was extremely low. There was no concrete evidence about the cause of this case. The possible reason was that students did not observe this situation or similar situations in the demonstration where the magnetic field did not affect the motion of charged particle.

4.2 Results of year 2015

Table 4.3 presents the mean score of students' response on the test in year 2015.

Table 4.3: Mean scores of student in 2015.

Class	Mean	Standard Error
G2A (ILD)	2.2	0.3
G2B (ILD)	1.0	0.2
G2C	2.4	0.3
G2D	1.5	0.2

The G2C student got the highest mean score of 2.4, followed by G2A with mean score of 2.2. The mean scores of both groups was not significantly different. The G2D got mean score of 1.5 and the lowest mean score of 1.0 belonged to G2B. The scores of 4 classes were quite low compare to full mark. This result indicates that students who studied by interactive activity does not always have better performances than traditional method. One possible reason for this conclusion, the high-school teacher gave the opinion that most students in 2015 had lower ability in physics than those in 2014.

Additional to the mean score, Figure 4.2 presents Percentage of students answered correctly in each post-test question of year 2015.

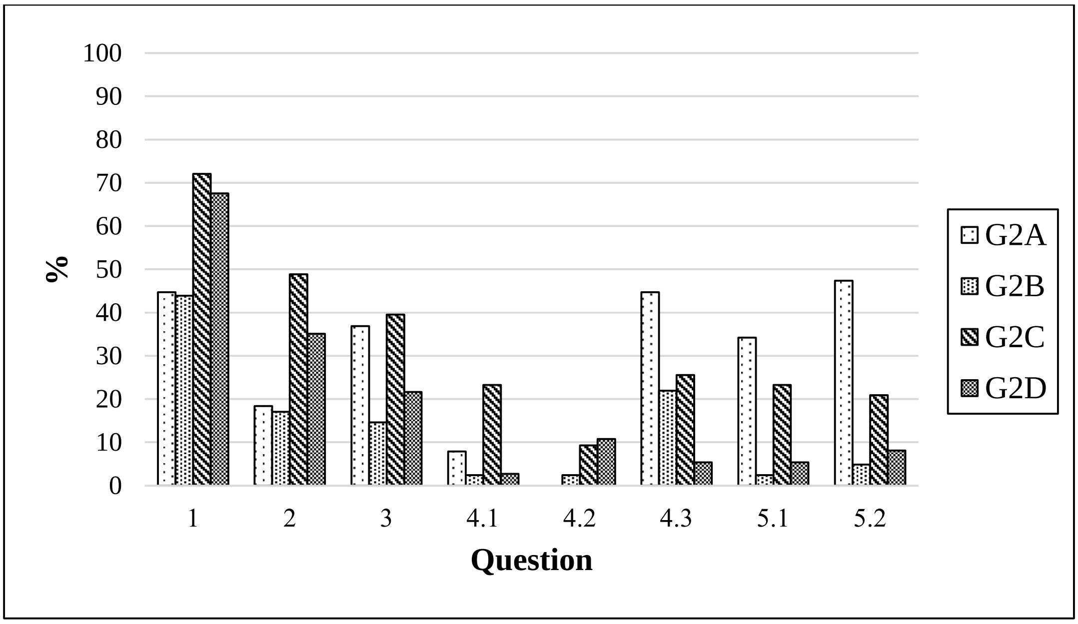


Figure 4.2: Percentage of students answered correctly in each post-test question of year 2015.

In this year, all groups got high score in Question 1, especially G2C and G2D (the class with traditional teaching). Question 2 has similarly trend to Question 1 but these bars decrease to 48% for G2C, 35% for G2D, 18% for G2A and 17% for G2B. Students' response on Question 3 of both G2A and G2C were greater than those of G2B and G2D by two folds. Most students could not answer Question 4.1 and 4.2. However, students in G2A responded with highly performance on Question 4.3, 5.1 and 5.2.

One special feature of the test in Question 5.1. It is not only an open-ended question, but also has two ways to answer correctly. Students need to consider that the charged can either be positive or negative. If student could answer one of the two correct answers, then the student would get full mark for this question. Nevertheless, we also record the number of students who could give both answers to this question as shown in Table 4.4.

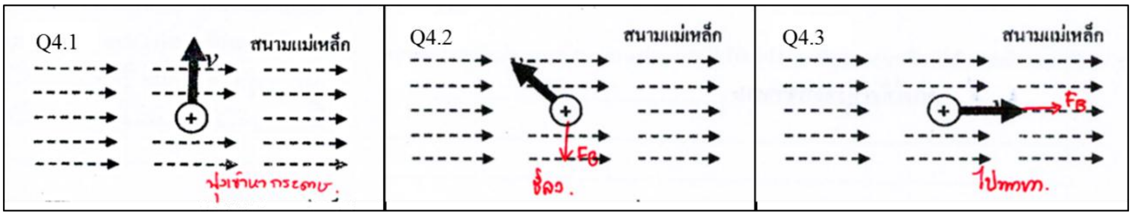
Table 4.4: Number of students answering Question 5.1 with two types of charged particle.

Year	**Class**	**Students answer two types of charged particle**	**N**
2104	G1A (ILD)	15	30
	G1B (ILD)	12	39
	G1C	6	37
2015	G2A (ILD)	18	38
	G2B (ILD)	7	41
	G2C	7	43
	G2D	3	37

It was clear that students learning with ILD considered the two possibilities of answers much higher than those with traditional teaching. So the ILD might give some insight into this topic that help students realize this kind of answer.

4.3 Consistency of students' answers to question in the same concept

Questions 4.1, 4.2 and 4.3 are in the same concept. These questions ask students to write down the vector of magnetic force (if it occurs). The results in Figure 4.1 and 4.2 present that the students did very well in Question 4.3 but got lower score in Question 4.1 and 4.2. Figure 4.3 shows an example of student's answers to Question 4.1, 4.2 and 4.3. The student was able to answer Question 4.1 correctly but failed both Question 4.2 and 4.3.



(point into page) (downward) (to the right)

Figure 4.3: Example of inconsistency students' response on question 4.1-4.3.

If students understand this topic, they have to show their consistency by answering all three questions with the same concept correctly, not just one or two of them. Table 4.5 presents the number of students of all sample groups who answered correctly all three question 4.1-4.3. In year 2014, eleven students of G1A showed consistency in this question set. Only a few students of G1B and G1C could achieved this consistency. In year 2015, there were only two students who could answer all three questions correctly and they were from G2C and G2D.

Table 4.5: Number of students answered correctly on all question 4.1-4.3.

Year	Class	Students answered completely	N
2014	G1A (ILD)	11	30
	G1B (ILD)	1	39
	G1C	3	37
2015	G2A (ILD)	0	38
	G2B (ILD)	0	41
	G2C	1	43
	G2D	1	37

Question 2 and 5.2 both probe the understanding of magnetic field direction that related to the force on the moving charged particle, but in the rather different contexts of charge type and trajectory. Table 4.6 shows the number of students who answered both question correctly. There were sixteen students of G1A who could respond correctly, only one student from G1B and none from G1C. In year 2015, seven students of G2A, and six students of G2B could respond all correctly. One student from each class of G2C and G2D could answer these two questions.

Table 4.6: Number of students answered correctly on all question 2 and 5.2.

Year	Class	Students answered correctly	N
2014	G1A (ILD)	16	30
	G1B (ILD)	1	39
	G1C	0	37
2015	G2A (ILD)	7	38
	G2B (ILD)	1	41
	G2C	6	43
	G2D	1	37

This analysis result suggests that most students still lack consistency to answer the questions in the test that probed the same physics concept in different contexts. Students could not extract the main idea of those questions. They confused about the contextual details. However, group G1A in year 2014 showed good performance in both sets of questions, and their scores were much higher than the other two classes. In year 2015, G2A and G2C did almost the same score but still quite low compare to G1A.

4.4 Students' response on ILD prediction sheet

In process of ILD, students were allowed to discuss their individual understanding with their peers in small group after they recorded the individual prediction on ILD worksheet. The purpose of this step was to encourage interaction among students in the class, which was expected to change their conceptual understanding. This means the student who has misconception would change to correct understanding by learning from their peers. The students' response on prediction sheet of ILD worksheet were categorized into 5 groups as shown in Table 4.7.

Table 4.7: Description of students' response categories.

Groups	Description
TT	Student who predicted the correct answer and did not change the prediction after discussion with peers.
FT	Student who predicted the incorrect answer and changed the prediction to correct answer after discussion with peers.
TF	Student who predicted the correct answer and changed the prediction to incorrect answer after discussion with peers.
Ff	Student who predicted the incorrect answer and changed the prediction to another incorrect answer after discussion with peers.
FF	Student who predicted the incorrect answer and did not change the prediction after discussion with peers.

Students whose response were in group TT was interpreted that they had clearly understanding. These students predicted the correct results and did not change their conceptual understanding after discussion with peers. The group FT was our target group in using ILD method because students' misunderstanding could be changed to correct understanding by discussion with their peer who had good performance. In contrast, TF and Ff were groups of students who were unconfident with their understanding and finally changed to the incorrect predictions. The last category, Ff described student who predicted incorrect individualy and still kept their own misunderstanding after discussion with peer.

Only students in experimental group(G1A, G1B, G2A, G2B) used the prediction sheet. The percentage of G1A students' response in each category of each demonstration set are shown in Figure 4.4.

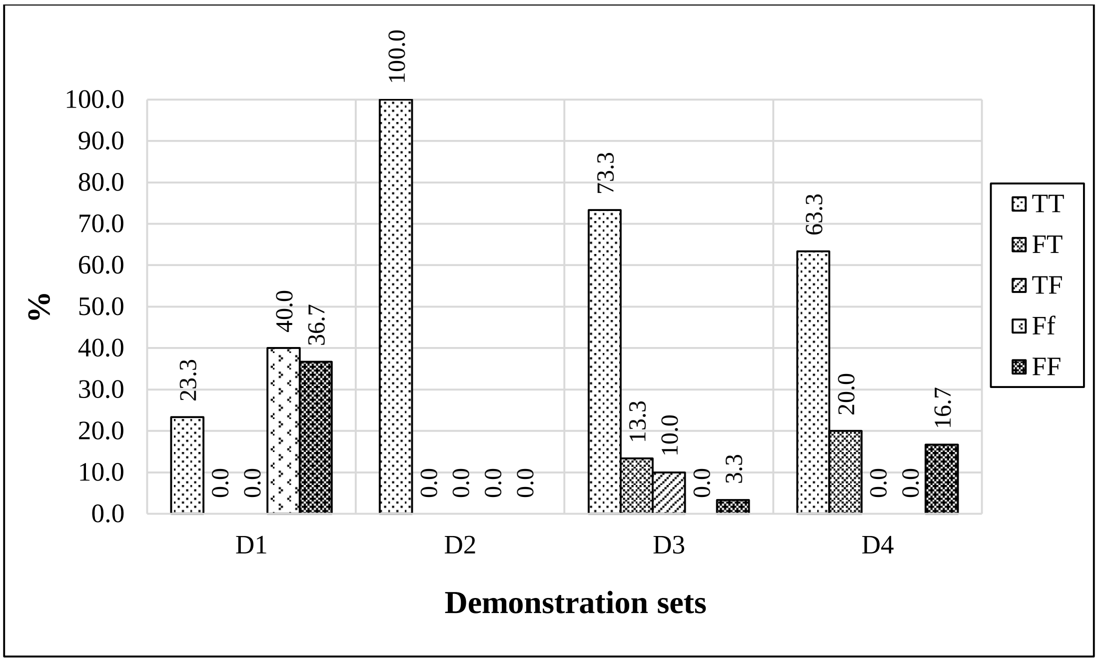
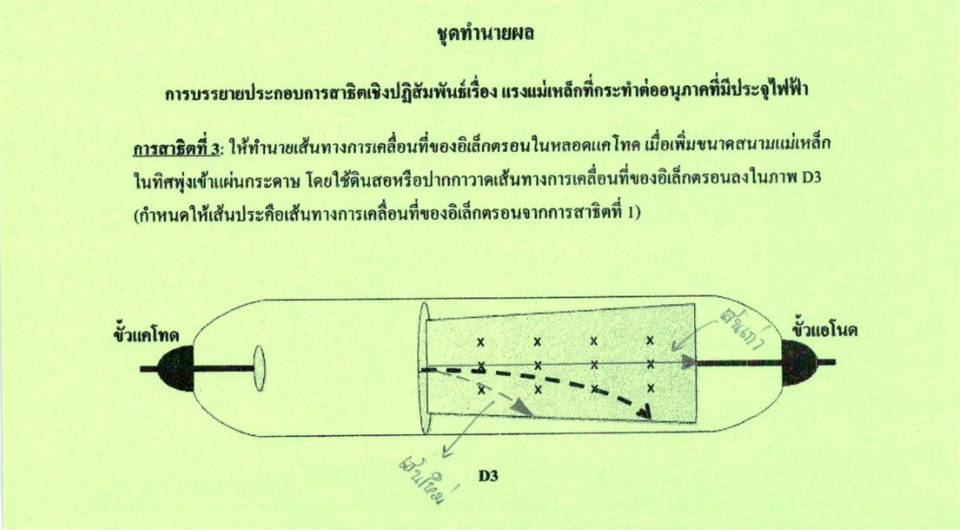


Figure 4.4: Types of prediction of students from G1A.

23.3% of students could predict correctly and kept their correct answers in D1 that asks student to predict the electron's trajectory when magnetic field was applied into the page. High percentage of students had difficulty with this demonstration, 40.0% for Ff, and 36.7% of FF (a combine of 76.7%). Example of incorrect prediction was the trajectory of electron to opposite direction of the correct trajectory.

All students had correctly predicted the result in D2 and still kept their prediction after discussion with peers. It asked students about the direction of magnetic field corresponding to the given trajectory of an electron. One possible explanation for this perfect prediction was the similarity between the demonstration sets D1 and D2.

D3 related to the effect of magnitude of magnetic field acts on electron beam. Students were asked to predict the trajectory of electron when the magnitude of magnetic field increased from that in D1. 73.3% of students had responses in group TT that means the radius of electron trajectory was shorter than trajectory in D1. One good sign was that 13.3 % of students changed their incorrect to correct prediction as shown in Figure 4.5.



ชุดทำนายผล

การบรรยายประกอบการสาธิตเชิงปฏิสัมพันธ์เรื่อง แรงแม่เหล็กที่กระทำต่ออนุภาคที่มีประจุไฟฟ้า

<u>การสาธิตที่ 3</u>: ให้ทำนายเส้นทางการเคลื่อนที่ของอิเล็กตรอนในหลอดแคโทด เมื่อเพิ่มขนาดสนามแม่เหล็กในทิศพุ่งเข้าแผ่นกระดาษ โดยใช้ดินสอหรือปากกาวาดเส้นทางการเคลื่อนที่ของอิเล็กตรอนลงในภาพ D3 (กำหนดให้เส้นประคือเส้นทางการเคลื่อนที่ของอิเล็กตรอนจากการสาธิตที่ 1)

Figure 4.5: An example of student's prediction sheet in D3.

However, another student had changed prediction from correct to incorrect prediction as shown in Figure 4.6. The percentage of students in this category was 10.0%.

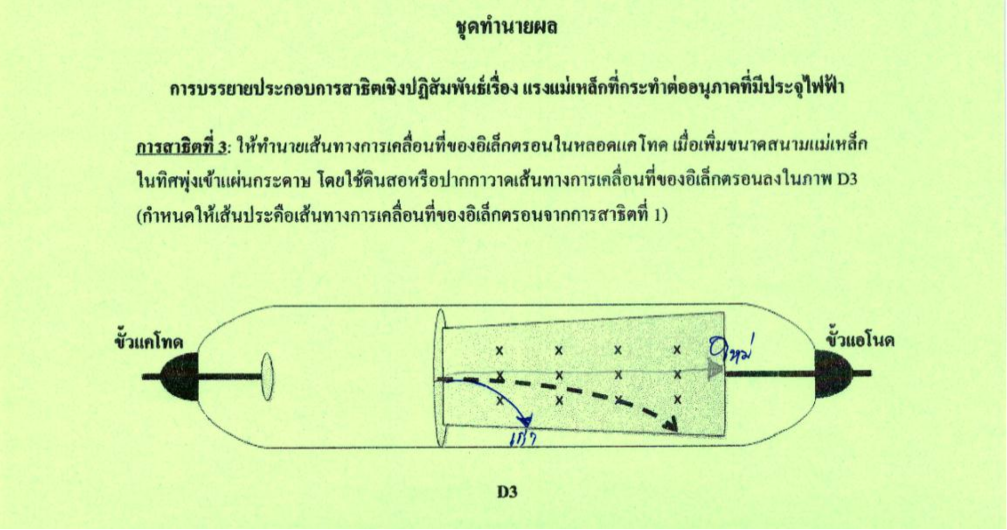


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Figure 4.6: An example of student's prediction sheet in D3.

The set D4 probed students in the same concept as D3, but the magnitude of magnetic field was varied by changing the angle between the field and particle velocity. Students were asked to predict the trajectory of electron compared with the trajectory in D1. The percentage of students with response in group TT was 63.3%. The students who changed their prediction to the correct one of FT was 20. 0% and there was 16.7% of students who were confident with their incorrect prediction.

Figure 4.7 presents the percentages of students' response on prediction sheet of G1B. There was no students in group TT for D1 demonstration. Most of students fell in group FF by number of 82.1%, and 17.9% for Ff.

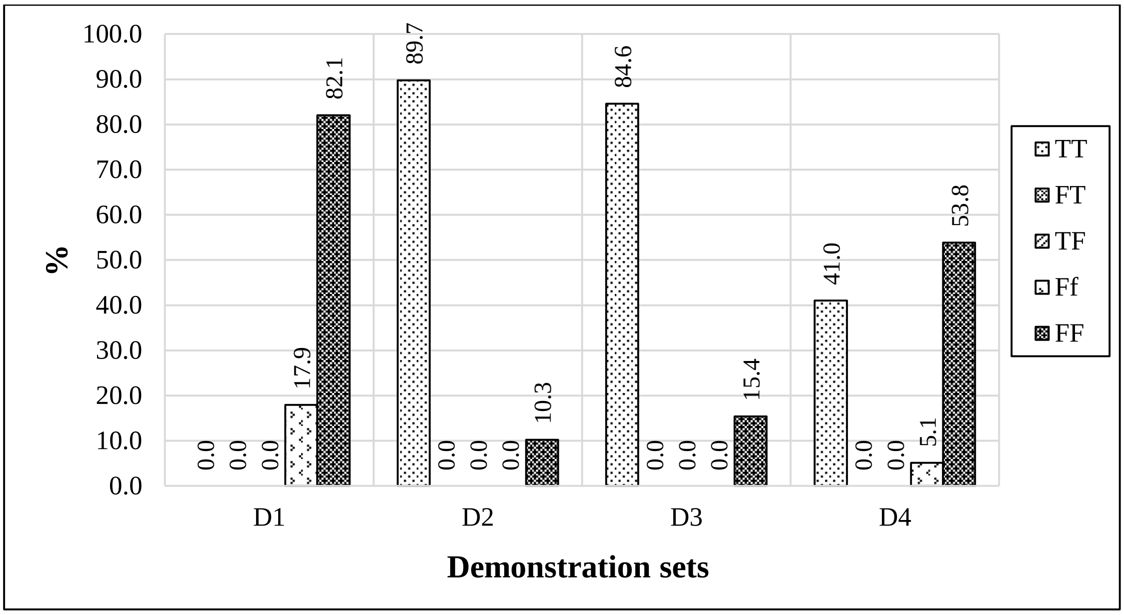

Figure 4.7: Types of prediction of students from G1B.

The pattern of G1B students' response on D2 was similar to that of G1A, there was 89.7% of students' response correctly. The number of students who still kept their incorrect result was 10.3%. They wrote the trajectory in the wrong direction.

In set of D3, most student (84.6%) were in group TT. There was no student in other categories except 15% for group FF who thought that the increasing of magnitude of magnetic field did not affect to the magnetic force.

The students' response in D4 was different from other sets. 41.0% of the students did very well and were categorized in group TT. However, a half of students in this class fell in group FF which students kept their incorrect answers despite talking with peers.

In year 2015, the ILD process was performed as same as the recent year. Students in G2A and G2B would be given the ILD worksheet to predict the result of the demonstration.

The percentages of G2A students' responses in each demonstration were presented in Figure 4.8.

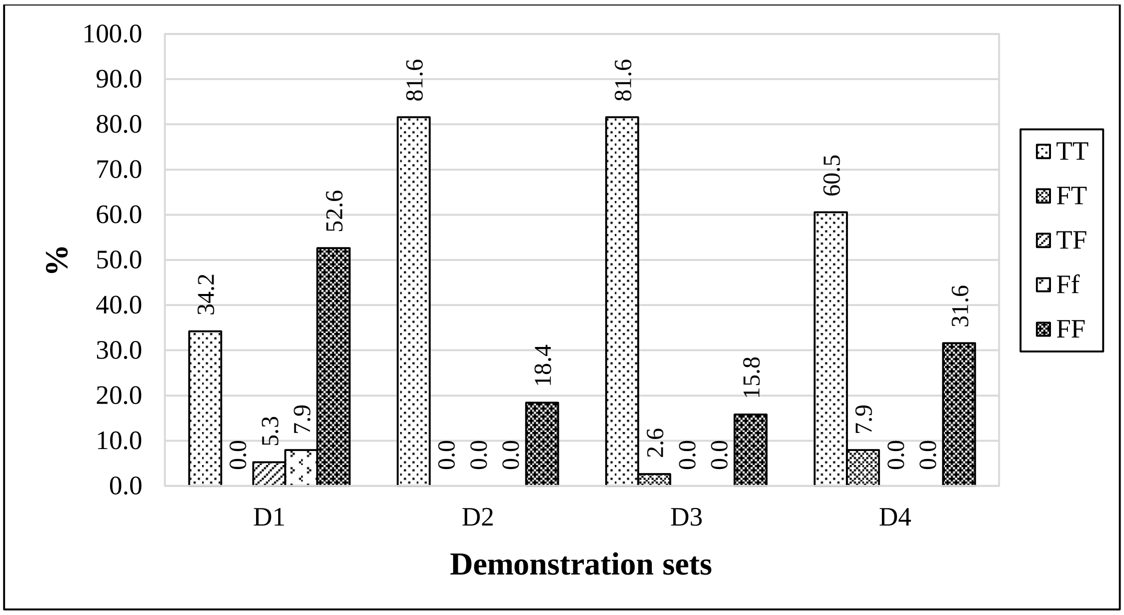

Figure 4.8: Types of prediction of students from G2A.

The highest percentage of 52.6% belonged to group FF. The number of students who could predict correctly in D1 was 34.2%. There were 5.3% for FT, and 7.9% for Ff which had conceptual change with incorrectly prediction.

The students' prediction on D2 was similar to the results in 2014. Students were able to learn from the set of D1 and used the idea in D2. However, there was still 18.4% of students who incorrectly predicted that the direction of magnetic field points into the page or points downward and still kept their prediction after discussion.

In set of D3, there were 81.6% of students who had the concept that magnitude of the force changes proportionally with the magnitude of the magnetic field. Only 2.6% of students could change their incorrect prediction to the correct one. One of incorrect predictions was the decrease of magnitude of the force caused by the increasing magnitude of magnetic field.

60.5% of students had answered their individual prediction correctly and did not change the answer. A few students changed their incorrect to correct prediction. Nevertheless, 31.6% of students predicted incorrectly that there was no effect to the initial trajectory or the trajectory curved upward.

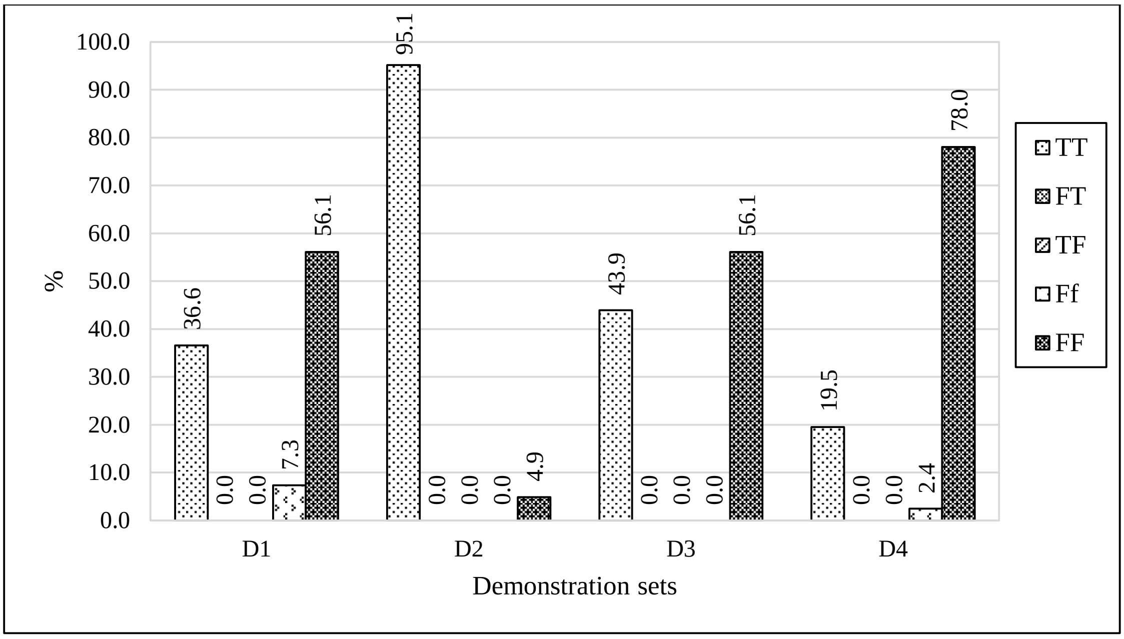

Figure 4.9: Type of prediction of students from G2B.

Figure 4.9 presents the responds of students in G2B class. For D1, there was 36.6% of students for group TT and 56.1% for group FF. Only 7.3% of students changed their incorrect answers to another incorrectly one. The high percentage of TT bar graph in D2 was similar to another sample group.

For D3, a half of students in G2B class fell in TT and the other half was in FF. The incorrect predictions were not surprise, these students thought that the increasing of magnitude of the field results in a larger radius of trajectory than the initial one. Some of students still though that there was no effect to the trajectory of electron.

For D4, the result showed the lack of understanding in the dependence of magnitude of magnetic force on the angle between the magnetic field and charged velocity. There was 19.5 % of students with correct prediction in group TT.

The possible factor that could explain the high percentage of students with incorrect prediction even after discussion with peers is that there were no students with good understanding in each subgroup. Even though the instructor led students to discuss with their peers but most students still did not do this process. They still agreed with their own individual prediction, therefore the conceptual changed from incorrect to correct prediction was not occurred.

4.5 Student difficulties

The analysis of students’ response on the specific questions and the analysis of the prediction sheets in both years presents the students’ misunderstanding on magnetic force on a moving charged particle. In addition, in year 2015, ten students of experimental groups were interviewed about their response on the test. The students’ misconceptions can be summarized as follows.

More than half of students in year 2014 responded on Question 1 that there is existed magnetic force on the charge at rest in uniform magnetic field. The percentage of student with this misconception decreased in 2015.

Students seem confusing about how to find direction of magnetic force and, especially by applied the right-hand rule. None of interviewed students applied the right-hand rule to find the answer in Question 2, some students guessed the answer or used another method to find the answer. One explained reasoning as follows:

> **Student:** I remember from the results of demonstration (in demonstration activity). If the magnetic field points into page, the trajectory (of negative charged) would curve downward. In contrast, the trajectory would curve downward if the magnetic field was out of page.

In addition, they were asked how to apply the right-hand rule. One student responded that she confused with the hand orientation. There was student who used both right-hand and left-hand to find the answer.

The students’ response on the demonstration set 3 and 4 were quite corresponding to the percentage of student answer correctly in Question 3 which indicated that students have difficulty of magnitude of the magnetic force. Some examples of those misunderstandings were presented in the students’ response on prediction sheet.

4.6 Students’ reflections on ILD teaching module

The ten students of ILD class who were interviewed about the test were also asked overall of the atmosphere in the class, the usefulness of demonstration activities and advantages of the cross product model.

Students were asked to describe that how did they perceive during the class. The common answer was that changing class instructor made students to be excited and actively involved in learning. Some of the interviewed student said that:

Student A: In part of demonstration, it’s very interesting because there was the experiments, or demonstration included in the classroom. To visualize the demonstration by using video camera displayed on the monitor in front of the class was helpful to me who was at the back of the class.

Student B: I understand the idea of this topic, the experiment presented the concrete results. I could apply the concept to explain the situation.

In demonstration activity part, students explained the characteristic of demonstration activities with what they used to learn before.

Student A: The instructor let me to predict the results before he presented the real result from the demonstration, and I compared my prediction with that. This was very useful to better understand what was my misunderstanding and I would remember what was the correct understanding.

Student B: I had learnt what is my idea from the demonstration. I could check our answer with the demonstration. If we made a mistake, we would know it immediately.

For the cross product model, seven of the eight students knew that the model was used to find direction of the force. However, they still confused with the model manipulation and the physical quantity representation of each arrow. Another student understood that this model used to describe direction of magnetic force that points into the page and out of page (the translucent plan represents the page) which is not correct objective of this tools.

CHAPTER V

CONCLUSIONS

This chapter presents the answer of the research question and the limitation of this study. The recommendations for the further work was also presented.

5.1 Answer research question

This research was study the effectiveness of Interactive Lecture Demonstration (ILD) to enhance high-school student conceptual understanding in the topic of magnetic force on a moving charged particle and compared with traditional teaching. The result in year 2014 presented that ILD has effectiveness to enhance high-school student conceptual understanding in this topic significantly greater than traditional teaching. Although the student in G1B (the second group of ILD) got the higher mean score than G1C (traditional) but both scores were still quite low. In addition to this, G1A (ILD) students had more consistencies to answer the same concept questions than other groups. In year 2015, the mean scores of G2A (ILD) and G2C (traditional) were not significantly different (G2A students has lower background than G2C students). For G2B and G2D who has lower background than both groups previously, G2D got the mean score higher than G2B. This result indicated that ILD method had effectiveness to teach in this physics topic, especially the students who had the good background. Some adjustment of the ILD need to be done in order to to teach low background students.

5.2 Limitations of this research

Even though, this research had performed carefully and tried to use statistics to analyze the data. However, there were also some limitations as followed.

(1) It was very difficult to control students' background to the same level for comparing student learning in different teachings.

(2) There were 30-40 students in each group that was a small number to make the results had more significance.

(3) This topic was normally finished in 1-2 periods (1-2 hrs.), therefore the instructor had a limited time to help the students familiar with the process of ILD.

(4) Students had not learnt this topic before, so this work was not be able to investigate student pre-knowledge to analyze the results by normalized gain.

5.3 Recommendations for further research

In demonstration activities, it was difficult for student predicted the trajectory of electron (Demonstration set 1) because they saw the demonstration set for the first time. The instructor should begin with demonstration set 2 that asks student about the direction of magnetic field corresponding to the given trajectory of electron.

The use of statistical method to analyze the data as comparison the mean score requires a large sample size. The result would be more significant if the class size is larger than 40 students.

The performance of ILD depends on student's ability in each group. The instructor should group students in the class in a way that each group consists of students who have a good understanding in the topic. These students could help their peers in discussion step and the whole group can achieve higher understanding.

In addition to the performance of teaching by ILD and traditional method, this study presented Thai high-school students' understanding on the topic of magnetic force on a moving charged particle. Although the use of ILD could be able to enhance students' understanding but there are some misunderstanding. It will require further study to find other teaching methods that can improve better students' understanding.

This work needs to be repeat to ensure the performance of teaching method (ILD). The adjustment of teaching steps or teaching tools must be minimized in order to avoid extra factors that can effect student's understanding.

5.4 Summary of this research

The use of Interactive Lecture Demonstration (ILD) has effectiveness to enhance high-school student conceptual understanding in the topic of magnetic force on a moving charged particle greater than traditional teaching and the effectiveness of ILD depends on students' ability.

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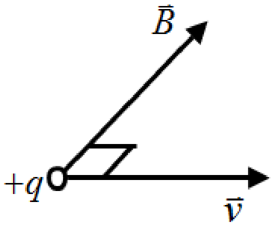
APPENDICES

APPENDIX A

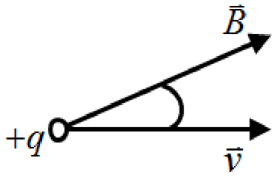
WORKSHEET (ENGLISH VERSION)

Worksheet: The Magnetic Force on a Moving Charged Particle

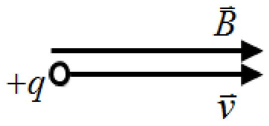
The particle with charged **q** moves in a direction that is not parallel to the magnetic field **B** caused the magnetic force **F** on the moving charged particle which is always perpendicular to both the direction of travel of the charge and the magnetic field.



a. $\vec{v}$ perpendicular to $\vec{B}$



b. $\vec{v}$ makes any angle of θ to $\vec{B}$



c. $\vec{v}$ parallel to $\vec{B}$

The magnitude of the magnetic force exerted on the moving charged particle is

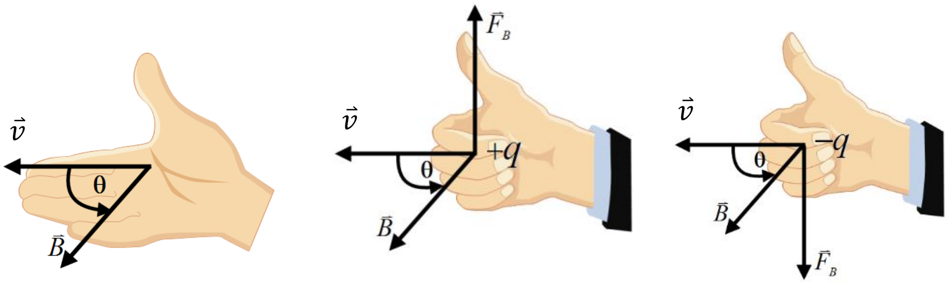
$$\boxed{F_B = \qquad\qquad\qquad\qquad}$$

The direction of the magnetic force on the moving charged follows the right-hand rule.

In case of $\vec{v}$ <u>**perpendicular**</u> to $\vec{B}$, $\theta =$............. and $\sin\theta =$..............$=$...............

$F_B =$ <u>Maximum magnitude of the magnetic force</u>

The direction of the magnetic force on the charge q follows the right-hand rule.



(Positive charged) (Negative charged)

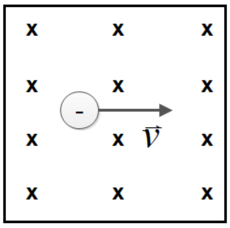
Step 1 **Step 2**

A-1: Hand manipulation of the right-hand rule.

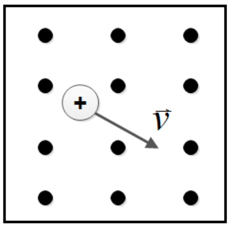
Exercise: Use the right-hand rule to determine the direction of magnetic force.

Known **X** The magnetic field into page

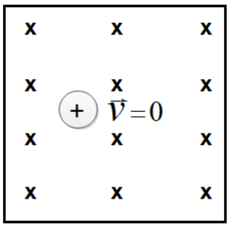
● The magnetic field out of page



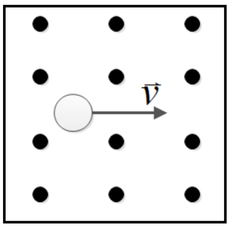
(A)



(B)



(C)



(D)

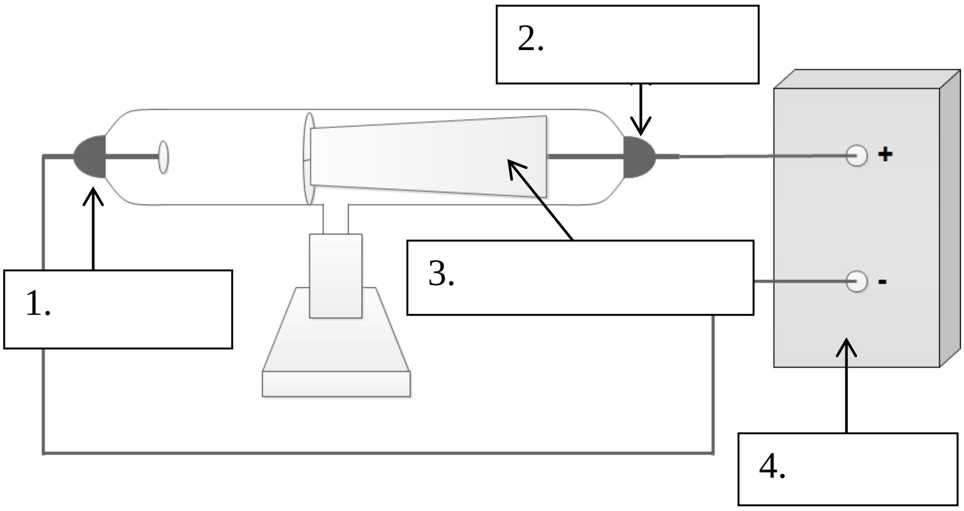
Note: There is magnetic force on a particle when**:**

1. **A particle carrying a charge** (positive or negative)
2. **A particle moves with velocity** $\vec{v}$
3. **Its velocity** $\vec{v}$ **is not parallel to magnetic field** $\vec{B}$

We can summarize these observations by writing the magnetic force in the form

$$\vec{F}_B = q\vec{v}\times\vec{B}$$

Demonstration: Electron traveling in magnetic field

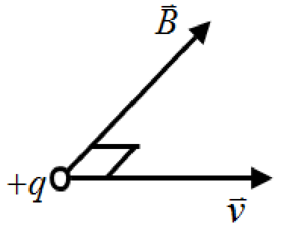


A-2: The Cathode-ray tube set.

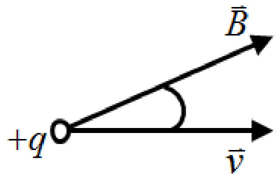
WORKSHEET (THAI VERSION)

ใบงาน: เรื่อง แรงแม่เหล็กที่กระทำต่ออนุภาคที่มีประจุไฟฟ้า

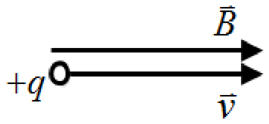
เมื่ออนุภาคที่มีประจุไฟฟ้า q เคลื่อนที่ด้วยความเร็ว $\vec{v}$ ภายในสนามแม่เหล็ก $\vec{B}$ ที่มีทิศทางไม่ขนานกับทิศการเคลื่อนที่จะทำให้เกิดแรงแม่เหล็กที่มีทิศตั้งฉากกับระนาบของความเร็ว $\vec{v}$ และสนามแม่เหล็ก $\vec{B}$



ก. $\vec{v}$ ตั้งฉากกับ $\vec{B}$



ข. $\vec{v}$ ทำมุม $\vec{v}$ กับ $\vec{B}$



ค. $\vec{v}$ ขนานกับ $\vec{B}$

ให้ $\vec{F}_B$ แทนแรงเนื่องจากสนามแม่เหล็กหรือเรียกว่า**แรงแม่เหล็ก** ที่เกิดจากสนามแม่เหล็ก $\vec{B}$ กระทำต่ออนุภาคที่มีประจุไฟฟ้า q มี**ขนาด**เท่ากับ

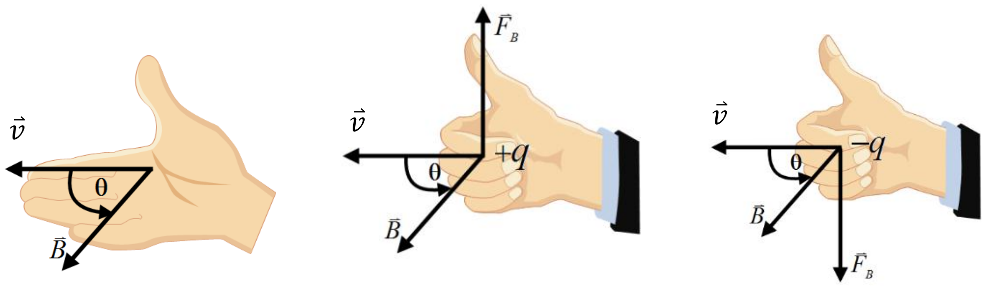
$F_B =$

แรงมีทิศทางเป็นไปตามกฎมือขวา

ในกรณี $\vec{v}$ **ตั้งฉากกับ** $\vec{B}$ จะพบว่า $\vec{v}$ = ... ทำให้ $\sin\theta =$ .... = ...

ดังนั้น $F_B =$ กรณีนี้ **แรงจะมีขนาดมากที่สุด**

การหาทิศทางของแรงแม่เหล็กโดยใช้กฎมือขวา



(กรณีอนุภาคมีประจุเป็นบวก) (กรณีอนุภาคมีประจุเป็นลบ)

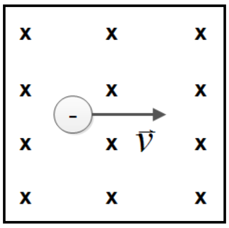
ขั้นที่ 1 ขั้นที่ 2

A-3: Hand manipulation of the right-hand rule.

ให้ใช้กฎมือขวาหาทิศทางของแรงแม่เหล็กในกรณีต่อไปนี้...

กำหนดให้ **x** แสดงทิศทางของสนามแม่เหล็กพุ่งเข้าหากระดาษ

● แสดงทิศทางของสนามแม่เหล็กพุ่งออกจากระดาษ



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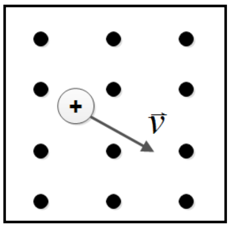

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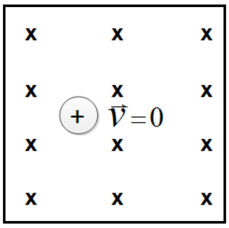
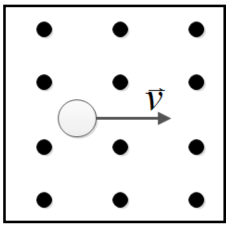


ค.



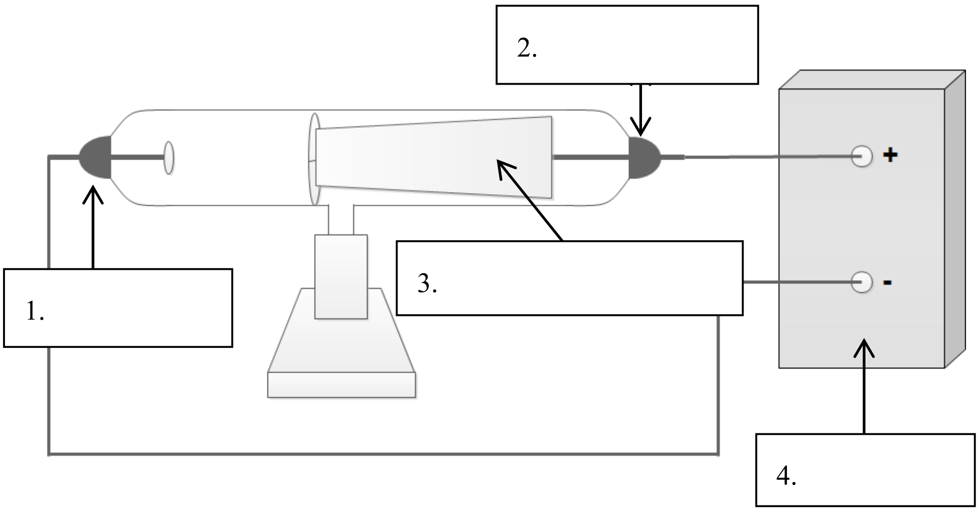
ง.

ข้อสังเกต แรงแม่เหล็กที่กระทำต่ออนุภาคจะเกิดขึ้นได้ก็ต่อเมื่อ

4. **อนุภาคมีประจุไฟฟ้าเป็นบวกหรือลบ**
5. **อนุภาคเคลื่อนด้วยความเร็ว** $\vec{v}$
6. $\vec{v}$ **ไม่ขนานกับ** $\vec{B}$

เราสามารถแสดงความสัมพันธ์ทั้งขนาดและทิศทางของแรงแม่เหล็กนี้ได้โดยสมการ $\vec{F}_B = q\vec{v}\times\vec{B}$

กิจกรรม : การเคลื่อนที่ของอิเล็กตรอนในสนามแม่เหล็ก



A-4: The Cathode-ray tube set.

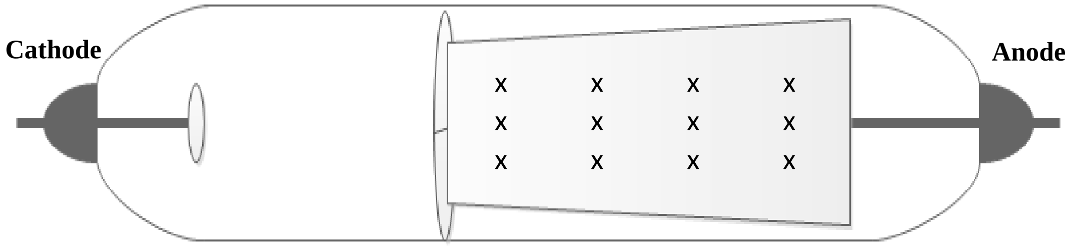
APPENDIX B

ILD WORKSHEET (ENGLISH VERSION)

Name.. Class.............. No. ....

-Prediction Sheet-

Demonstration 1: Sketch your prediction of the electron trajectory in Cathode- ray tube when the magnetic field is pointing into the page.



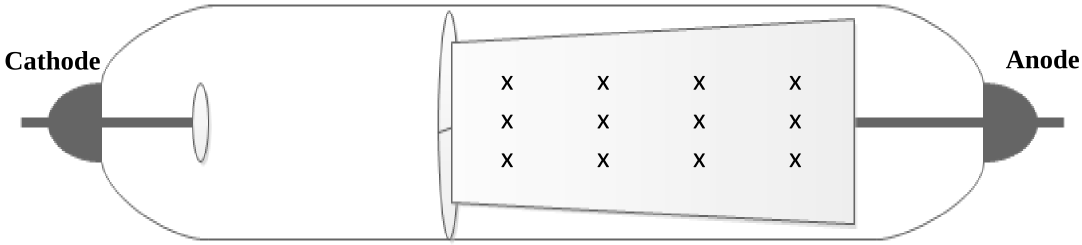
D1

(Hand in this sheet)

Name.. Class.............. No. ....

-Result Sheet-

Demonstration 1 : Sketch your prediction of the electron trajectory in Cathode- ray tube when the magnetic field is pointing into the page.



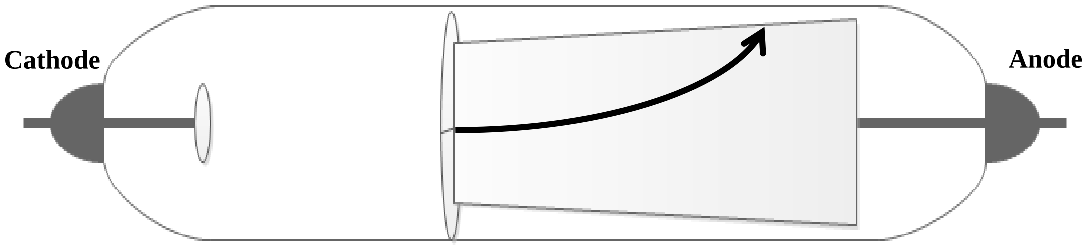
D1

(Keep this sheet)

Name.. Class.............. No. ....

-Prediction Sheet-

Demonstration 2: Sketch your prediction of the direction of magnetic field that makes electron to have trajectory as in the figure.



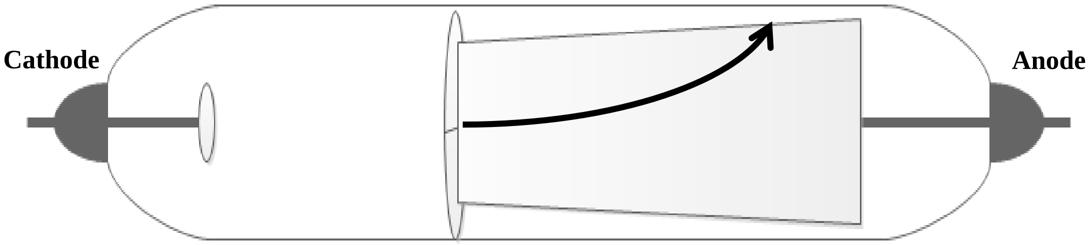
D2

(Hand in this sheet)

Name.. Class.............. No. ....

-Result Sheet-

Demonstration 2: Sketch your prediction of the direction of magnetic field that makes electron to have trajectory as in the figure.



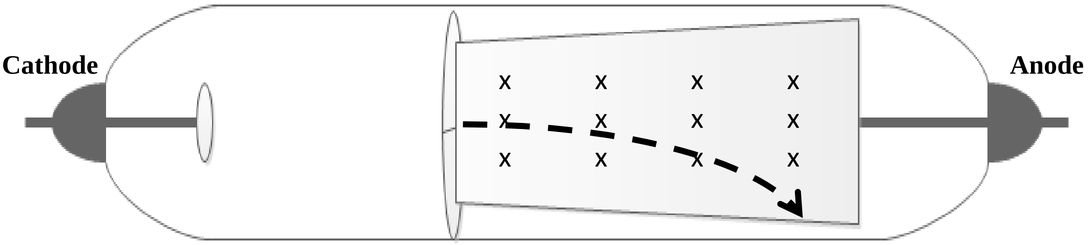
D2

(Keep this sheet)

Name.. Class.............. No. ....

-Prediction Sheet-

<u>Demonstration 3</u>: Sketch your prediction of the electron trajectory in Cathode- ray tube when the magnetic field is pointing into page with magnitude higher than that in Demonstration 1. (The dashed line represents the trajectory in Demonstration 1)



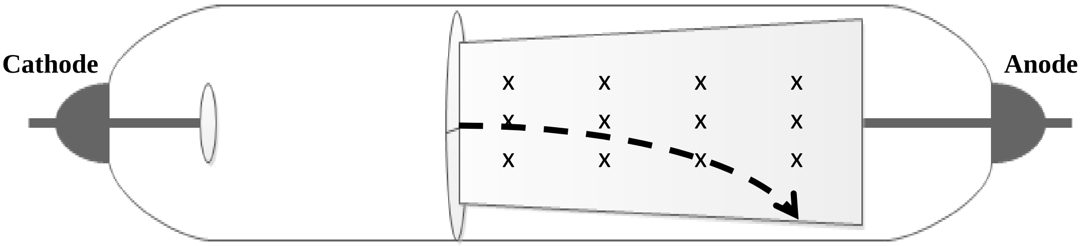
D3

(Hand in this sheet)

Name.. Class.............. No. ....

-Result Sheet-

<u>Demonstration 3</u>: Sketch your prediction of the electron trajectory in Cathode- ray tube when the magnetic field is pointing into page with magnitude higher than that in Demonstration 1. (The dashed line represents the trajectory in Demonstration 1)



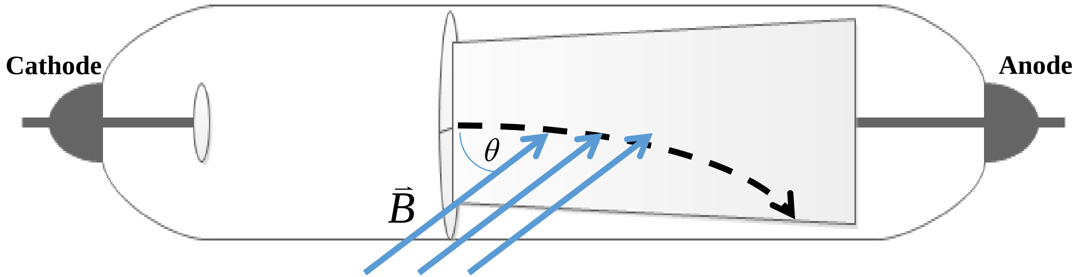
D3

(Keep this sheet)

Name.. Class.............. No. ....

-Prediction Sheet-

Demonstration 4: Sketch your prediction of the electron trajectory in Cathode- ray tube when the magnetic field has the same magnitude to that of Demonstration 1 but is in the direction that makes the angle of θ to the velocity of electron. (The dashed line represents the trajectory in Demonstration 1)



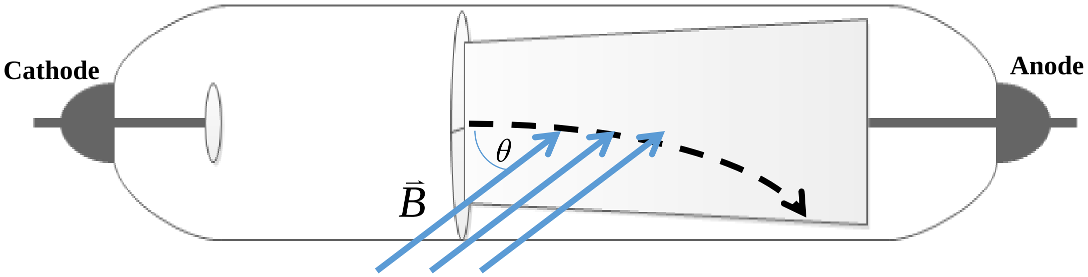
D4

(Hand in this sheet)

Name.. Class.............. No. ....

-Result Sheet-

Demonstration 4: Sketch your prediction of the electron trajectory in Cathode- ray tube when the magnetic field has the same magnitude to that of Demonstration 1 but is in the direction that makes the angle of θ to the velocity of electron. (The dashed line represents the trajectory in Demonstration 1)



D4

(Keep this sheet)

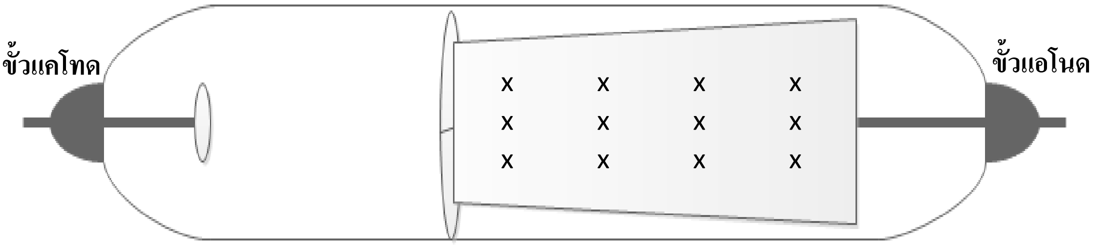
ILD WORKSHEET (THAI VERSION)

ชื่อ-นามสกุล.. ชั้น.................... เลขที่..............

-ใบทำนายผล-

การบรรยายประกอบการสาธิตเชิงปฏิสัมพันธ์เรื่อง แรงแม่เหล็กที่กระทำต่ออนุภาคที่มีประจุไฟฟ้า

<u>การสาธิตที่ 1</u>: ให้ทำนายเส้นทางการเคลื่อนที่ของอิเล็กตรอนในหลอดแคโทด เมื่อให้สนามแม่เหล็กในทิศพุ่งเข้าแผ่นกระดาษ โดยใช้ดินสอหรือปากกาวาดเส้นทางการเคลื่อนที่ของอิเล็กตรอนลงในภาพ D1



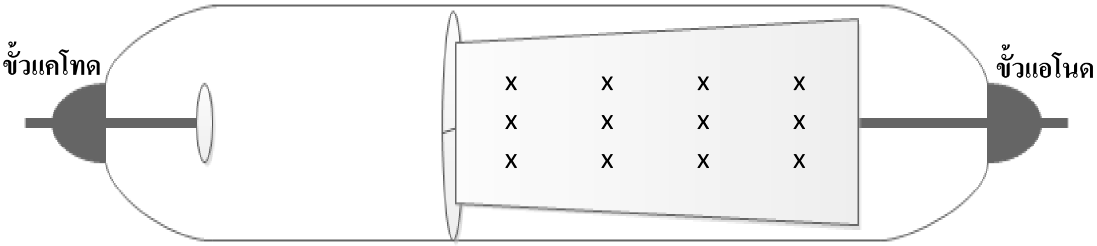
D1

ชื่อ-นามสกุล.. ชั้น.................... เลขที่..............

-ใบบันทึกผล-

การบรรยายประกอบการสาธิตเชิงปฏิสัมพันธ์เรื่อง แรงแม่เหล็กที่กระทำต่ออนุภาคที่มีประจุไฟฟ้า

<u>การสาธิตที่ 1</u>: ให้ทำนายเส้นทางการเคลื่อนที่ของอิเล็กตรอนในหลอดแคโทด เมื่อให้สนามแม่เหล็กในทิศพุ่งเข้าแผ่นกระดาษ โดยใช้ดินสอหรือปากกาวาดเส้นทางการเคลื่อนที่ของอิเล็กตรอนลงในภาพ D1



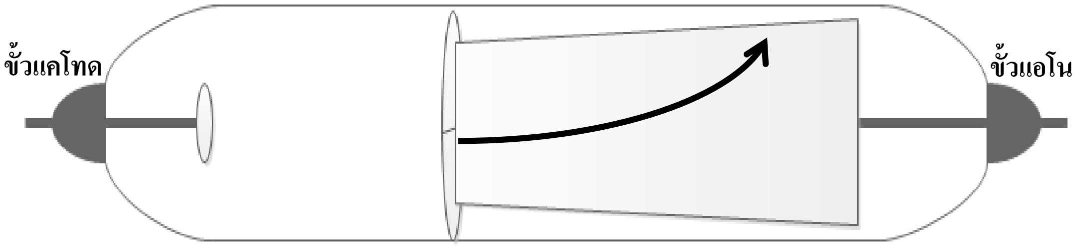
D1

ชื่อ-นามสกุล.. ชั้น...................... เลขที่...............

-ใบทำนายผล-

การบรรยายประกอบการสาธิตเชิงปฏิสัมพันธ์เรื่อง แรงแม่เหล็กที่กระทำต่ออนุภาคที่มีประจุไฟฟ้า

<u>การสาธิตที่ 2</u>: ให้ทำนายทิศทางของสนามแม่เหล็กที่ทำให้อิเล็กตรอนมีเส้นทางการเคลื่อนที่ดังในรูป D2 โดยใช้ดินสอหรือปากกาวาดทิศทางของสนามแม่เหล็กลงในรูปดังกล่าว



D2

ชื่อ-นามสกุล.. ชั้น...................... เลขที่...............

-ใบบันทึกผล-

การบรรยายประกอบการสาธิตเชิงปฏิสัมพันธ์เรื่อง แรงแม่เหล็กที่กระทำต่ออนุภาคที่มีประจุไฟฟ้า

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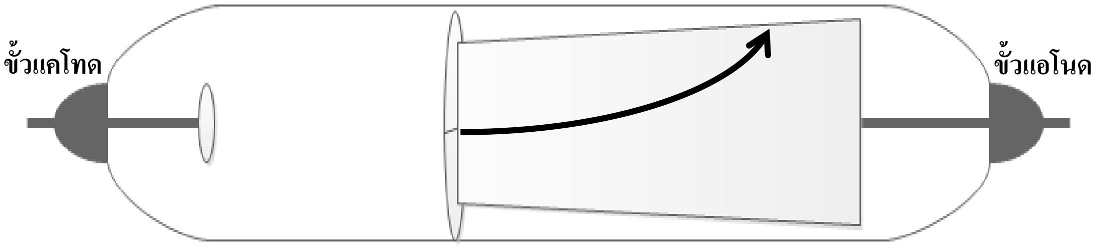


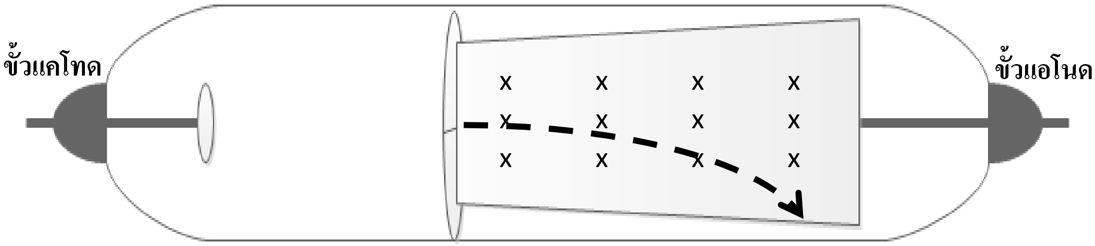
D2

ชื่อ-นามสกุล.. ชั้น..................... เลขที่...............

-ใบทำนายผล-

การบรรยายประกอบการสาธิตเชิงปฏิสัมพันธ์เรื่อง แรงแม่เหล็กที่กระทำต่ออนุภาคที่มีประจุไฟฟ้า

<u>การสาธิตที่ 3</u>: ให้ทำนายเส้นทางการเคลื่อนที่ของอิเล็กตรอนในหลอดแคโทด เมื่อเพิ่มขนาดสนามแม่เหล็กในทิศพุ่งเข้าแผ่นกระดาษ โดยใช้ดินสอหรือปากกาวาดเส้นทางการเคลื่อนที่ของอิเล็กตรอนลงในภาพ D3 (กำหนดให้เส้นประคือเส้นทางการเคลื่อนที่ของอิเล็กตรอนจากการสาธิตที่ 1)



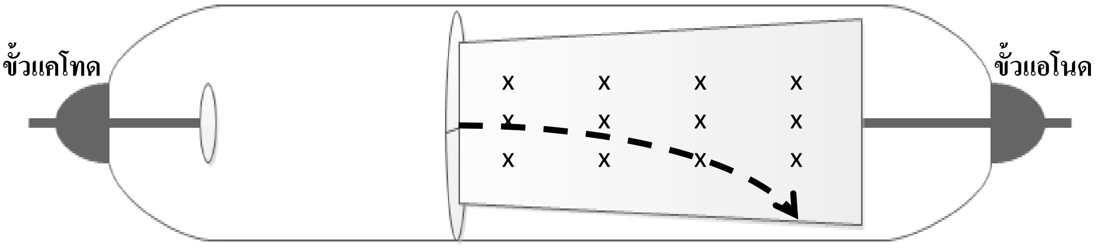
D3

ชื่อ-นามสกุล.. ชั้น..................... เลขที่...............

-ใบบันทึกผล-

การบรรยายประกอบการสาธิตเชิงปฏิสัมพันธ์เรื่อง แรงแม่เหล็กที่กระทำต่ออนุภาคที่มีประจุไฟฟ้า

<u>การสาธิตที่ 3</u>: ให้ทำนายเส้นทางการเคลื่อนที่ของอิเล็กตรอนในหลอดแคโทด เมื่อเพิ่มขนาดสนามแม่เหล็กในทิศพุ่งเข้าแผ่นกระดาษ โดยใช้ดินสอหรือปากกาวาดเส้นทางการเคลื่อนที่ของอิเล็กตรอนลงในภาพ D3 (กำหนดให้เส้นประคือเส้นทางการเคลื่อนที่ของอิเล็กตรอนจากการสาธิตที่ 1)



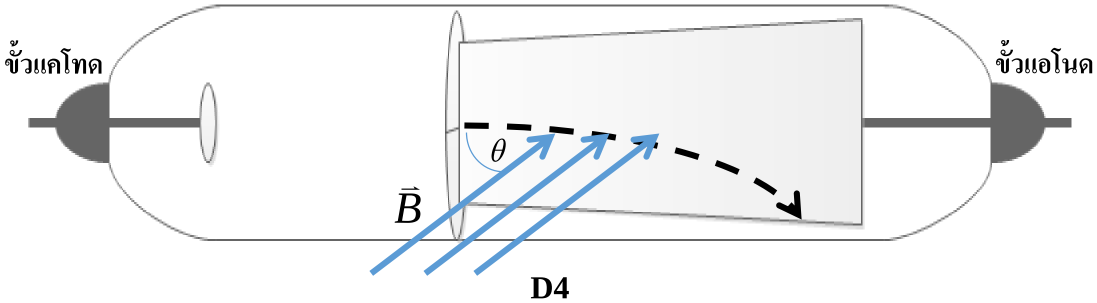
D3

ชื่อ-นามสกุล.. ชั้น...................... เลขที่...............

-ใบทำนายผล-

การบรรยายประกอบการสาธิตเชิงปฏิสัมพันธ์เรื่อง แรงแม่เหล็กที่กระทำต่ออนุภาคที่มีประจุไฟฟ้า

<u>การสาธิตที่ 4</u>: ให้ทำนายเส้นทางการเคลื่อนที่ของอิเล็กตรอนในหลอดแคโทด เมื่อให้สนามแม่เหล็กทำมุม θ กับทิศความเร็วของอิเล็กตรอนดังรูป โดยใช้ดินสอหรือปากกาวาดเส้นทางการเคลื่อนที่ของอิเล็กตรอนลงในภาพ D4 (กำหนดให้เส้นประคือเส้นทางการเคลื่อนที่ของอิเล็กตรอนจากการสาธิตที่ 1)



D4

ชื่อ-นามสกุล.. ชั้น...................... เลขที่...............

-ใบบันทึกผล-

การบรรยายประกอบการสาธิตเชิงปฏิสัมพันธ์เรื่อง แรงแม่เหล็กที่กระทำต่ออนุภาคที่มีประจุไฟฟ้า

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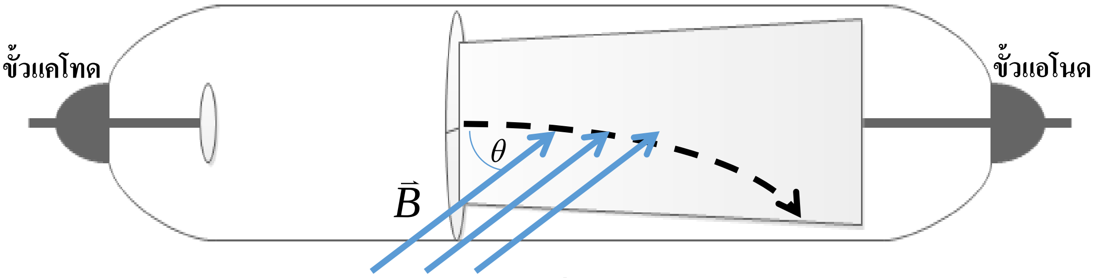


D4

APPENDIX C

THE MAGNETIC FORCE ON A MOVING CHARGED PARTICLE TEST

(ENGLISH VERSION)

Name... No.............. Class................ School........................

Part 1: Circle ○ only one correct answer.

1. What happens to a positive charge that is placed at rest in a uniform magnetic field? (A uniform field is one whose strength and direction are the same at all place.)

a) It moves to the left.

b) It moves to the right.

c) It moves upward.

d) It moves downward.

e) It remains at rest.

2. An electron initially moves horizontally toward a screen. The electron moves along the curved path because of magnetic force caused by magnetic field. In what direction does that magnetic field point?

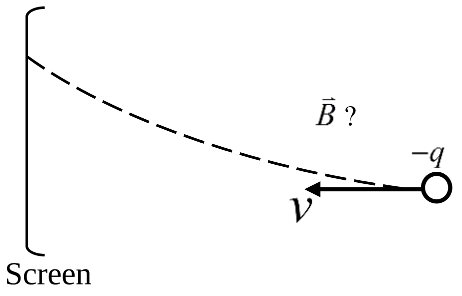
a) Toward the top of page

b) Toward the bottom of page

c) Into the page

d) Out of the page

e) The magnetic field is in the direction
of the curved path.



3. The figures below represent positively charged particle moving in the same uniform magnetic field. The field is direction from left to right. All of the particle have the same charge and the same speed v. Rank these situations according to the magnitudes of the force exerted by the field on the moving charge, from greatest to least.

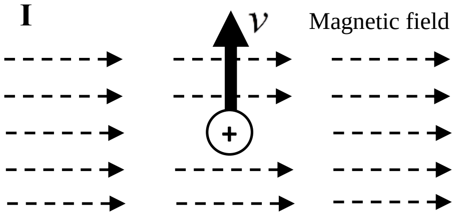
a) I = II = III

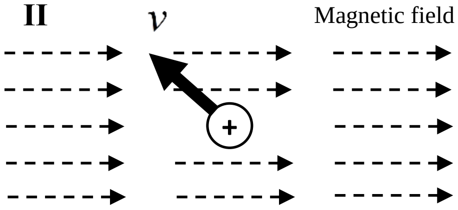
b) III > I > II

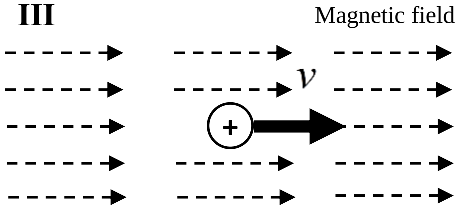
c) II > I > III

d) I > II > III

e) III > II > I

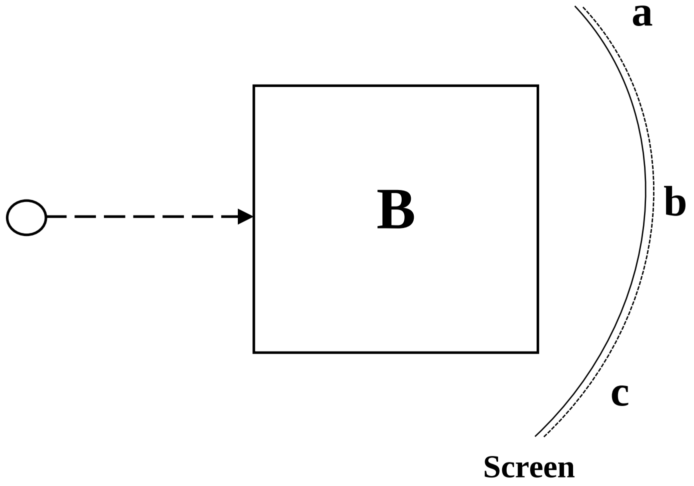






4. Sketch the direction of magnetic force in each situation of Question 3 (I, II, III) with caption as upward, downward, out of page, into page and etc. If the force does not occur, indicates that "No force" and gives the explanation.

Part 2: The charged particle move through the magnetic field **B** to the screen. (No external force exerts on the particle)



Answers the question as followed:

5.1 What charged types (positive, negative or no charged) and direction of the magnetic field that make the particle to move toward screen at point **a**? (Write all possible answers.)

....

....

....

....

....

5.2 If the particle is positive charged and it moves toward the screen at point **c**, in what direction does that magnetic field point?

....

....

....

....

....

THE MAGNETIC FORCE ON A MOVING CHARGED PARTICLE TEST

(THAI VERSION)

ชื่อ-สกุล..เลขที่..............ชั้น................โรงเรียน....................................

ตอนที่ 1 ให้ทำเครื่องหมายวงกลม ○ เพื่อเลือกคำตอบที่ถูกต้องเพียงคำตอบเดียว

1. จะเกิดอะไรขึ้นกับประจุบวกเมื่อนำไปวางลงในสนามแม่เหล็กสม่ำเสมอ (สนามแม่เหล็กสม่ำเสมอ คือ สนามแม่เหล็กที่ความเข้มของสนามเท่ากันทุกจุดและมีทิศทางเดียวกัน)

ก) ประจุจะเคลื่อนที่ไปทางซ้าย

ข) ประจุจะเคลื่อนที่ไปทางขวา

ค) ประจุจะเคลื่อนที่ขึ้น

ง) ประจุจะเคลื่อนที่ลง

จ) ประจุยังคงหยุดนิ่ง

2. อิเล็กตรอนหนึ่งอนุภาคเคลื่อนที่ไปตามแนวระดับเข้าหาฉาก การเคลื่อนที่ของอิเล็กตรอนตามวิถีโค้งที่แสดงไว้ดังรูป เป็นผลเนื่องจากถูกแรงจากสนามแม่เหล็กกระทำ ทิศทางของสนามแม่เหล็กเป็นอย่างไร

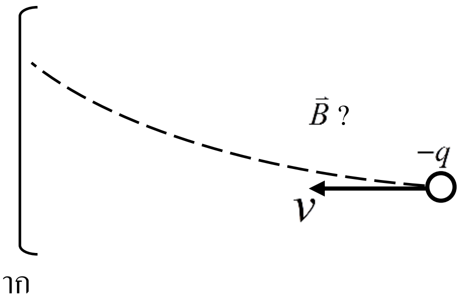
ก) ชี้ไปทางด้านบนของกระดาษ

ข) ชี้ไปทางด้านล่างของกระดาษ

ค) พุ่งเข้าหาหน้ากระดาษ

ง) พุ่งออกจากหน้ากระดาษ

จ) ตามเส้นทางโค้งดังภาพ



3. รูปข้างล่างแสดงอนุภาคซึ่งมีประจุเป็นบวกที่เคลื่อนที่อยู่ในสนามแม่เหล็กสม่ำเสมอ โดยสนามแม่เหล็กมีทิศไปทางขวา อนุภาคทั้งสามกรณีเป็นประจุบวกขนาดเท่ากันและมีอัตราเร็ว v เท่ากัน จงเปรียบเทียบขนาดของแรงเนื่องจาสนามแม่เหล็กที่กระทำต่อประจุที่กำลังเคลื่อนที่ในแต่ละกรณี

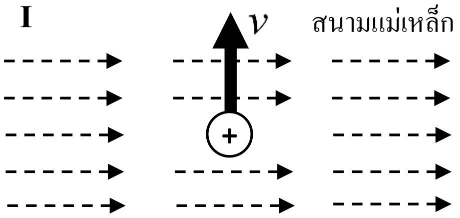
ก) I = II = III

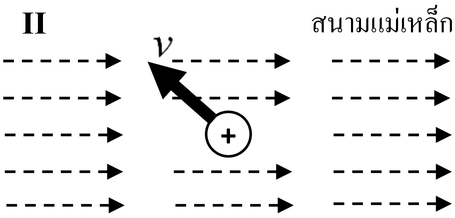
ข) III > I > II

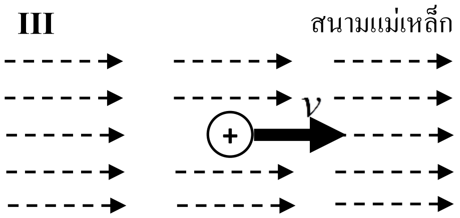
ค) II > I > III

ง) I > II > III

จ) III > II > I

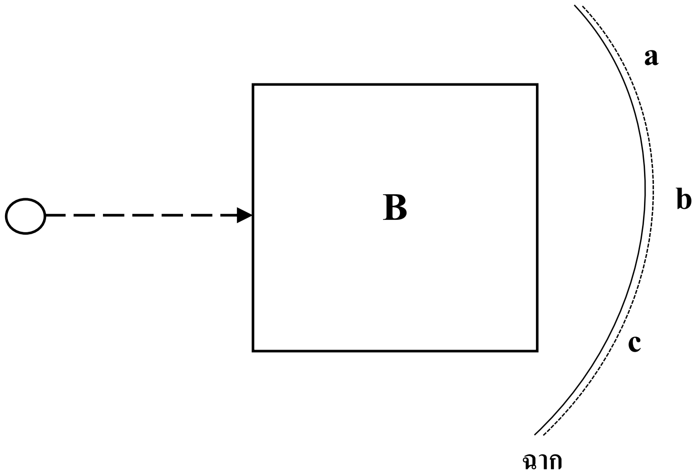






4. จงวาดลูกศรระบุทิศทางของแรงแม่เหล็กที่กระทำต่ออนุภาคลงในแต่ละรูปในข้อ 3 โดยเขียนอธิบายทิศทางของแรงกำกับด้วย (เช่น ชี้ขึ้น ชี้ลง พุ่งออกจากกระดาษ พุ่งเข้ากระดาษ ไปทางซ้าย ไปทางขวา ฯลฯ) หากกรณีใดไม่เกิดแรงแม่เหล็กให้ระบุพร้อมอธิบายเหตุผลประกอบ

ตอนที่ 2 อนุภาคหนึ่งเคลื่อนที่ผ่านบริเวณที่มีสนามแม่เหล็กสม่ำเสมอ B ไปยังฉากที่อยู่ด้านหลัง ดังรูป (ไม่มีแรงอื่นใดมากระทำต่ออนุภาคนี้)



จงตอบคำถามต่อไปนี้

5.1 ถ้าต้องการให้อนุภาคนี้เคลื่อนที่ไปยังตำแหน่ง a บนฉาก อนุภาคนี้ควรมีประจุเป็นแบบใด (บวก ลบ หรือเป็นกลาง) และสนามแม่เหล็กควรมีทิศทางอย่างไร (อาจมีคำตอบได้มากกว่า 1 แบบ จงตอบให้ครบทุกแบบ)

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5.2 ถ้าอนุภาคมีประจุไฟฟ้าเป็น**บวก**และต้องการให้เคลื่อนที่ไปยังตำแหน่ง c บนฉาก สนามแม่เหล็กควรมีทิศทางอย่างไร

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APPENDIX D
TRADITIONAL TEACHING PROCEDURE

The high-school teacher performed the traditional teaching with student in control group. The video record was analyzed the procedure of this teaching method as followed.

1. Introduce the Cathode ray tube set.
2. Ask students to predict the trajectory of electron beam when giving the magnetic field by magnetic bar.
3. Carry out the demonstration to the whole class.
4. Describe the results and introduce to the magnetic force on a moving charged particle topic.
5. Lecture the content of this physics topic which starting by direction of the magnetic force with applying the right-hand rule.
6. Ask students to practice using the right-hand rule by given problems.
7. Lecture the magnitude of magnetic field.
8. Conclude this physics topic.

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