DIAGNOSIS OF ELEVENTH GRADE STUDENTS' MISCONCEPTIONS ABOUT GEOMETRIC OPTIC BY A THREE-TIER TEST

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY

YASIN KUTLUAY

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF SCIENCE
IN
SECONDARY SCIENCE AND MATHEMATICS EDUCATION

SEPTEMBER 2005

Approval of the Graduate School of Natural and Applied Sciences.

_____
Prof. Dr. Canan ÖZGEN
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

_____
Prof. Dr. Ömer GEBAN
Head of Department

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

_____
Assist. Prof. Dr. Ali ERYILMAZ
Supervisor

Examining Committee Members

Assoc. Prof. Dr. Bilal GÜNEŞ	(Gazi Univ., SSME)	_____
Assist. Prof. Dr. Ali ERYILMAZ	(METU, SSME)	_____
Assoc. Prof. Dr. Safure BULUT	(METU, SSME)	_____
Assist. Prof. Dr. Jale ÇAKIROĞLU	(METU, ELE)	_____
Dr. Mehmet SANCAR	(METU, SSME)	_____

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last name : Yasin KUTLUAY

Signature :

ABSTRACT

DIAGNOSIS OF ELEVENTH GRADE STUDENTS' MISCONCEPTIONS ABOUT GEOMETRIC OPTIC BY A THREE-TIER TEST

Kutluay, Yasin

M.S., Department of Secondary Science and Mathematics Education

Supervisor: Assist. Prof. Dr. Ali ERYILMAZ

September 2005, 127 pages

The main purpose of this study was developing a three-tier test for assessing 11th grade students' misconceptions about geometric optic. The accessible population was all 11th grade science students in Bayrampaşa, Istanbul. While developing the test, interviews and open-ended tests were used to collect data to create the three-tier test. An interview questionnaire was developed based on the literature review. 15 11th grade students were interviewed by this questionnaire. Then, an open-ended test was created based on the interview results and also the literature review. It was applied to 114 11th grade science students. The responses of the students for each item were categorized considering the frequencies. Then, these categories were used in the development of the Three-tier Geometric Optic Misconception Test (TTGOMT). The categories were used as the distracters of the items in the TTGOMT. Besides, some of the distracters were extracted from the interview results and the literature review even if they had no frequencies in open-ended test results. The test was applied to the 141 11th grade high school students. A factor analysis was conducted to establish the content validity of the TTGOMT and five categories were found. Also, the proportions of the false positives and false negatives were

estimated to establish the content validity and found 28.2 % for the false positives and 3.4 % for false negatives. The construct validity was established by estimating a correlation between the scores of the students for the first two tiers and confidence levels for the third tier. Two reliability analyses were conducted by using Cronbach alpha. One of the reliability analyses was estimated based on the correct answers of the students for all the three tiers together and found 0.55. The other one was estimated based on the misconceptions of the students and found 0.28. Moreover, item analysis was done for each item by using Iteman program.

Keywords: Physics Education, Misconceptions, Geometric Optic, Misconception Test, Three-tier Misconception test

ÖZ

11. SINIF ÖĞRENCİLERİNİN GEOMETRİK OPTİK HAKKINDAKİ KAVRAM YANILGILARINI ÖLÇEN ÜÇ-AŞAMALI TEST GELİŞTİRME

Kutluay, Yasin

Yüksek Lisans, Ortaöğretim Fen ve Matematik Alanları Eğitimi Bölümü

Tez Yöneticisi: Yrd. Doç. Dr. Ali ERYILMAZ

Eylül 2005, 127 sayfa

Bu çalışmanın asıl amacı 11. sınıf öğrencilerinin geometrik optik hakkındaki kavram yanılgılarını ölçen üç-aşamalı test geliştirmektir. Çalışılabilir populasyonu İstanbul'un Bayrampaşa ilçesindeki tüm 11. sınıf fen grubu öğrencileridir. Testin oluşum aşamasında gerekli olan veriyi toplamak için bire-bir mülakatlar ve açık-uçlu sorular kullanıldı. Literatür sonuçlarına dayanarak bir mülakat formu geliştirildi ve 15 onbirinci sınıf fen öğrencisi mülakat edildi. Sonra, mülakat sonuçları ve aynı zamanda literatür sonuçları da göz önünde tutularak açık-uçlu bir test geliştirildi. Bu test 141 onbirinci sınıf öğrencisine uygulandı. Öğrencilerin her bir soru için verdiği cevaplar frekanslarına göre kategorize edildi. Bu kategoriler Üç-aşamalı Geometrik Optik Kavram Yanılgısı Testinin (ÜAGOKYT) çeldiricilerini oluşturmak için kullanıldı. Bazı çeldiriciler açık-uçlu test sonuçlarında frekansları olmasa bile mülakat ve literatür sonuçlarından

oluşturuldular. Test 141 onbirinci sınıf fen öğrencisine uygulandı. ÜAGOKYT' nin içerik geçerliliğini oluşturmak için faktör analiz yapıldı ve 5 faktör bulundu. Faktör analizden başka, içerik güvenirliği için yanlış sebepli doğruların ve doğru sebepli yanlışların oranları hesaplandı. Yanlış sebepli doğruların oranı % 28.2 ve doğru sebepli yanlışların oranı % 3,4 bulundu. Yapısal geçerlilik için, öğrencilerin ilk iki basamağa verdikleri cevaplardan aldıkları puanlarla üçüncü basamakta belirttikleri özgüvenleri arasındaki korelasyon hesaplandı. Testin güvenirliği için iki güvenirlik analizi Cronbach alpha katsayısıyla hesaplandı. İlk olarak, öğrencilerin testte üç aşamaya birden verdiği doğru cevaplar üzerinden güvenirlik analizi yapıldı ve Cronbach alpha 0,55 bulundu. Diğer güvenirlik analizi öğrencilerin 3 aşamaya birden verdikleri cevaplarla ortaya çıkan kavram yanılgıları üzerinden yapıldı ve Cronbach alpha 0,28 bulundu. Bunlardan başka, testteki her bir soru için Iteman programını kullanarak soru analizi yapıldı.

Anahtar Kelimeler: Fizik Eğitimi, Kavram yanılgıları, Geometrik Optik, Kavram Yanılgısı Testi, Üç-aşamalı Kavram Yanılgısı Testi

To My Parents

ACKNOWLEDGMENTS

I would like to thank my supervisor Assist. Prof. Dr. Ali ERYILMAZ for his valuable guidance and help throughout the study.

I am grateful to my parents who provided valuable support throughout my life and this study. Thank you for your encouragement and patience.

I want to thank my friends; Ertuğrul, Vedat and Gökhan for their valuable contributions and supports to the study.

My special thanks go to Haki Peşman for his valuable support and contributions.

I also wish to express my deep appreciation to the administrators and teachers who helped to enable this study. I also want to thank to the students who participated in the study and gave time.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

One focus of research studies in the literature in education and psychology has been the nature of learning and learning environment. Moreover, these research studies have concentrated on factors external to the learner that influence learning, such as teaching methods and strategies, teacher variables, books, contents, and classroom environments Wittrock (as cited in Al-Rubayea, 1996). However, learners can not be excluded from learning process. Students' minds are not empty entities that teachers fill up. Students come to the classes with a set of assumptions of how the world operates. Their prior assumptions before instruction are called prior knowledge or preconceptions Lucido (as cited in Al-Rubayea, 1996). Although, these preconceptions help students to understand the world around them, sometimes these preconceptions are not true in scientific view. Education researchers call these wrong conceptions as misconceptions (Al-Rubayea, 1996). Moreover, since these misconceptions help the students to understand the world, they are resistant to change and obstructing the learning process (Klammer, 1998).

It might therefore be reasonably argued that the more teachers know about theirs students' misconceptions, the more they will be able to provide them to learn. From this perspective science learning should involve modifying a student's cognitive structure in such a way that the student can explain things both better and more scientifically (Osborne & Gilbert, 1980).

Identifying the students' misconceptions in any field of the science requires great effort. Researchers have developed many methods to explore students' misconceptions, such as interviews, concept maps and diagnostic tests (Tsai & Chou, 2002). Although, researchers gain more information by depth of probing and flexibility of questioning by interviews (Beichner, 1994), they require a large amount of time to interview with a large number of students (Chen et al., 2002) to get greater generalizability (Beichner, 1994). On the other hand, multiple-choice tests can be administered to a large number of students for generalization

and easily be analyzed. However, the disadvantage of the multiple-choice tests was their effectiveness. According to Rollnick and Mahooana (1999) the disadvantage of multiple-choice tests is that questions do not provide deep enough inside into the students' ideas on the topic and students very often give correct answers for wrong reasons. To overcome this problem, Staver and Gebal; Lavson; Lavson, Adi, and Karplus; Tobin and Capie (as cited in Al-Rubayea, 1996) recommended that students should justify their answers. As a result, researchers extended the multiple-choice tests into several tiers, two or three tiers. In a two-tier test, the first tier presents a multiple choice content question and the second tier presents a set of reasons for the given answer in the first tier Treagust (as cited in Odom & Barrow, 1995).

Nonetheless, Griffard and Wandersee (2001) asserted that two-tier tests have some deficiencies. They used a two-tier test that had been developed by Haslam and Treagust (as cited in Griffard & Wandersee, 2001) in their study and criticized it. They said that the test was not developed by considering the students' minds. Therefore, they asserted that since the test items are based on scientifically correct propositions from the concept map which had been used in the design of the test, the test items actually diagnose isolated errors in a conceptual framework rather than robust naïve theories. They also emphasized that the test results overestimate the percentage of misconceptions because gap in knowledge cannot be discriminated from misconceptions.

Three-tier tests remove this problem. Because of the some mentioned concerns for the two-tier tests, Eryılmaz and Sürmeli (2002) developed a three-tier test to assess students' misconceptions concerning heat and temperature. As a result of the study, it can be absolutely said that three-tier tests have the advantage over the two-tier tests in term of discriminating students' lack of knowledge from their misconceptions by means of the third tier items which assess how confident the students are about their responses for the first and second tiers.

1.1 The Main Problem and Sub-problems

The research questions investigated in this study can be classified as the main problem and the sub-problems.

1.1.1 Main Problem

The researcher's main purpose in this study was to develop a Three- tier Geometric Optic Misconception Test (TTGOMT). The second purpose was assessing 11th grade Turkish students' misconceptions in geometrical optic by the test. And the third purpose of the study was to compare the results with respect to the type of the test by assuming that the first tier items of the test present a multiple choice test and both the first and second tier items of the test present a two-tier test.

1.1.2 Sub-Problems

1. Is the TTGOMT test valid and reliable?
2. What are the difficulty level and the index of discrimination of each item in the test?
3. What are the misconceptions which eleventh grade students hold about geometric optic?
4. Are there any new misconceptions which have not been mentioned in the literature?
5. What is the percentage of lack of knowledge for each item and in average?
6. How does the fraction of the students having a misconception change with respect to the type of the test?
7. How does the fraction of the students giving the correct answer(s) change with respect to the type of the test?
8. Can the misconceptions be grouped meaningfully as a result of the factor analysis?
9. Can the test items be grouped meaningfully as a result of the factor analysis?
10. What are the percentages of false positives and false negatives?

1.2 Definition of Important Terms

This section includes some important definitions related to the study.

Concept: An abstract or general idea inferred or derived from specific instances (The Free Dictionary, 2005).

Conception: The ability to form or understand mental concepts and abstractions (The Free Dictionary, 2005).

Misconception: The intuitive ideas that students have constructed for themselves as a result of experiences with their physical environment Gilbert and Watts (as cited in Al-Rubayea, 1996). Misconceptions have also been called students' conceptions, children's science, alternative conceptions or alternative frameworks Gilbert and Watts (as cited in Fetherstonhaugh & Treagust, 1992), and as private concepts, naive theories Mintzes (as cited in Odom & Barrow, 1995), and as naive conceptions or naive knowledge (Reiner, Slotta, Chi, & Resnick, 2000), and as commonsense beliefs (Hestenes, Wells, & Swackhamer, 1992).

False Negatives: False negatives can be defined as the incorrect answers that are given by the students who have the correct, scientific conception for answering the questions (Hestenes & Halloun, 1995).

False Positives: False positives can be defined as the correct answers that are given by the students who do not have the correct, scientific conception (Hestenes & Halloun, 1995).

Diagnostic test: A test with items in a multiple- choice or short answer format that has been designed with common misconceptions in mind (Rollnick & Mahooana, 1999).

Two-tier multiple choice diagnostic test: A two-tier test is a two level multiple-choice question that diagnoses students' alternative conceptions in science (Tsai & Chou, 2002). The first tier is in the multiple-choice format asking the content knowledge of the students with two, three or four choices. The second tier is again in the multiple-choice format asking the reason for the response given in the first tier Treagust (as cited in Odom & Barrow, 1995).

Three-tier misconception test: Three-tier tests are very similar to the two-tier tests. In three-tier tests, an item has one additional tier which asks students confidence about the answer of the former two-tiers (Çataloğlu, 2002).

1.2 Significance of the study

In this study, the researcher will develop a three-tier test and assess the misconceptions of the 11th grade Turkish students' misconceptions in geometrical optic. This study's product and results are important for five reasons. First, it gives a diagnostic instrument to teachers to measure their students' geometrical optic misconceptions. Second, in the literature for physics education there was great number of studies have been in the area of mechanics, particularly students' conceptions of force and motion. Studies for students' understanding of geometrical optics, however, are relatively rare (Watts, 1985). Moreover, there were no previous studies that investigate the students' misconceptions in optics and developing a three-tier multiple choice diagnostic tests to evaluate these misconceptions in Turkish Literature. Third, the results and conclusions provide information to help teachers take students' misconceptions into account in their teaching, thereby improving physics education in Turkey. Fourth, identifying students' misconceptions in optics can give some feedback to the textbook editors, thereby enhancing the quality of Turkish textbooks. Finally, this study can lead to development of new diagnostic multiple-choice tests for the other physics subjects and the other science lessons, thereby improving science education in Turkey.

CHAPTER 2

REVIEW OF LITERATURE

This chapter is a review of literature related to this study. In this study, review of literature can be divided into four main parts. (1) Information about the knowledge. (2) General knowledge about misconceptions of the students. (3) Methods used for identifying the misconceptions of the students especially focusing the development process of two-tier diagnostic tests. (4) Students' misconceptions in geometrical optic.

2.1 Knowledge

The field of psychology started to influence education and was used to explain learning process. The spectrum of learning theories consists of many approaches or ways of explaining how humans learn. Behaviorism, cognitivism and constructivism are three fundamental theories. Theorists of behaviorism are J.B Watson, E. L Thorndike and B. F. Skinner. They focused on behavior rather than internal thought process. According to them, learning is manifested by a change in behavior. They thought environment shapes what one learns, not by the individual learner. Skinner (as cited in Mcleod, n.d.) studied operant conditioning and explained learning principle like that learning occurs through positive reinforcement and old patterns are abandoned by negative reinforcement. Behaviorists were unable to explain certain social behaviors. For example, children do not imitate all behavior that has been reinforced. Furthermore, they may model new behavior days or weeks after their first initial observation without having been reinforced for the behavior (Mergel, 1998).

A constructing view of learning was developed by the cognivistic theorists to behaviorism. They refused learning as response to stimuli from the environment. They thought learning process should be much more than this. Thus, they thought

learning process as an internal and active process, which develops within a learner. They included learner in the learning process. One assumption of cognitivism is that an existing knowledge structure must exist to learn. These structures are called as schema (Mcleod, n.d.). In cognitivism, human brain and nervous system and their development are very important. Jean Piaget studied human cognitive development process. According to him, there are four stages in cognitive development process:

1. Sensorimotor period (0-2)
2. Preoperational Period (3-7)
3. Concrete operational period (8-11)
4. Formal operational period (12-15)

In the sensorimotor stage, intelligence takes the form motor actions (reaching-grasping-pulling). In preoperational stage, intelligence is intuitive in nature and partially logical thought begins. In concrete operational stage, cognitive structure is logical but it is concrete. In formal operational stage, cognitive structure is logical and also abstractions can be made in this stage. He stated that cognitive development is effected by three processes. Assimilation, accommodation and equilibration. Assimilation is integration of new information with existing schemas. Accommodation is the adjustment of schemas to the new situation or constructing new schemas. Equilibrium is the continuing readjustment between assimilation and accommodation (Gredler, n.d.). Piaget's this study can be called as genetic epistemology. Because, he described in his study nature and origin of knowledge. Piaget's assumptions about knowledge and learning process are similar to constructivist theory. Constructivism is a theory of knowledge that describes the nature of knowledge and how an individual acquires it. In constructivism, knowledge is created in the mind of the learner i.e. the student attempts to make sense of his or her world using previously acquired knowledge through everyday experiences or formal learning. According to Merril (as cited in Mergel, 1998) there are six assumptions of constructivism:

- Knowledge is constructed from experience.
- Learning is a personal interpretation of the world.
- Learning is an active process in which meaning is developed on the basis of experience.

- Conceptual growth comes from the negotiation of meaning, the sharing of multiple perspectives and changing of our internal representations through collaborative learning.
- Learning should be situated in realistic settings; testing should be integrated with the task and not a separate activity.

According to Von Glasesferld (as cited in Al-Rubayea, 1996), 'Constructivism assumes that knowledge is actively built up by the learner through a process of construction or interpretation in a way that fits his or her own world. So students learn by trying to fit what they are taught to their own worlds; learning from constructivist perspective is the production of self-organization.

2.2 Misconceptions

There have been a lot of studies conducted in science education. Many of these studies were interested in students' ideas concerning phenomena taught in science. These studies' results show that students come to class with their existing knowledge that they construct with their experiences or formal learning (Fetherstonhaugh & Treagust, 1992). Students' this prior knowledge is called as preconceptions. Some of these preconceptions are in conflict with the scientific view. Preconceptions which are in conflict with the scientific view are called as misconceptions. In the literature misconceptions have also been called as students' conceptions, children's science, alternative conceptions or alternative frameworks Gilbert and Watts (as cited in Fetherstonhaugh & Treagust, 1992), and as mistakes, errors, misunderstandings, misleading ideas, misinterpretation of facts Barras (as cited in Odom & Barrow, 1995), and as private concepts, naive theories Mintzes (as cited in Odom & Barrow, 1995), and as naive conceptions or naive knowledge (Reiner, et al., 2000), and as commonsense beliefs (Hestenes, et al., 1992). It is important to understand that not all preconceptions are misconceptions (Klammer, 1998). It is also necessary to say that a misconception is not a mistake and it does not stem from lack of knowledge. Misconception is understanding of a conception in a wrong or missing way. If a student has a misconception, his/her conception is

not true or missing whereas it is true for himself/herself. Although it is wrong, it works for the student (Eryılmaz & Sürmeli, 2002).

In the past students were thought as empty entities when they came to the classes. The role of the teachers was to fill these empty entities with knowledge. If the students' minds are filled with misconceptions, where do they originate? What are the sources of misconceptions? According to Klammer (1998) the sources of the misconceptions are

- Experiences
- Language
- A curriculum of "truths"

For example, students experience that feathers fall down more slowly to the ground than do stones. However, when the students in secondary schools are confronted with the experiment that stones and feathers fall at the same rate in a vacuum, they are confused and surprised with this situation. Because, their experiences and the experiment are in conflict. Similarly, there are many metaphors ingrained in language. Although these metaphors help the students understand the world they do not function in scientific fields every time. The researcher also stated that teachers and textbooks are always dealt with truths. Students never experience with proofs. So, always dealing with truths can lead to students to see nice-looking but wrong equations or relationships as true. For example, some students think the equation $\sqrt{a^2+b^2} = (a+b)^2$. Moreover, in the lectures teachers teach the subjects with their simplest forms. Students do not explore the full logical development of an idea or theory.

Reiner et all. (2000) stated that students' misconceptions can stem from their substance-based knowledge. Students come to classes with their existing knowledge that are constructed with their everyday experiences in substance-based environment. Therefore, students try to assimilate new physics knowledge with their substance-based knowledge. For example, they consider force as a property of moving objects. They tend to understand abstract physics concepts with properties of material substances such as force, heat, electricity and light. In the absence of relevant knowledge, students explain some of these concepts with the materialistic language that is used in everyday language as well as in the science classroom. For example, "close the door, you are letting all the heat out," "throw some more light on things," etc. These concepts are difficult to learn for them. Therefore, students have too many robust misconceptions in these concepts.

Ivovi (as cited in Al-Rubayea, 1996) interestingly stated that the sources of misconceptions of the students were teachers and textbooks. He investigated the secondary school students' physics misconceptions in Nigeria and administered a 20 item multiple-choice test to the students from eight schools. He also gave the test to the teachers in these schools. He found some misconceptions among the Nigerian students. The results also showed that teachers had similar misconceptions in the same area of physics that the students had.

Researches on the misconceptions show us that misconceptions are resistant to change. Because, these misconceptions help students to understand the world around them. Dupin and Johsua investigated the students' misconceptions about direct-current electricity. They concluded that some of the misconceptions can be overcome by teaching; however, some are resistant to change. Meyer (as cited in Al-Rubayea, 1996) stated that misconceptions may stay for a long time because they serve many different functions for the people who hold them, and give them explanations for their problems.

Moreover, misconceptions are resistant to change; they interfere with learning process and inhibit students' learning. Nussbaum and Novick (as cited in Al-Rubayea, 1996) stated that students' misconceptions can interfere with learning process and cause a great of difficulty when students learn new information because their misconceptions give inaccurate interpretations for new concepts. According to Perkins (as cited in Klammer, 1998), the term naive knowledge refers the misconceptions which retain after instruction. He believed that to incorporate some new knowledge, learners must change the connections among the things they already know. The alternatives to the necessary restructuring are to distort the new information to fit their old ideas or to reject the new information entirely. According to him, students do not understand the physical science with deep understanding. Although, they are able to pass almost any exam through the memorization of basic problem skills, they do not understand the principles involved in the problems. For example, in a private university, Harward university graduates were given a battery, a light bulb, and a piece of wire and were asked to make the light bulb light. Although, these students were exposed the concept of electrical circuits with very complex problems in their education program, only a few students were able to be successful. They had either forgotten the topic or

compartmentalized the knowledge without making connections to real life situations.

To sum up, misconceptions have become a part of science education. Researchers have done lots of studies to investigate the students' misconceptions. Teachers should take care of them seriously to teach their students in a reliable way.

2.3 Identifying the misconceptions

It is important to know what prior knowledge students bring to learning environment in order to help them to construct new knowledge. In the past, students' prior knowledge was not considered seriously. When the misconception studies started to appear in the literature, science educators have focused on developing valid and reliable methods to identify them. Therefore, they proposed variety of methods to identify students' misconceptions such as various types of interviews, word associations, open-ended questions, multiple-choice tests, multiple-choice tests with explanation, and two-tiered multiple choice tests (Al-Rubayea, 1996).

2.3.1 Interviews and Open-ended Tests

Interview methods used by Osborne and Gilbert (as cited in Chen, et al., 2002), Posner and Gertzog; Bell (as cited in Tsai & Chou, 2002) and open-ended questionnaires have some advantages and disadvantages. Although, researchers gain more information by depth of probing and flexibility of questioning by interviews (Beichner, 1994), they require a large amount of time to interview with a large number of students (Chen et al., 2002) to get greater generalizability (Beichner, 1994). Moreover, these methods also require additional training of researchers (Treagust and Haslam, as cited in Chen et al., 2002). Also, although open-ended questionnaires give students more time to think and write about their ideas, interpretation and analyzing the results of the open-ended questionnaires are difficult and time consuming (Al-Rubayea, 1996).

2.3.2 Multiple-Choice Tests and Force Concept Inventory (FCI)

Multiple-choice tests have been found an effective way of identifying the misconceptions of the students by researchers. Bar (as cited in Al-Rubayea, 1996) stated that multiple-choice tests are more effective than oral or written open-ended essays in detecting students' misconceptions.

Force Concept Inventory (FCI) is the one of the most popular multiple-choice test in physics education to monitor understanding of students' conception of force and kinematics. The first version of FCI, Mechanics Diagnostic Test (MDT), was published in 1985 by Halloun and Hestenes (Savinainen & Scot, 2002). It consisted 34 items designed to identify students' misconceptions (Chapter 2 Review of the Literature, n.d.).

Initially, it was implemented to the college students in written and open-answer form. Then, students' misconceptions were identified from their responses and multiple-choice version of the test was constructed based on these misconceptions (Savinainen & Scot, 2002). In 1992, an improved version of MDT was published by Halloun and Hestenes with 29 multiple-choice items (Chapter 4. Multiple-Choice Concept Tests, n.d.). The questions of the FCI were categorized into six dimensions: kinematics, first law, second law, third law, superposition principle, and kinds of force. They also provided a list of 30 misconceptions the test probed and which questions addressed each misconception (Chapter 2 Review of the Literature, n.d.).

Steinberg and Sabella (1997) investigated the how student performance on the FCI correlates with their understanding of the subject matter. They found that sometimes students' performances on the FCI do not correlate. They do not attribute it to the test and claimed that it may due to the inconsistency in student thinking about the physics. Palmer (as cited in Tan et al., 2002) described this situation as students may have more than one conception for a particular concept. The researchers also found that items of the FCI are given from real life experiences. However, in formal exams there are no or a few items include real life situations. Therefore, students find the items of the FCI very strange which can confound the data. Finally, they found that since the students knew that the results of the test would not be counted towards their grades, some students did not take the test seriously.

Multiple-choice tests have many advantages. They can be scored immediately and objectively. Teacher can administer them easily and they are applicable to large number of students (Al-Rubayea, 1996). Moreover, Ooesterhof (as cited in Çataloğlu, 2002) expressed that multiple-choice tests are better liked by the students than other measures and can give diagnostic information. Scott (as cited in Marx, 1988) expressed nine appropriate reasons for using of multiple-choice tests: (1) They provide greater variety of questions. (2) They can be qualitative questions regarding physics principles. (3) Choosing between alternatives and having a general understanding are much more like real life. (4) Options act like hints. (5) The teachers can ask subtle points with them. (6) Multiple-choice items are next best thing to essay type questions. (7) The teachers can ask for a quick numerical calculation and make them worth a point. (8) More material can be covered. (9) They are good for review.

There are also some criticisms to the multiple-choice tests. According to Rollnick and Mahooana (1999) the disadvantage of multiple-choice tests is that questions do not provide deep enough inside into the students' ideas on the topic and students very often give correct answers for wrong reasons. According to Stiggins (as cited in Çataloğlu, 2002) multiple-choice tests direct the students' attention on information in isolation by testing one element at a time. Therefore, the larger context and structure of relationships between and among the elements get lost. According to Bork (as cited in Marx, 1988) multiple-choice tests should never be used. He expressed five reasons to support his assertion. First, multiple-choice items encourage guessing. Second, the items are not from real life situations. Third, they are not friendly for students. Because, students see them in somewhat a derogatory fashion, connected with the fact that guessing is involved. Fourth, he stated that 'There is no real use for them. For example, we hardly ever use multiple-choice in the computer based quizzes'. And the last, writing good items is too difficult. He had seen A-grade students do B-grade in the multiple-choice exams and vice-versa. He attributed this to careless wording of stems and questions based on weak examples. Sandin (as cited in Marx, 1988) added two more reasons for why multiple-choice tests are not effective: First, students may have extracted the right answer by a fortuitous combination of errors. Second, multiple-choice tests heavily depend on reading comprehension skills. According

to Al-Rubeyya (1996) when researchers used them to identify the students' misconceptions, researchers became worried about memorization of the students to select the correct answer.

As it is seen, multiple-choice tests are easily applicable and their results can be analyzed quickly and easily. The problem is their effectiveness. To overcome this problem, Staver and Gebal; Lavson; Lavson, Adi, and Karplus; Tobin and Capie (as cited in Al-Rubayea, 1996) recommended that students should justify their answers. As a result, researchers extended the multiple-choice tests into several tiers, two or three tiers.

2.3.3 Two-tier Tests

Two-tier tests include, in addition to selecting correct answer among the distracters, multiple reasons or justifications from which the students choose their reason for their response is required in the second tiers. Treagust (as cited in Odom & Barrow, 1995) described the item format of the two-tier multiple choice tests as the first tier consisting of a content question with two, three, or four choices. The second tier consists of four possible reasons for the first part with three of them alternative reasons and one desired reason. The second tier can also include a blank that students can write a reason for the first tier when they can not see their reasons among the alternatives of the second tier (Griffard & Wandersee, 2001).

2.3.3.1 Advantages of the two-tier tests

Tsai and Chou (2002) stated that 'since, two-tier test is in multiple-choice format, it is much easier for teachers to score or interpret students' responses. In this way, even with numerous students, a teacher can efficiently diagnose their alternative conceptions.' According to Zeilik (n.d.) teachers can use these diagnostic tests for formative and summative assessments over semesters. If teachers use them as a formative test, they will understand their students' cognitive states, preconceptions and misconceptions prior to instruction. Therefore, they can take some precautions for misconceptions which can possibly obstruct the lecture.

For example, they can tutor the students in their weak areas individually or assign the students into heterogeneous cooperative learning teams. If teachers use the diagnostic tests for summative assessment, they will see impact of their instruction method positive or negative which can serve feedback for later on instructions. However, it is important to say that results of the diagnostic tests cannot be used for assigning the grades of the students. Because, the main purpose of the tests is to diagnose not to assess achievement of the students.

2.3.3.2 Development process of two-tier tests

Developing reliable and valid conceptual diagnostic tests is a struggling process and requires great efforts (Zeilik, n.d.). The development process of a two-tier test was defined by Treagust in three main phases (as cited in Odom & Barrow, 1995):

Phase 1:

1. The content boundaries were defined with a list of prepositional knowledge statements.
2. Content validity of prepositional knowledge statements was determined.

Phase 2:

3. Students' misconceptions were identified by interviews.
4. Multiple-choice questions with free response reasons were constructed and administered.

Phase 3:

5. Final test questions were constructed based on multiple-choice questions with free response reasons.
6. The final test questions were revised and a pilot study was conducted.
7. Final content and face validity of each test item were determined with the assistance of a specification grid.
8. The final version of the test was administered.

Some two-tier diagnostic tests were developed based on this process in different fields of science education. Most of the development of two-tier diagnostic tests include both interviews and open-ended questionnaires or multiple-choice tests to identify the misconceptions of the students which will be used for distracters of the two-tier test. Including interview method gives a chance to researcher to probe the students' mind deeper and ask the questions more flexibility. On the other hand, including open-ended or multiple-choice tests gives a chance to the researcher to deal with more subjects to generalize the results (Beichner, 1994). In the following part, some studies including development process of two-tier tests are told.

Odom and Barrow (1995) developed and applied a two-tier diagnostic test to identify college students' misconceptions in diffusion and osmosis. They followed a procedure that is similar to the Treagust model. First, they defined the content boundaries of the topic and listed propositional knowledge statements about the topic by using two college biology texts books and a college biology laboratory manual. The content validity of the propositional statements was established by a panel of two science education professors and one biology professor. Second, 20 volunteer introductory college biology students were interviewed. The interview questions were-open ended questions. The interviews were audiotape recorded and were used to develop a list of student misconceptions about diffusion and osmosis concepts. Third, 15-item multiple-choice format test with free response was developed based on the propositional knowledge statements and the findings of the interviews. The first tier of this test was in multiple-choice format with two, three or four choices. In the second tier students were asked to give their reasons for their multiple-choice selection in the first tier. This test was administered 171 non-science major introductory college biology students who had previously been taught diffusion and osmosis concepts. Fourth, two-tier multiple choice test including 12 items was constructed based on multiple-choice questions with free response reasons. Fifth, face validity of the test was checked. Two major questions were addressed while determining the face validity: Does the question assess the content as defined by the validated propositional statements? And is the question at a level of sophistication appropriate for college freshman biology students? If these criteria were not met, the item was dropped. Finally, the test was

applied to 240 students enrolled in a freshman biology laboratory course. In analyzing the results of the test, the researchers estimated discrimination indexes and difficulty levels for each item and they estimated the reliability of the test by using the Spearman-Brown formula.

Tan, Goh, Chia, and Treagust (2002) developed and applied a two-tier multiple-choice diagnostic instrument to assess high school students' understanding of inorganic chemistry. Their methodology was very similar to Odom and Barrow's study (1995) in which they used Treagust model (as cited in Odom & Barrow, 1995). So, it is needless to explain their methodology step by step. Differences of this study from Odom and Barrow's study were a concept map was created in addition to the propositional knowledge statements while defining content boundaries.

Chen et al. (2002) investigated the high school students' misconceptions about image formation by a plane mirror. They developed a two-tier diagnostic test based on Treagust model. There are two differences in this study from the previous study described above. First, an open-ended questionnaire, not a multiple-choice test with free response, was used to identify students' misconceptions which could serve as distracters for the later construction of the multiple choice instrument. Second, interviews were conducted after open-ended questionnaire was administered, not before. In analyzing the results, they estimated the reliability by using Cronbach alpha and they also calculated discrimination index and difficulty level for each item. They gave attention to the misconceptions which existed in at least 10% of the student sample.

Beichner (1994) developed a diagnostic multiple-choice test to identify the misconceptions of the students in kinematics graphs. The construction process of the test was very similar to the Treagust Model (as cited in Odom & Barrow, 1995). The difference was that in defining content boundaries of the study, he wrote specific objectives instead of concept map or propositional statements.

2.3.3.3 Critics about the two-tier tests

Although, diagnostic tests are very helpful for teachers to identify the misconceptions of the students, some researchers criticize them. According to Yarroch (as cited in Griffard & Wandersee, 2001), forced choice instruments like two-tier tests give clues to the students to select correct answers that they would not have had in interviews and open-ended questions.

Griffard and Wandersee (2001) investigated the effectiveness of a two-tier instrument developed by Haslam and Treagust in 1987 about photosynthesis. The test was given to the students and wanted them to think aloud while they were answering the items. They found that, using unnecessarily wording to distract students caused them to make mistakes. It is not certain that whether these mistakes were due to misconceptions that students had or unnecessarily wording of the test. Moreover, these unnecessarily wording can cause create a new misconception in students' mind. They also stated that 'students consider the second tier as a distinct multiple-choice item and finalized their choice on the basis of whether it logically follows from their response to the first tier. Therefore, two-tier test seemed to measure the students' test-taking skills rather than the extant knowledge'. Moreover, the feelings of the students are very important. Students bring these types of tests different amounts of sincerity, anxiety, persistence and meticulousness which can confound the test results. They also criticized the two-tier test about the estimating the proportions of the misconceptions. According to them, two-tier tests overestimate the proportions of the misconceptions because gab in knowledge can not be discriminated by two-tier tests. Therefore a third tier is necessary to be sure that whether a wrong answer for the first two-tiers is a misconception or a mistake due to lack of knowledge.

2.3.4 Three-tier Tests

Three-tier tests are very similar to the two-tier tests. In three-tier tests, an item has one additional tier which asks students confidence about the answer of the former two-tiers (Çataloğlu, 2002). Eryılmaz and Sürmeli (2002) developed a three-tier test to assess the misconceptions of the 9^{th} grade students about heat and

temperature. According to them all misconceptions are errors but not all errors are misconceptions. Some errors may stem from lack of knowledge. If a student explains his/her error as a true with reasons and says his/her confidence, it is acceptable that this student has misconception. In two-tier tests and multiple-choice tests it is not asked to the students for their confidence about their answers. Three-tier tests are required to remove this problem. These types of tests have one more tier in which it is asked to the students their confidence about the first two tiers. In their study, they compared the proportions of the misconceptions that the students had with respect to the tiers of the items. They found the students had misconceptions with an average 46 % for the first tiers of the items, with an average 27 % for the first two tiers of the items and with an average 18 % for all three tiers of the items. From these results the researchers concluded that one tier and two-tier tests overestimate the proportions of the misconceptions. For the one tier tests it is accepted all wrong answers are misconceptions. However, some of the wrong answers may be false negatives which are incorrect answers by mistake in spite of correct reasons in the second tier and some may be due to randomly given answers by chance because related reasons of the incorrect answers were not chosen on the second tiers. Therefore, 19 % (subtracting 27 % from 46 %) indicated incorrect answers by mistake or chance. The researchers also found that two tiers tests also overestimate the proportions of the misconceptions. Because as mentioned above, it is required if a student has a misconception he/she should say his/her confidence. In two-tier tests it is not asked to the students whether they are confident about for their responses. The researchers found that 9 % of the students were not confident for the answers of the first two-tiers even if their answers indicated the misconceptions. They explained that those students gave incorrect answers due to lack of knowledge. To sum up, the researchers concluded that three-tier tests assess the misconceptions of the students more validly than one-tier and two tier tests.

2.4 Misconceptions in Geometric Optic

Although, there have been great number of studies done to investigate the students' misconceptions in mechanics, there have been relatively rare studies done to investigate the students' misconceptions in geometrical optics. Misconception studies in geometrical optics show that students have difficulties in understanding vision and the nature and propagation of light.

Langley, Ronen, and Eylon (1997) investigated pre-instruction students' conceptions and representations of optical systems, light propagation, illumination patterns and visual patterns. Langley et al. found that students did not indicate light emanating from the light source in even single diagram. They showed something existing around the light source, without an explicit connection with it. Light was not shown emanating from the specific points of the light source. Moreover, the path of emanation and propagation of the light was influenced by barriers around the source or by remote optical components. The students rarely indicated directionality in their representation of light. They used variety of graphic objects to represent light: straight lines, dashes, curves and filled-in areas. In the study students also showed little understanding how to see luminous and nonluminous objects. The understanding that there is no sight without light was shared by about 50% of the sample. The students who involved the light in the sight process:

- Showed the light emanating from the object and being received by the eye.
- Saw the object because it was contained within the geometrical sector spanned by the eyes.
- Saw the object because the observer directs sight lines toward it, with light possibly emitted from the eyes.

Fetherstonhaugh and Treagust (1992) investigated the 8-10 grades students' (age 13-15 years) understanding of light and its properties. In their findings students' conceptions were:

- Light travels a different distance depending upon whether it is day or night.
- Light does not travel during the day.
- Light does not travel at all during the night.

As given above students had some conceptions about traveling of the light. In the interviews some students thought that light does not hit anything, light can travel a variable distance. Some of the students thought light does not travel and the distance light travels depends on its energy.

Students also had some misconceptions about sight process:

- People see by looking, not by light being reflected to their eyes.
- People can just see in the dark.
- Cats can see in the dark.

In the interviews students were asked how we see an object, for example a pencil, what light does before we can see and if there was no light, could we see? Students answered these questions in a varied way. Several students said that something leave the eye and strike to the pencil. Moreover, they claimed that it is possible to stare at a person's back and have that person feel the stare. For seeing in the darkness, significant numbers of the students expressed that eyes can get used to seeing in total darkness.

In another study about light, Bendall, Goldberg, and Galili (1993) investigated the prospective elementary teachers' prior knowledge about light and shadow. They interviewed with 30 prospective teachers who were all in their junior or senior year and very few had taken a physics course in high school. Bendall et al. found that about 20% of their subjects tended to explain the shadow phenomenon in terms of a reified shadow (attributing the shadow to the presence of something, rather than to the absence of light). The students also could not explain how would be the shadow when two light sources were used at the same time. Most of the students reasoned that in the region of geometrical overlap there would be either lightness (full illumination) or darkness (shadow). They did not consider semi darkness. In the study, students had a static general illumination conceptualization in which light only exists in space. For example, students could not explain the brightness of a screen. They did not recognize the role of the light in that process (light had to go from the bulb to the screen). Like, for example, in the interview studies a student recognized that light must be present to observe mirror images, but did not recognize any explicit role for light in that process. In the interviews most of the students thought that presence of the light was necessary

to see the nonluminous objects in which they gave to the light a static role. Even if, the students said that for seeing luminous objects light must enter to eyes, they did not drew ray diagrams for this situation. Students also had difficulties in understanding of the idea that light from each point on a source goes out in all directions. They thought of light as emanating in only one direction from each source, like flash light beams. In their ray diagrams, they tended to show only single lines going outward from individual points on the bulb which is the root of many students' difficulties in understanding image formation.

Feher and Rice (1988) investigated the middle school children's conceptions of shadow formation. They interviewed 40 children using a protocol that was developed through more than fifty interviews. The children explained the shadow as the presence of something that is pushed, moved or thrown to the screen i.e. as a reified shadow. They gave a material characteristic to the shadow. In their diagrams, there were movements of dark areas or shadows between object and screen. Most of the children gave a role to the light in the shadow formation as initiating the shadow by hitting to the object and pushing it to the screen. Some of these students thought that light reflects off the object and due to this reflection shadow is formed and light carries it to the screen. Moreover, in the study children were asked "Is there a shadow in the dark, where there is no light?" The students thought shadow exists in the dark but they cannot see it. They explained this situation in two different ways. One is that either the object produces the shadow hiding within the object and can not be produced or cast until the light hits the object and provokes it to do so. The other one is that their visual mechanisms are not operative in the darkness. The researchers also found most of the children had an idea that shadow belongs only to the non-luminous object and it always looks like the object. The students did not consider the role of the light source in the shadow formation.

Misconceptions of the students about nature and propagation of light and shadows point out that students have difficulties in explaining and interpretation of image formation by mirrors and lenses.

Langley et al. (1997) investigated pre-instruction students' conceptions about plane mirror images. They found that the students thought that creating images was an inherent attribute of the silvery mirror material, rather than the product of the reflection process. The students did not show image observation without including a representation for image formation in their diagrams. In some situations the issues were treated separately, with the image projected holistically onto or into mirror and the observer directing sight lines at the image.

Goldberg and McDermott (1986) investigated the students' difficulties in understanding image formation by a plane mirror by using individual demonstration interviews. They found that one-third of the students believed that the image of an object in a plane mirror lies on the surface. In the study, students had difficulties in understanding the position of the image depends only on the position of the object relative to the mirror and is independent of the observer's position. They had a misconception that an image in a plane mirror lies behind the mirror along the line of sight between a viewer and the object. Moreover, some of the students invoked a parallax argument for their explanation in which they meant to their experience of watching an object shift its position as they viewed it from different perspectives. They had mistaken that the absolute position of the object remains the same as an observer moves. Only change is its apparent position relative to the background. Finally, they found that the students believed they would see more of themselves in the plane mirror by moving back. In fact, in a plane mirror anyone can see more of himself/herself with a minimum amount of eye movement not with moving back.

Bendall et al. (1993) investigated the prospective elementary teacher's ideas about mirror images. They interviewed with prospective teachers and asked open-ended questions to learn how they think about a mirror works. For creation of image, only about half of the students thought that light was necessary for image creation but they were not able to explain the role of light in that process. In their diagrams, the lines between the light source and its image in the mirror suggest a holistic way of thinking. They just implied that the image somehow went to the mirror. Moreover, most of the students thought that nothing happened between their eyes and mirror for seeing image of any object in a plane mirror. They said that they saw just by looking. Although, most of the students thought light is

necessary for them to see the image, they seemed to be thinking only that back round light was necessary for their eyes to function, and not that light from the mirror had to enter their eyes to see the image of any object in the mirror. In the interviews, an interesting interpretation of how a mirror works was interpretation of reflection term differently from a scientific view. When the students said the mirror reflects the light, they did not mean something actually bounding of the mirror. Instead, they meant that the mirror makes a reproduction or duplicates. According to some of the students, the ability of the mirror to make a reproduction of the image was due to reflective substance of the mirror. Almost half of the students thought that a mirror could make a reproduction even if there was no light in the medium. For example, in the interviews, one student said: "it will be a picture of the bulb, but it will be covered with dark."

Chen et al. (2002) developed a two-tier diagnostic test to identify the misconceptions of high school students about image formation by a plane mirror. They found 9 misconceptions in the study: (1) Students thought that to see an image of any object, it should be inside the front region straight ahead of the mirror. (2) Students thought that image of an object depends on the observer and they believed that image of any object is located right ahead of the observer. (3) Students claimed that image of an object is located on the surface of the mirror, not equal distance behind the mirror as the object is in front. (4) Students thought that if a person wants to see him or herself, he or she should illuminate the mirror rather than himself or herself. (5) Students believed that image of an object is in the line sight of the observer. They could not realize image of an object does not depend on the observer. (6) Students confused the image with the shadow. They expressed image of an object on the mirror was its shadow. (7) Students claimed that image of a black object on the mirror was due to black rays bouncing off the black object. They could not realize that image of the black object was due to the reflection of surroundings around the object and there was no light reflected from the mirror due to the black object. (8) Students confused image formation with shadow formation. They believed that in the presence on an illuminant the position and size of the image of an illuminated object depends on the illuminant. For example, they thought image size of an object gets longer when the illuminant is gotten closer to the object. (9) Finally, students thought position and size of the image of any object depends on the location of the observer. They thought when the observer retreats size and position of the observer is changed.

Gee (1988) investigated a different aspect of the image in a plane mirror. According to researcher, students believed that plane mirrors rotate the right to the left and vice versa. School texts books mention this topic lateral inversion when discussing the nature of the image in a plane mirror. Some texts books state that lateral inversion occurs but they do not explain how it occurs. The only thing understood is left and right are reversed. In reality, plane mirrors causes no lateral inversion. The only thing occurs in a plane mirror is object points near to mirror have images near to mirror and object points further to mirror have further images. This is longnitual inversion in fact which reality of plane mirror is.

2.5 Summary of the Literature Review

Students come to classes with existing knowledge that they construct with their experiences or learning (Fetherstonhaugh & Treagust, 1992). Some of these students' prior knowledge can be in conflict with the scientific view and called as misconceptions. It is important to say that a misconception is not a mistake and it does not stem from lack of knowledge. If a student has a misconception, his or her conception is wrong scientifically, but it is true for him or her and works properly and helps to understand the world (Eryılmaz & Sürmeli, 2002).

Research studies show that misconceptions resist changing. Hewson (as cited in Al-Rubayea, 1996) said that misconceptions do not change because they make better sense of the world than anything else. Moreover, according to Nussbaum and Novick (as cited in Al-Rubayea, 1996) they interfere with learning process and inhibit students' learning.

Misconceptions have become a part of science education. Researchers have done lots of studies to investigate the students' misconceptions. Teachers should take care of them seriously to teach their students in a reliable way. There were many methods used and developed to investigate the misconceptions of the students; interviews, word associations, open-ended questions, multiple-choice tests, multiple-choice tests with explanation, two-tier tests and three –tier tests.

Even if the interviews provide more information by depth of probing and flexibility, it is necessary to study with the larger samples to generalize the results (Beichner, 1994). Moreover, conducting interviews require a large amount of time

(Chen et al., 2002). On the other hand, even if the open-ended tests overcome generalizibilty problem, information obtained from open-ended tests are not as deep as interviews' (Beichner, 1994).

For the multiple-choice tests, although they are easily applicable to a large number of the samples and can be scored easily and objectively (Al-Rubayea, 1996), one of the main disadvantages of multiple-choice tests is that questions do not provide deep enough inside into the students' ideas on the topic and students very often give correct answers for wrong reasons (Rollnick & Mahooana, 1999). According to Bork (as cited in Marx, 1988) multiple-choice tests should never be used. He expressed that multiple-choice items encourage guessing.

As it is understood, multiple-choice tests are easily applicable and their results can be analyzed quickly and easily, the problem is their effectiveness. To overcome this problem, Staver and Gebal; Lavson; Lavson, Adi, and Karplus; Tobin and Capie (as cited in Al-Rubayea, 1996) recommended that students should justify their answers. In two tier tests, the first tiers consist of a content question with two, three, or four choices. The second tiers consist of four possible reasons for the first part with three of them alternative reasons and one desired reason. It is required students to justify their responses in the first tier by the reasons in the second tier Treagust (as cited in Odom & Barrow, 1995). However, Griffard and Wandersee (2001) investigated the effectiveness of a two-tier instrument developed by Haslam and Treagust in 1987 and criticized two-tier tests. One of the main critics is that two-tier tests overestimate the proportions of the misconceptions because gab in knowledge can not be discriminated by two-tier tests. Therefore, an additional tier is required to discriminate a mistake whether it stems from a misconception or lack of knowledge.

Eryılmaz and Sürmeli (2002) stated that misconceptions do not stem from lack of knowledge. In three-tier tests, in the third tier it is asked to the students whether they are confident with their answers for the first two tiers. Asking the students' confidence in the third tier provides information whether a wrong answer to the first to tiers due to misconception or lack of knowledge. It is expected that if a student explains his or her false as a true with reasons and says his confidence, it is acceptable that this student has misconceptions.

Finally, the misconceptions in geometric optic found from the literature review can be listed as the following:

1. For seeing in the darkness, students express that eyes can get used to seeing in total darkness (Fetherstonhaugh & Treagust, 1992).
2. Students think that light travels a different distance depending upon whether it is day or night (Fetherstonhaugh & Treagust, 1992).
3. Students think of light as emanating in only one direction from each source, like flash light beams (Bendall et al., 1993).
4. Students have an idea that shadow belongs only to the non-luminous object and it always looks like the object (Feher & Rice, 1988).
5. Most of the students reason that in the region of geometrical overlap there would be either lightness (full illumination) or darkness (shadow). They do not consider semi darkness. Students treat the shadow as the presence of something i.e. they give material characteristics to the shadow, rather than absence of the light (Bendall et al., 1993).
6. Students think that to see an image of any object, it should be inside the front region straight ahead of the mirror (Chen et al., 2002)
7. Students have a misconception that an image in a plane mirror lies behind the mirror along the line of sight between a viewer and the object (Goldberg & McDermott, 1986).
8. Students think that an observer see the object because the observer directs sight lines toward it, with light possibly emitted from the eyes (Langley et al., 1997).
9. Students confuse image formation with shadow formation. They believe that in the presence on an illuminant the position and size of the image of an illuminated object depends on the illuminant. For example, they think image size of an object gets longer when the illuminant is gotten closer to the object (Chen et al., 2002).

10. Students think that the position and size of the image of any object depend on the location of the observer. They have an idea that when the observer retreats size and position of the observer is changed (Chen et al., 2002).
11. Students claim that image of a black object on the mirror was due to black rays bouncing off the black object (Chen et al., 2002).
12. Students think that creating images is an inherent attribute of the silvery mirror material, rather than the product of the reflection process. The students say that "The mirror reflects and so the person sees" (Langley et al., 1997)
13. Students have a misconception that while watching an object its position also shifts as they view it from different perspectives. They mistake that the absolute position of the object remains the same as an observer moves. Only change is its apparent position relative to the background (Goldberg & McDermott, 1986).
14. Some of the students believes that image of any object is located right ahead of the observer (Chen et al., 2002).
15. Students think that if a person wants to see him or herself in a dark room, he or she should illuminate the mirror rather than himself or herself (Chen et al., 2002).

CHAPTER 3

METHODOLOGY

The focus of this chapter is the methodology which was used to conduct this study. It contains the research design, description of the subjects, variables of the study, description of instruments used in the study, procedure by which the study was conducted and description of the statistical techniques used in analyzing the results.

3.1 Research Design

This study is a cross-sectional survey method study. In the developing process of the TTGOMT, the students were interviewed and administered a free-response test to collect data. Based on these data, the three-tier test was developed and administered to the students to assess the misconceptions of the students about geometric optic. The data from the three-tier test results were analyzed.

3.2 Population and Sample

The target population of this study was all 11^{th} grade high school students in Istanbul, in Turkey. However, it is appropriate to define an accessible population, since it is not feasible to study with this target population. So, the accessible population was 11^{th} grade high school students in Bayrampaşa, in Istanbul. Since the study includes development process of a three-tier test and its application, three different groups of subjects were used; interview group, open-ended test group, and three-tier test group.

3.2.1 Interview Group

First group was 15 11th grade students (8 male and 7 female) from three types of high school in Bayrampaşa district to conduct the interviews. Table 3.1 shows the school type and number of students chosen. The age of the students was between 16 and 19. Two-above-average male and female, two average male and female and one-below-average students who had been taught the geometrical optic in their curriculum were selected from each type of schools by considering their physics teachers' recommendations. School types were Anatolian High Schools, Government High Schools and Foreign Language High Schools. They were selected by convenience sampling. Table 3.1 shows the list of interviewees based on the gender and school types.

Table 3.1 Students Having Been Interviewed

School Type	Male	Female	Total
Government High School	2	3	5
Foreign Language Teaching High School	3	2	5
Anatolian High School	3	2	5
Total	8	7	15

3.2.2 Open-ended Group

The second group was 114 11th grade students from three classes from each school type. The classes were selected by convenience sampling. These students were again from the same school type as like the students in the interview group; 39 from Foreign Language High School, 36 from Government High School and 39 from Anatolian High School. Since it was difficult to adjust the sample by equating the male-female ratio, one class from each type of schools satisfying this criteria was selected. Table 3.2 shows the list of the students' genders and school type who have taken the open ended test.

Table 3.2 Students Having Taken the Open-Ended Test

School Type	Male	Female	Total
Government High School	22	14	36
Foreign Language Teaching High School	20	19	39
Anatolian High School	16	23	39
Total	58	56	114

3.2.3 Three-tier Test Group

The third group who was administered the final version of the three-tier test developed by the researcher was 141 students; 86 students were male and 55 students were female. It was selected by convenience sampling. All the students were 11^{th} grade students from Government High Schools and had been taught geometric optic. It is recommended that for an item analysis of a test which is widely used such as the Graduate Record examination should be based on a sizable and representative sample perhaps of thousands of subjects. However, it can be smaller for doctoral students who develop an instrument for a dissertation research. 200 subjects are the minimum desired number for this type of studies. Even if 141 is smaller than 200, the sample size also can be calculated with rule-of-thumb. This rule requires 5 to 10 times as many subjects as the items of the test. In the TTGOMT, if the third tiers are not accepted as an item, there were 32 items (first and second tiers). 141 subjects is slightly less than 5 times of the items. Table 3.3 shows the students' genders and school type who had taken the TTGOMT (Schwab, 2005)

Table 3.3 Students Having Taken the TTGOMT

School Type	Male	Female	Total
Government High Schools	86	55	141

3.3 Variables

In the study, seven variables were formed for each of student using answer key of the TTGOMT (see Appendix D), choice selections indicating misconceptions (see Appendix E), and the raw data (see Appendix F), and The Excel program was used to enter the raw data. The raw data was changed to (dummy-coded) nominal level. In analyzing the results 0 was accepted as incorrect answer or non-existing misconception. 1 was accepted as correct answer or existing misconception. The variables were obtained by using logical functions (IF, AND, OR functions) of the Excel program. The variables are as the following:

Score-1: Each student's answer was coded as 0 (wrong answer) and 1 (correct answer) for the first tiers of the each item on the TTGOMT. The proportions of the correct answers to the first tiers for each item and total correct answers of the students for the first tiers of test was calculated.

Score-2: Each student's answers was coded as 0 (wrong answer) and 1 (correct answer) for the first-two tiers of the each item on the TTGOMT. The proportions of the correct answers to the first two tiers for each item and total correct answers of the students for the first two tiers of test were calculated.

Score-3: Each student's answers was coded as 0 (wrong answer) and 1 (correct answer) for the all three tiers of the each item on the TTGOMT. In the third tiers the confidences of the students were asked for the answers of the first two tiers. It is important to say that even if a student's answers for the first two tiers

were correct, it was not accepted unless the student clarified his/her confidence in the third tier. If the student said “Yes, I am sure” it was accepted true and if the student said “No, I am not sure” it was accepted false. The proportions of the correct answers to the all three tiers for each item and total correct answers of the students for all the three tiers were calculated.

Misconception-1: This variable was obtained by using the choice selections indicating a misconception. A choice selection indicating a misconception for the first tiers accepted as 1 and other choices accepted as 0. The proportions of the misconceptions according to first tiers were estimated and also the number of the misconceptions for each student for the first tiers was calculated.

Misconception-2: This variable was estimated as similar as misconception-1. A choice selection indicating a misconception for the first two tiers was accepted as 1 and other choices were accepted as 0. The proportions of the misconceptions according to first two tiers were estimated and also the number of the misconceptions for each student for the first two tiers was calculated.

Misconception-3: They were obtained by coding the choice selections indicating a misconception for all three tiers as 1 and others as 0. It is important to say that even if a student choice selection for the first two-tiers indicated a misconception it was not accepted as a misconception Unless the student clarified his/her confidence in the third tier. The proportions of the misconceptions according to all three tiers were estimated and the number of the misconceptions for each student for all the three tiers was calculated.

Confidence levels: They were obtained by using the student answers for only to the third tiers. If the students showed their confidence for the answers of the first two tiers in the third tier it is accepted as 1, the rest were accepted as 0.

3.4 Instruments

In this study, three instruments were used. During the construction process of the TTGOMT to identify the misconceptions of the students in geometrical optic a semi-structured interview protocol was prepared based on the misconceptions found in the literature. Then, an open-ended test was created based on the interview results and misconceptions found in the literature. Finally, open-ended test results

were analyzed and three-tier misconception test was created. Since, developments of these three instruments were part of the study, they were told in more details in the procedure part.

3.5 Procedure

The study started with a detailed review of the literature. Then a keyword list was determined. After determining the keyword list, the researcher searched Dissertation Abstracts International, Social Science Citation Index (SSCI), Educational Resources Information Center (ERIC), Ebscohost, Science Direct and INTERNET (e.g., Google). The studies made in Turkey also were searched from YÖK, Hacettepe Eğitim Dergisi, Eğitim ve Bilim Dergisi and, Çağdaş Eğitim Dergisi. The photocopies of the available documents were obtained from METU Library, Hacettepe University Library, Tubitak-Ulakbim Library and, INTERNET. All the related documents were read.

The procedure followed in this study was similar to the Treagust model (as cited in Odom & Barrow, 1995). The difference was in defining the content boundaries of the study. The content boundaries of the study were designated by the misconceptions found in the literature. The researcher tried to include the topics which were more studied in geometrical optic in the literature. There were three main parts in the procedure; interviews, open-ended test and three-tier misconception test.

3.5.1 Interviews

After finding the misconceptions from the literature, a semi-structured interview-protocol (see Appendix A) was prepared on the basis of the literature results. In the literature review, there were so many studies found conducted to investigate the students' misconceptions in geometrical optics. In these studies different types of methods were used to collect data; interviews, open-ended questions, multiple-choice tests and two-tier tests. The researcher extracted the questions of the interview questionnaire from these studies. Some of the questions were taken without making any changes and some of the questions were modified.

There were 16 open-ended questions in the questionnaire. Some questions required students to draw a diagram that describes and explains a phenomenon. These types of questions included some simple sketches and students were asked to complete the sketches in a manner that explains the physical phenomenon. It was said to the students that their drawings were not expected in artistic standards and their simple drawings would be enough. Moreover, for interview questions 3, 4, 5, 8 and, 10 simple demonstrations were used to make the questions more understandable. In some questions verbal presentation used only.

By means of this protocol, students' misconceptions were investigated in a deeper way. There were 16 questions in the protocol and 15 students were interviewed one to one. In the interviews, students were also asked additional questions to investigate the reasons for their answers and what lies behind their answers. The researcher recorded interviews with an audio-type recorder and each interview lasted approximately 40-50 minutes. Collecting interview data and analyzing it took 3 weeks.

3.5.2 Open-ended Test

After the interviews, the researcher developed an open ended test (see Appendix B) to get greater generalizibility and create the distracters of the three-tier test. It was developed based on the interview results and misconceptions found in the literature. Almost all the questions were selected from the interview-protocol. However, the third question in the open-ended test was used instead of interview questions 3, 4 and 5.

This replacement was done because students had some difficulties to understand these three questions. So, there were 13 questions in the open-ended test. The test was given to a physics teacher from Tuna High School and an instructor from the department of Secondary School Science and Mathematics Education at METU with the aim of establishing the content validity. And also, the grammatical structure of the test was checked by a Turkish teacher. It was administered to selected 114 11^{th} grade students from three types of schools. The required permissions were taken from the school directors. The researcher applied the test in the physics lessons with the surveillance of the physics teachers. Students were informed that results of the study would not affect any of their grades in their school.

Each application takes 30-35 minutes. In the analyzing process, the researcher categorized the results coming from the students for each item and made a frequency table for it. Application of the test and analyzing the results took 6 weeks (see Table 4.1).

3.5.3 Three-tier Geometric Optic Misconception Test

After analyzing the results of the open-ended test, the researcher developed the TTGOMT (see Appendix C) especially based on the open-ended test results. Interview results and misconceptions found in the literature were also considered. There were 16 items in the test and each item had three tiers. The items were as similar to open-ended test items. 4^{th}, 9^{th}, 10^{th} items were added the test. 4^{th} item was a different version of the 3^{rd} item and both items asked clearness of the shadow. 5^{th} item of the interview-protocol was very similar to it. The 9^{th} item was a different version of the 8^{th} item and both items asked what would happen to the image of any object if an illuminant's position was changed. The researcher constructed the distracters of the test by considering the frequency table which had been done for the open-ended test results. The most frequent categories were chosen as the distracters. Also, some of the distracters were written according to interview results and misconceptions found in the literature. The test was given to a physics teacher from Merkez High school and an instructor from the department of Secondary School Science and Mathematics Education at METU with the aim of establishing the content validity. Grammatical rules and language of the test was checked by a Turkish Teacher. Before administration of the test, required permissions were taken from the school directors. The test was administered to selected 141 11^{th} grade students who had been taught geometric optic in the physics lessons. The students were from Government High Schools and 86 students were male and 55 students were female. The schools and classes were selected by convenience sampling. The test was administered in the classes by the surveillance of the physics teachers. Each application for one class took approximately 30-35 minutes.

3.6 Analysis of Data

Since this study was a development of a three-tier misconception test, there were three times data collected from the students; interviews, open-ended test, and three-tier misconception test. Interviews' and open-ended tests' results were qualitative data and they were given in the results part in chapter 4.

One of the main purposes of the study was assessing the misconceptions of the students by the developed three-tier misconception test. The data was entered to an Excel file in which columns show the items and rows show the students responding the three-tier test. The data was analyzed statistically by using the Excel program. Then, the researcher transferred to the data from an Excel file to a Statistical Package For The Social Sciences Program (SPSS). Additional required statistical analyzes were done by using this program. Data entry and analyzing the results took 3 weeks.

Reliability, item difficulty, item discrimination, factor analysis for correct answers for the first two tiers and factor analysis for the misconceptions, false positives and false negatives were calculated.

3.6.1 Validity

Validity refers to the appropriateness, meaningfulness, and usefulness of the specific inferences researchers make based on the test results (Fraenkel & Wallen, 1996, p. 153). Three major types of validation studies are:

1) Content validity- Content validity refers to the content and format of the test. The purpose of the content validation is to assess whether the items adequately represent a performance domain or construct of specific interest i.e. how well the exam portrays the domain of concepts it is intended to represent.
2) Criterion validity- Criterion validity refers to the relationship between scores obtained using the instrument and scores obtained using one or more other instruments or measures i.e. it is a predictive power of a measure.

3) Construct validity- Construct validity is the degree to which an exam measures an intangible quantity such as depression, happiness, leadership or mental retardation.

Validity of the TTGOMT was established by using two quantitative techniques. First, correlation between students' scores on the first two tiers and confidence levels on the third tiers were investigated to establish construct validity. Because it is expected on a properly working test that students with higher scores would be more confident about the correctness of their answers if they properly understand what they read on a test (Çataloğlu, 2002). The correlation was estimated by using SPSS program.

Second, factor analysis method was used to establish validity. When several items are administered to the examinees, one aspect of validation may involve determining whether there are one or more clusters of items on which examinees display similar performance. Factor analysis was conducted by using SPSS program. Before starting the factor analysis, it is important to meet some requirements to conduct it. If these requirements are not met, factor analysis is not appropriate. According to Schwab (2002), these requirements are:

- The variables included must be metric level or dichotomous (dummy-coded) nominal level.
- The sample size must be greater than 50 (preferably 100).
- The ratio of cases to variables must be 5 to 1 or larger.
- The correlation matrix for the variables must contain 2 or more correlations of 0.30 or greater.
- Variables with measures of sampling adequacy less than 0.50 must be removed.
- The overall measure of sampling adequacy must be 0.50 or higher.
- The Bartlett test of sphericity must be statistically significant.

According to Schwab (2002) after satisfying the requirements, variables and components should satisfy the following requirements:

- The derived components explain 50% or more of the variance in each of the variables, i.e. have a *communality* greater than 0.50.

- None of the variables have loadings, or correlations, of 0.40 or higher for more than one component, i.e. do not have complex structure.
- None of the components has only one variable in it.

Third, probabilities of false positives and false negatives were estimated because they were expressed by Hestenes and Halloun (1995) to be related to the content validity.

3.6.2 Reliability

Reliability is the consistency of the scores obtained. A test is considered meaningful if it produces consistent or reliable results. The reliability of the test was calculated by calculating coefficient alpha which is a measure of internal consistency of an exam. This coefficient (α) is a general form of Kuder-Richardson reliability coefficient (Fraenkel & Wallen, 1996, p. 160). Coefficient alpha can not be determined for all types of exams. For example, it can not calculate the reliability of the speed tests. A speed test in which people are expected to get every item they encounter correct, but, because of time limitation most people will not finish the test. However, coefficient alpha can determine the reliability of power tests. A power test is an exam in which all people are intended to finish, but, because of difficulty of the items many people will get a number of items incorrect (Marx, 1988).

There are many factors that influence the reliability; speed of the test, test length, item difficulty, the number of the options offered in an item, subjectivity on the scoring and group homogeneity (Marx, 1988).

3.6.3 Item Difficulty

Item difficulty was calculated for each item. Item difficulty, p, is essentially average score for a particular exam question. It shows how much ratio of the students answers the item correctly. It ranges from 0.00 to 1.00. A high item difficulty, for example above 0.50, shows a majority of the students answered the item correctly i.e. the higher the value of the item difficulty, the easier the test

question. According to Gronlund and Liinn (1990), for a norm-referenced test, it is very important to get rid of too easy or too difficult items for spreading scores, thus increasing the reliability. However, for a criterion-referenced test, difficulty is not as important as for a norm-referenced test. The main purpose of a criterion-referenced test is to assess students' performance on a content domain, and so, difficulty level of an item depends on the difficulty of each specific objective within the defined content domain. Therefore, any attempt to arrange difficulty levels on a criterion-referenced test is behind the importance of the specification table.

3.6.4 Item Discrimination Index

Item discrimination index, *D*, shows how a test item discriminates between high scorers and low scorers. If a test has items with high discrimination indexes it shows that high scorers on the exam tend to answer the items correctly whereas low scorers tend to answer the items incorrectly. It ranges from $-1 \leq D \leq 1$. If a test scores are normally distributed discrimination index can be obtained by comparing the highest scoring 27 % versus the lowest scoring 27 % of the examinees Gregory (as cited in Marx, 1988)

According to Gregory, interpretations of *D* values are as the followings;

- If $D \geq 0.40$, the item is functioning quite satisfactorily.
- If $0.30 \leq D \leq 39$, the item requires little or no revision.
- If $0.20 \leq D \leq 0.29$, the item is marginal and needs revision.
- If $D \leq 0.19$, the item should be eliminated or completely revised.

3.6.5 Descriptive Statistics

The following is a brief overview of commonly used statistical terms to describe properties of the exam scores.

- Mode- The mode is the most frequent score in a distribution.
- Median- The median is the point below which 50 percent of scores fall.

- Mean- The mean is the arithmetic average of the scores in a distribution.
- Standard Deviation- The standard deviation is the average of the differences between the scores and the mean. It shows how the scores are spread throughout the distribution.
- Skewness- The skew of a distribution indicates how much a distribution "leans" toward low scores or high scores, relative to the mean. A positive skew means there are more scores at the low end, while a negative skew means there are more scores at the high end. The skew can have values from - $\sqrt{t}$ to $\sqrt{t}$, where t is the number of the test items.
- Kurtosis- The kurtosis measures how much the distribution is peaked or flattened as compared to the normal distribution. A positive kurtosis corresponds to a peaked distribution, while a negative kurtosis corresponds to a flattened distribution. The kurtosis can have values from –t to t, where t is the number of the test items.

CHAPTER 4

RESULTS

In this chapter results of the study were explained in three parts. First, interview results are explained. In the second part, the results of the open-ended tests are presented in a table. In the third part, the statistical analyses for the results of the TTGOMT are presented.

4.1 Interview Results

The investigator prepared a questionnaire on the basis of the literature results. In literature review, there were so many studies found conducted to investigate the students' misconceptions in geometrical optics. In these studies different types of methods were used to collect data; interviews, open-ended questions, multiple-choice tests and two-tier tests. The investigator extracted the questions of the interview questionnaire from these studies. Some of the questions were taken without making any changes and some of the questions were modified. There were 16 open-ended questions in the questionnaire. Some questions required students to draw a diagram that describes and explains a phenomenon. These types of questions included some simple sketches and students were asked to complete the sketches in a manner that explains the physical phenomenon. It was said to the students that their drawings were not expected in artistic standards and their simple drawings would be enough. Moreover, these types of questions and also the other types of questions were supported by simple demonstrations. In some questions verbal presentation used only.

Question 1 was presented verbally and asked the following: In a room perfectly sealed to external light there are some flowers in a vase. When a candle is lit in the room, one can see that the vase is white and that there is a red flower, a yellow flower, a purple flower, a pink flower and some green leaves. What will we see after the candle is extinguished? 8 students explained that light is necessary to see the objects. If there is no light, we can not see anything. Their colors are not

important. The important thing is light. If light is present, it hits to the objects and reflects from them to our eyes and we can see the objects. 2 students said they would see the white vase only. Because, light colored objects can radiate the light by themselves. This is their inner features. 4 students said they would see just the shapes of the objects but they could not perceive the colors of the objects. They explained this situation like that since the light was not in the medium, it could not come to their eyes so they could not realize the colors of the objects. One of these students said, the eyes would get used to darkness and we would see the objects and we would see the light colored objects better than dark colored objects. One student said that she could see the vase and also she could see the shapes of flowers but not their colors. Because, before the candle was extinguished the white vase absorbed all the lights on it. The others were absorbed less light because they were selector compared to the white colored objects. One student, interestingly, said that she could not see anything. Because, when the candle was extinguished, black light comes to the vase and reflects from it. So, since black light comes to our eyes we can not see the objects.

Question 2 asked the students whether the light travels a different distance depending upon whether it is day or night. 9 students said that the light travels equal distances on a day and at a night. It has a constant velocity in the atmosphere so it travels equal distances. If the light enters in a different medium with a different index so it will travel different distance. One student said that light seems to travel faster at night. Because, the light is clearer at night and it is less clear in the sun shine. Therefore, the light seems to travel faster in the darkness than in a sunny day. 2 students thought that light travels faster in the dark. Because, in the day light there can be some light in the medium to block the light and slow down the light. However, in the darkness there is no light to block our light and therefore it goes much distance. One student said that it travels a different distance. Because, we see better and far distance in daylight but we see worse and less distance at night. One student said it travels faster in the daylight but he could not explain the reason. One student said that he does not know the answer.

In Question 3, the students were asked to predict what they would see on the screen if a card with a small hole was placed on the middle of the light bulb and question 4 is the next question of the third question, the students were asked to predict what would happen when the screen was moved farther and farther away from the light bulb. One student explained these both questions correctly. 9 students said that illuminated region would get smaller and if the screen was moved from light bulb illuminated region would get bigger according to similarity principle valid for the triangles. 3 students explained that the screen would be illuminated completely and two of them said that illuminated region get bigger according to the similarity principle. One of the student from these students said that the screen, again, would be illuminated completely, nothing would be changed. However, this student said nothing about the intensity of the illumination. One student said that illumination region would get smaller and when the screen was moved away, the intensity of the light decreased so it would be illuminated less but the region of the illuminated part would get bigger. One of the students explained the situation similarly like that the previous student but he predicted the shape of the illuminated region on the screen as a rectangular shape.

Question 5 asked to the students why the shadow of the pencil diffused when the pencil was removed from the screen and became clearer when the pencil was drawn near to the screen. 5 students explained the situation in a correct scientific way. 5 students could not explain the situation. One student said that when the pencil was near the bulb it was illuminated too much therefore the shadow of the pencil was not formed clearly. When the pencil was drawn near to the screen, since the light became far away from the pencil, we can see the shadow clearer. One student said that as the pencil was drawn near to the bulb, the angle of the emerging rays from the top and bottom increased and the shadow got bigger. So it lost its sharpness. Moreover, one student said that since the shadow got bigger, the probability of the light from other sources in the medium increased so it lost its sharpness.

Question 6 wanted the students to predict the shape of a small bead put in front of a cross shape light source. Only two students predicted the shadow shape of the bead as cross shape. 7 students predicted the shadow of the bead as a circular shape. Most of them said that the shape of the light source is not important; the

important thing is the shape of the object put in front of the light source. 3 students predicted the shape of the bead as circular like seven students did. But, they said that there would be a cross illuminated area on the screen and the circular shape of the bead would be in the centre of the cross illuminated area. One student interestingly predicted 3 circular shapes on the screen and attributed this to the shape of the light source. He explained that the light source had three parts one was in the middle and vertical and the other two were horizontal near the right and left side of the vertical part. Since the light source had three parts there would be three circular shadow shapes on the screen. One student predicted the shape as a daisy shape. One student predicted the shadow as a mix shape of cross and circular shape.

In Question 7 it was said to the students that there would be a cross shape shadow on the screen and wanted them to explain why there would be a cross shape. Only one student explained the situation scientifically correct. Three students said that it can not be cross shape. Because, the shape of the shadow has to be similar to the shape of the object. 4 students said that they do not know and insisted that it can not be a circular shape. One student said, it would be a mix shape of circular and cross shapes. It can not be a cross shape only. Two students decided that there could be a cross shape after drawing some rays on the sketch. The other students could not explain the situation.

In Question 8 there were two light sources side by side and a small card and a screen were mounted upright to the these sources respectively in the sketch. Students were wanted to predict the shape of the shadow when the both sources were turned on. In question 9 the correct shape of the shadow was showed to them and wanted them to explain the situation. 10 students predicted that there would be a total darkness and semi-darkness on the right and left of the total darkness and explained the situation scientifically correct. Three of the ten students predicted the shape of the shadow correct but explained the semi-shadows in the wrong way. They said that these were due to mixture of illumination and darkness. They confused the situation with harmony of the colors. One of the student among these three students said that the shadow inhibited the full illumination. 3 students predicted that the shadows due to each light source would intersect and there would be a total darkness in the intersection area and the other parts would be illuminated.

Because, these parts took light from the one of the light sources even if the other one was blocked. One student predicted that there would be a full shadow on the screen due to connection of the both shadows.

In Question 10, the student was seated in a position that is no longer directly in front of a covered plane mirror but beyond the right edge. The rod was also placed beyond the right edge so that the positions of the rod and student lied along a line that intersected the covered mirror. The students were asked whether they would see the image of the rod in the mirror if the mirror was uncovered and also the same question was asked for the investigator. 5 students answered the question correctly for both observers; for himself or herself and for the observer. Two students said that if the angle was proper the image would be created on the mirror and both observers would see the image. These students drew different images of the rod in different places for both observers. One student said that both observers could not see the image. Because, the rod was not inside the front region straight ahead of the mirror in order for its images to be seen. One student said both observers would see the image. Because, the rays from the rod would reflect to the both observers. So, they would see the image in the mirror. Two students said that they would see the image. Because, the light would come to their eyes and reflect from their eyes to the object then would go to the mirror and create the image so they would see it. The investigator would not see. Because, the light emerging from the observer's eye would not go to the mirror. So, the observer could not see the image. According to them, the image was created in the sight line of the observer. Three students said that they would see the image and the observer would not see it. Because, the object was in their sight region whereas it was not in the sight region of the investigator.

In Question 11, in a room, a lamp was the only illuminant inside the room. An observer looked to the mirror and could see an image of the pencil in the mirror placed in front of the plane mirror. The students were wanted to predict what happened to the image of the pencil if the lamb was raised a bit higher. 5 students said that there would be nothing to the image which is a scientifically correct answer. 4 students mistook images for shadows and said that it would get smaller and slide down to the mirror. One student said that the light would come to the eye and reflect to the mirror and the person could see the image. When the light was

raised the image would slide up to the mirror. 3 students said that, since the angle of the incident ray changed, the image would be located in a different position. In here, the angle of the incident ray slide down, so the image would slide down. One student drew rays and concluded that the image would slide to the left.

In Question 12, students were wanted to express image formation of white and black balls in a plane mirror. 4 students expressed image creation process correctly for each ball. 7 students said that the light came to the ball from the sun and reflected from it to the mirror and again reflected from mirror to the eye so the person could see the ball. It was the same thing for the black ball. One student attributed the situation to the characteristic structure of the mirror. This structure was as similar to eye's structure. The image of the object was created in the mirror. So, the mirror created the images for each ball. Two students said that since both balls were in the sight region, the observer could see each ball. The color of the object was not important for seeing them. One student said that, the light from the eyes went to the ball and then to the mirror and the image was created in the mirror. It was the same thing for the black ball.

In Question 13, students were asked whether they would see an image of a light bulb when all the lights were turned off and the light bulb was also turned off and the light from outside could not get into the room. 9 students said that they could not see the image. They explained that since there was no light, the image could not be created in the mirror. Two students said that our eyes got used to darkness and we could see the objects. We could not see them exactly and there would not be a clear image in the mirror, but we could realize their shapes. One student said that we could see the white and light colored objects even if the room was dark. The light emerged from these objects so we could see them. However, we could not see dark colored objects since there was no light to emerge in dark colored objects.

Question 14 was a following question of the previous question. The students were asked even if you could not see the image of the object, there would be an image in the plane mirror. Three of the nine students said that there would be an image in the mirror even if they could not see it in the plane mirror.

Question 15 is a following question of the previous question. Students were asked whether they would put their fingers exactly the same place as for the previous question if they were seated in the investigator's position. 8 students said that again they would put their fingers on the top of the rod. The others said they would put their fingers to the different places. One student said that for the shadows the position of the eye was important so the location of the image looking from different positions would change. 3 students said that they would put their fingers to the different places. Because, anyone looking from different positions sees the image of the object in different positions. Two students said that if anyone moves toward to the right the image of the object will move to the left. One student said that it depends on the angle between the mirror and the rod.

In Question 16, there was a girl standing one side of a room and looking to the mirror. There was a flower in the room and the girl could see the flower. The students were wanted to explain how the girl could see the flower in the mirror. 6 students explained the situation correctly. Five students explained that the light came to the mirror and the image was created in the mirror and the girl saw it since it was in the sight region of the girl. Some of these students said only that the flower was in the sight region of the girl so she could see the flower. One of the four students said the structure of the mirror was similar to the eye. One student explained the situation as like the four students. But, he said that firstly, the light reflected from the mirror and then went to the flower. Then, it again reflected from flower to the mirror and created the image in the mirror and since it was in the sight region of the girl she would see it. Two students said that the light emerged from the girl's eyes came to the mirror and reflected to the flower so the girl could see the flower. One student said that the image would be located on the mirror with an angle of 90º between the flower and the mirror. But, the girl would not see it there. Since she was looking to the mirror from right side, she would see it on the left side of the mirror. The image would slide to the left. It was related with the sight angle of the girl to the mirror.

4.2 Open-Ended Test Results

The open-ended test was administered to 141 11th grade students from three different schools. The results of the test were categorized for each item based on the students' responses.

Table 4.1 shows the categories and category frequencies for each item. Categories were formed based on the answers of the students on the open-ended test items. The researcher wrote answers of the students for each item. Then, he grouped the similar answers and created one factor that comprises all the answers in that group. Some of the categories having no frequencies were extracted from interview results and literature results even if they have no frequency in the open ended test results. The categories which have "*" sign are the correct answers.

Table 4.1 Categories of the Open Ended Test Results for Each Item

	Categories	Frequencies
Item 1	When the candle is extinguished, black light will be in the medium. Therefore, the objects will reflect of black colored.	-
	When the candle is extinguished, the eyes will get used to seeing in the darkness.	14
	Even if the colors of the objects can not be seen exactly, the shapes of the objects can be seen.	10
	* There is nothing can be seen. To see the objects the light must reflects of objects and enter into the eyes of the observer.	75

Table 4.1 (continued)

	The white vase and light colored objects will be seen. Because, these objects emits light by themselves, thus making themselves to be seen in the darkness.	12
Item 2	Categories	Frequencies
	The light travels more distance at nights. Because, reflection is at the minimum level in the nights.	15
	The light travels more distance at the daytime. Because, the distant objects that can be seen in the daytime can not be seen in the nights.	3
	The light travels more distance at the daytime. Because, the sunlight helps it to move further distances.	4
	* The light travels equal distances whether it is daytime or night. The velocity of the light depends on the density of the medium.	51
	The light travels more distance in the daytime. Because, it uses its energy for going further and also illumination of the medium. In the daytime, it is not necessary to illuminate the medium.	3
	The light travels more distance at nights. Because, the light spreads out to everywhere in the day time, whereas it focuses on a fixed point in the darkness.	10
	The light travels more distance in the daytime. Because, the sunlight blocks the motion of the light.	13
	The bulb gives more powerful light when it gets bigger. The more the light, the more it hits the pencil, thus creating clearer shadow.	21
	The shadow gets smaller when the bulb gets bigger. When a shadow gets smaller, it will be clearer.	38
	* When the bulb gets smaller it will approach a point light source that causes less semi shadows areas. Therefore, the shadow gets clearer.	23
	The bulb sizes do not affect the clearness of the shadows.	17

Table 4.1 (continued)

	Categories	Frequencies
Item 4	Since the light source is too big as compared to bead, it will send light to all parts of the screen. Therefore, there will be no shadow on the screen.	4
	The light goes to screen linearly and create a cross shape illumination. Since the bead blocks the light coming on it, there will be a circular shadow in the middle of the cross illumination.	41
	The shape of the light source is not important on the formation of shadow. The important thing is the shape of the object that blocks the light.	38
	One of the light rays emanating from one point of the light source is blocked by the bead. There will be shadows on the screen for the each point of the cross shaped light source creating a cross shaped shadow.	9
Item 5	Categories	Frequencies
	Since the card blocks the light emanating from both light sources, there will be two shadows on the screen. And, these shadows are connected on the screen and seen as a unique and big shadow.	19
	The intersection area of the shadows will be dark. The other parts will be illuminated by each bulb, thus there will be no shadows at these parts.	13
	* There will be a dark shadow at the region where both light sources are blocked. Near the dark shadow, there will be less illumination in which one bulb can send light and the other one can not send as compared to region in which both light sources can send light.	61
	There will be a dark shadow at the region where both light sources are blocked. There will be light shadows at the both sides of the dark shadow due to interaction of the shadow of the one bulb and light of the other one.	-

	Table 4.1 (continued)	
	Since each bulb sends light to the areas that the other one can not, there will be full illumination on the screen.	3
Item 6	Categories	Frequencies
	The line sight of the teacher does not intersect the mirror, whereas the line sight of the student intersects the mirror.	32
	* The light rays reflecting from the pencil reflect of the mirror and come to the teacher. However, it is not possible for the student.	36
	Since the pencil is not inside the front region straight ahead the mirror, both observes can not see the image of the pencil.	9
	Both observers can see the image. Because, the pencil is inside the sight region of the both observers.	3
	The light ray emanating from the eyes of the teacher come to mirror and reflects toward to the pencil. It is not possible for the student.	-
	The image is formed in the mirror and both observers can see it since their sight angles are appropriate.	9
Item 7	Categories	Frequencies
	* Since, the position of the pencil is fixed there will be no change. Because, image formation is not related with the location of the light source.	42
	When the bulb holds up, the angle of the light rays will change causing the image to slide down.	23
	When the bulb holds up, the angle of the light rays with the horizontal will get bigger causing the image to get smaller.	17
	When the bulb holds up, the light rays will extend with a bigger angle. Therefore, the incident rays become greater and the image will get bigger.	8

Table 4.1 (continued)

	Categories	Frequencies
Item 8	Going away from the mirror or removing to the mirror widens the sight angle causing to see the whole parts of the body.	59
	* Changing the angle of the mirror provides to see whole parts of the body.	19
	Approaching the mirror widens the sight angle causing to see the whole parts of the body.	3
	Going up a higher position causes the increasing of the sight region causing to see the whole parts of the body.	9
Item 9	Categories	Frequencies
	The black ball reflects of the light to the mirror and the light reflects from the mirror and come to the observer's eyes.	43
	The light rays emanating from the observer's eyes reflect from the mirror and comes on the black ball.	5
	The black ball emits black light rays and these rays reflect from the mirror and come to the observer's eyes.	-
	The color of the ball is not important. Since the black ball is inside the line sight of the observer, the observer can see it.	53
	* The light rays coming from the surroundings of the blackball reflect to the mirror and come to observer's eyes. However, there will be no light reflecting from the ball to the mirror and thus creating a dark area due to absence of the light.	5
	The black ball neither scatters nor emits light.	-

Table 4.1 (continued)

	Categories	Frequencies
Item 10	* Since there is no light in the room, an image will not be formed in the mirror.	57
	Since the bulb is white colored, it can emit light and an image will be formed in the mirror.	4
	There will be an image in the mirror due to inner characteristics of the mirror. But, the observer can not see the image since there is no light.	32
	In the total darkness, eyes will get used to darkness and the observer will see the image even if it is not clear.	1
	Since the room is in total darkness, there will be black light rays in the medium and they will reflect to the mirror. But, since all the reflections are black, the observer can not differentiate the image of the bulb.	4
	Categories	Frequencies
Item 11	Since the line sight of the student is changed, the student will see the image at the right side of the mirror.	37
	Since the student slides to the left side, the image will slide to the left side, too.	6
	* Since the location of the pencil is fixed, the student will see the image at the same place in the mirror.	54
	Categories	Frequencies
Item 12	* The flashlight should be aimed at his chin. The light rays coming from the chin reflect from the mirror and comes to his eyes.	55
	The flashlight should be aimed at his chin.	26
	The flashlight should be aligned parallel to the mirror.	9
	The direction in which the flash light is aimed does not make any difference.	5

Table 4.1 (continued)

	Categories	Frequencies
Item 13	The light rays emanating from the eyes of the girl reflect from the mirror and come on the flower.	14
	Since the flower is not inside the front region straight ahead the mirror, the girl can not see the image of the flower.	24
	Since the flower is not inside the sight line of the girl, she can not see the image in the mirror.	19
	The light rays reflecting from the flower create an image in the mirror and the girl sends light rays to see the image.	24
	* The light rays reflecting from the flower go to the mirror and reflect from it and come to the girl's eyes.	18
	Since the flower is inside the sight region, she can see the image.	11

4.3 Analyzing Results of the TTGOMT

There were many quantitative techniques were used to analyze the results of the TTGOMT. They were used to establish the validity and compute the reliability of the test. Descriptive statistics for the overall test results were done and also item analysis was conducted for each item.

4.3.1 Validity

Validity of the test was estimated by three quantitative techniques. First, correlation of the scores on the first two tiers and confidence levels on the third tiers were investigated to establish construct validity. Second, factor analysis was conducted. Third, probabilities of false positives and false negatives were estimated.

4.3.1.1 Construct validity

Construct validity refers to the nature of the psychological construct or characteristic being measured by the instrument. According to Çataloğlu (2002), it is expected on a properly working test that students with higher scores would be more confident about the correctness of their answers if they properly understand what they read on a test. The correlation was estimated by using SPSS program. Table 4.2 shows the correlation between student scores (score-2) and confidence levels.

Table 4.2 Correlations between Student Scores and Confidence Level

		Score-2	Confidence Level
	Pearson Correlation	1.000	.329**
	Sig. (2-tailed)	.	.000
	N	141	141

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 4.1 shows the scatter plot of score-2 vs. confidence levels. When the scatter plot was investigated, at the right bottom of the graph some students claimed they were confident despite of their low scores. These students probably selected wrong answers to the first two tiers by chance and then they selected Yes, I am confident. The lower the number of such students was, the higher the correlation would be. However, despite such students the value of correlation coefficient was found a significant value of 0.33 at the 0.01 alpha level.

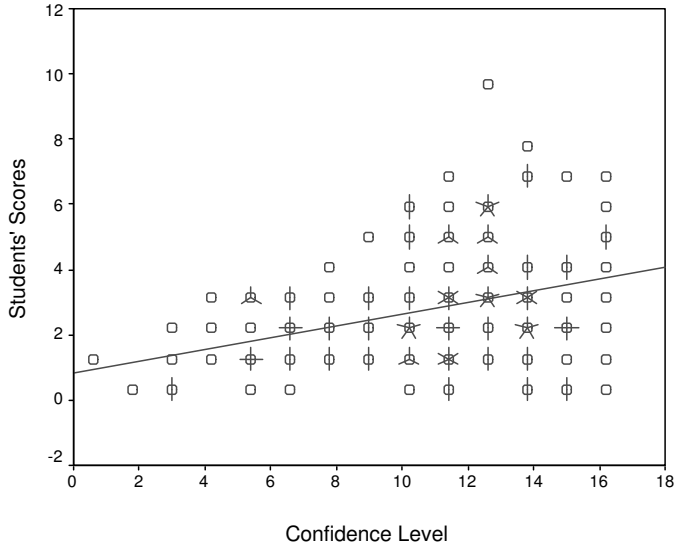


Figure 4.1 Scatter plot of Student Scores for the First Two-tiers vs. Confidence Levels

4.3.1.2 Factor analysis

The second quantitative technique for establishing the validity is factor analyzing. When several items are asked to the same examinees, one aspect of validation may involve determining whether there are one or more clusters of items on which examinees display similar relative performance. These clusters are called factors. A factor is an unobservable or latent variable. There were two factor analyses were conducted. One of them was conducted based on the correct answers of the students on all the three tiers. The other one was conducted based on the misconceptions of the students for on all the three tiers.

Firstly, the factor analysis which is based on the correct answers for all the three tiers were conducted. Before starting to conduct a factor analysis, there are some requirements should be satisfied to conduct it. These requirements were satisfied. The variables were in dichotomous nominal level. The sample size was 141 which is greater than 50. The ratio of cases to variables was 9 to 1 which is greater than 5 to 1. The correlation matrix for the variables must contain 2 or more

correlations of 0.30 or greater. There were six correlations in the matrix satisfying this requirement.

It is required in factor analyzing that Measures of Sampling Adequacy (MSA) values for each variable must be greater than 0.50. This was satisfied by removing the items having anti-image correlations less than 0.50. Therefore, items 5, 6, 8, 9, 10, 11 were removed from the analysis.

In addition to the MSA values, the overall MSA values must be greater than 0.50. Table 4.3 shows KMO and Bartlett's test of sphericity. The KMO value was found 0.63 which is greater than 0.50 and the probability associated with the Bartlett's test of sphericity (p-value) was less than the significance level (0.001). That is the desired condition.

Table 4.3 SPSS Output Showing KMO and Bartlett's Test for score-3

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.627
Bartlett's Test of Sphericity	Approx. Chi-Square	177.506
	df	45
	p-value	.000

One of the requirements of the factor analysis is that all communalities of the variables must be greater than 0.50. If there had been any item whose communality is less than 0.50, then it would have been eliminated from the analysis. Table 4.4 shows the communalities for each item. It is seen all communalities are higher than 0.50. The communalities represent the proportion of the variance for each of the variables included in the analysis that is explained or accounted for by the components in the factor solution. The derived components should explain at least half of each original variable's variance, so the communality value for each variable should be 0.50 or higher (Schwab, 2002). In addition, cumulative percent of variance accounted for was arranged to be an acceptable

value, 70 % under the criterions for retaining the factors. The cumulative percent of variance was 70.4 % which is an acceptable value.

Table 4.4 SPSS Output Showing Communalities

	Initial	Extraction
Q1	1.000	.658
Q2	1.000	.685
Q3	1.000	.657
Q4	1.000	.699
Q7	1.000	.716
Q12	1.000	.787
Q13	1.000	.728
Q14	1.000	.820
Q15	1.000	.636
Q16	1.000	.651

Extraction Method: Principal Component Analysis.

Finally, items 13 and 16, 7 and 15, 4 and 3, 12 and 1 formed factors according to factor analysis result, shown in Table 4.5.

Table 4.5 SPSS Output Showing Rotated Component Matrix for the score-3

	Component				
	1	2	3	4	5
Q13	.791	.304	-.062	.034	-.068
Q16	.783	-.038	.166	.038	-.083
Q7	.135	.770	.125	.169	-.248
Q15	.272	.607	-.210	.219	.320
Q4	.244	-.122	.790	-.003	-.029
Q3	-.097	.157	.772	.002	.166
Q14	.247	.042	-.029	.867	.063
Q2	-.287	.372	.040	.673	.098
Q12	-.071	-.149	.047	.139	.859
Q1	-.183	.449	.312	-.051	.568

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

The reliabilities of the factors were estimated 0.58, 0.44, 0.47, 0.48 and 0.43 respectively for the first, the second, the third, the fourth and the fifth factors. The correlation coefficients between the items were found 0.42, 0.30, 0.32, 0.32 and 0.28 respectively for the items 13 and 16, 7 and 15, 4 and 3, 14 and 2, 12 and 1. It is seen that the reliabilities of the factors are a bit low.

Correlation coefficient is the square of the correlation between two variables. It gives information about at what ratio in the variance of a variable is related with the other variable's variance. Therefore, 18 % of the variance in item 13 is associated with the variance in item 16. Similarly, 9 % of the variance in item 7 is associated with the variance in item 15, 10 % of the variance in item 4 is associated with the variance in item 3, 10 % of the variance in item 14 is associated with the variance in item 2 and 8 % of the variance in item 12 is associated with variance in item 1. Table 4.6 presents the interpretation of factors formed as a result of the factor analysis.

Table 4.6 Interpretation of the factors

		Item(s)	Factor Name (Interpretation)
Factors	1	13, 16	Items 13 and 16 ask whether the image position of any object in a plane mirror depends on the observer's position.
	2	7, 15	Items 7 and 15 ask whether an observer can see image of any object that is not inside the front region straight ahead of the mirror.
	3	3, 4	Items 3 and 4 ask what would happen to the shadow of any object when the illuminant position is changed or different sizes of illuminants are used. Both items mainly focus on the shadow formation with point of light source.
	4	14, 2	Although there is a good relation in the items 14 and 2 in the factor analysis, there is not a good expression to explain that relationship.
	5	12, 1	Items 12 and 1 ask whether the objects are seen in the total darkness.

Secondly, besides conducting the factor analysis for the correct answers of the students for all of the three tiers, a factor analysis was also conducted for the students' misconceptions on the TTGOMT by considering all of the three tiers. All the requirements were satisfied to conduct the factor analysis which was done for the previous factor analysis. It is important to say that in the correlation matrix there was no correlation found greater than 0.30. That result contradicts with Schwab's criteria (2002); the correlation matrix for the variables must contain 2 or more correlations of 0.30 or greater. Table 4.7 shows the KMO and Bartlett's test of sphericity for the misconception-3. However, since the Bartlett's test of sphericity (p-value) was significant, the factor analysis was continued.

Table 4.7 SPSS Output Showing KMO and Bartlett's Test for misconception-3

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.500
Bartlett's Test of Sphericity	Approx. Chi-Square	61.903
	df	1
	Sig.	.000

The other requirements of the factor analysis were satisfied by adjusting the MSA values for each variable to be greater than 0.50 and communality values to be greater than 0.50. Both criteria were satisfied again by removing the misconceptions having anti-image correlations less than 0.50 and communalities less than 0.50. Therefore, except the misconceptions 12 and 18 all the misconceptions were removed. In addition, the cumulative percent of variance was 80.0 % which was an acceptable value.

Finally, it is seen in Table 4.8 that only one factor was obtained. Misconceptions 12 and 18 formed a factor together. In fact, it is an expected result. Misconception 12 emphasizes that students think an image in a plane mirror lies behind the mirror along the line of sight between a viewer and the object.

Misconception 18 focus on whether the image position changes in a plane mirror when the observer changes his/her position.

Table 4.8 SPSS Output Showing Rotated Component Matrix for the misconception-3

	Component
	1
M18	.895
M12	.895

Extraction Method: Principal Component Analysis.

The reliability of the factor was estimated by using Cronbah alpha and found 0.75. And, the correlation coefficient between the misconceptions 12 and 18 was found 0.60. The coefficient of determination was found 0.36. It means that 36 % of the variance in Misconception 12 is associated with the variance in Misconception 18.

4.3.1.3 Proportion of False Positives and False Negatives

Hestenes and Halloun (1995) stated that to be certain how accurate the test results, false positives and false negatives must be estimated. This estimation actually is an indication of the content validity as the same as the factor analysis. They used follow-up interviews to estimate the false positives and false negatives. However, this estimation was a qualitative data and also time consuming. Moreover, the results were from the interviews not from the original test. Three-tier tests are very suitable to compute the false positives and false negatives. Because, not only students response to the first tiers, ordinary multiple choice item, but also their reasoning is available from the second tiers.

The proportions of false positives and false negatives were estimated by using Excel program. To compute the proportions, students' responses for only the first tiers and for only the second tiers were changed to metric level or dichotomous (dummy-coded) nominal level i.e. correct responses were scored as 1 and wrong responses were scored as 0. And then, the proportion of the false positives was estimated by counting the students who gave correct answer to the first tier of any item and wrong answer to the second tier of that item. This value was compared with the number of the students (141). And percentage ratio was calculated easily in the Excel program for each item. The mean of the false positives was calculated by adding the all proportions of the false positives for each item and dividing it to the number of the items. For the false negatives, wrong answers to the first tier of any item and correct answer to the second tier of that item were counted. And again, percentage ratio was calculated easily in the Excel program for each item and mean proportion false negatives was found as similar with false positives. The mean proportion of the false positives was estimated as 28.2 %. The mean proportion of the false negatives was estimated 3.4 % which is a desired value. According to Hestenes and Halloun (1995) the probability of false negatives should be certainly less than 10 %.

4.3.2 Reliability

Coefficient alpha (α) was calculated to measure the reliability of the test. It should be clear that α takes on values $0 \leq \alpha \approx 1$. The larger the value of α, the greater the reliability of the test. The value of α for the three-tier misconception test considering the correct answers of the students was 0.55. Perhaps this is not a robust value. The reported reliability coefficients for the achievement tests are typically 0.90 and for classroom tests are 0.70. In general it is acceptable that reliability should be at least 0.70 (Fraenkel & Wallen, 1996, p. 163). It is important to say that this reliability was calculated based on the correct answers for all three tiers. Therefore it shows us how well the students understand the geometric optic qualitatively in other words the students understood the geometric optic with a reliability of 0.55. However, it is necessary to estimate the reliability by considering the misconceptions. Therefore, one more reliability calculation was

also calculated based on the misconceptions for all three-tiers. It was found 0.28 which is smaller than the reliability of the correct answers. Since it was a low value, a discrimination analysis was conducted by using the Excel program to investigate the reason of the low reliability. The discrimination index was obtained by comparing the misconceptions of the highest scoring 27 % versus the lowest scoring 27 % of the students. And, the mean of the misconceptions' discrimination index was found 0.01. It shows us that high scorer students and low scorer students had misconceptions nearly at same proportion.

4.3.3 Item Analysis

Item difficulty levels and item discrimination indexes on the TTGOMT were estimated by using the ITEMAN item analysis program. Table 4.9 shows item difficulty levels and discrimination indexes for each item. In Table 4.9, Prop. Correct values represent the item difficulty levels. Point Biser. values represent the correlation between student responses on an item scored as 0 or 1 (wrong or right) and the score the student received on the test (Marx, 1988). In fact, it shows how a test item discriminates between high scorers and low scorers as the item discrimination does. Therefore, Point Biser. values represent the item discrimination indexes.

Table 4.9 Output of the ITEMAN based on Score-3

		Item Statistics			Alternative Statistics				
Seq. No.	Scale -Item	Prop. Correct	Biser.	Point Biser.	Alt.	Prop. Endorsing	Biser.	Point Biser.	Key
1	0-1	0.163	0.689	0.459	1	0.163	0.689	0.459	*
					2	0.837	-0.689	-0.459	
					Other	0.000	-9.000	-9.000	
2	0-2	0.255	0.730	0.538	1	0.255	0.730	0.538	*
					2	0.745	-0.730	-0.538	
					Other	0.000	-9.000	-9.000	
3	0-3	0.085	0.689	0.385	1	0.085	0.689	0.385	*
					2	0.915	-0.689	-0.385	
					Other	0.000	-9.000	-9.000	

Table 4.9 (continued)

4	0-4	0.177	0.459	0.312	1	0.177	0.459	0.312	*
					2	0.823	-0.459	-0.312	
					Other	0.000	-9.000	-9.000	
5	0-5	0.028	0.142	0.056	1	0.028	0.142	0.056	*
					2	0.972	-0.142	-0.056	
					Other	0.000	-9.000	-9.000	
6	0-6	0.213	0.584	0.415	1	0.213	0.584	0.415	*
					2	0.787	-0.584	-0.415	
					Other	0.000	-9.000	-9.000	
7	0-7	0.270	0.707	0.527	1	0.270	0.707	0.527	*
					2	0.730	-0.707	-0.527	
					Other	0.000	-9.000	-9.000	
8	0-8	0.028	0.551	0.215	1	0.028	0.551	0.215	*
					2	0.972	-0.551	-0.215	
					Other	0.000	-9.000	-9.000	
9	0-9	0.014	0.601	0.183	1	0.014	0.601	0.183	*
					2	0.986	-0.601	-0.183	
					Other	0.000	-9.000	-9.000	
10	0-10	0.057	0.461	0.227	1	0.057	0.461	0.227	*
					2	0.943	-0.461	-0.227	
					Other	0.000	-9.000	-9.000	
11	0-11	0.035	0.451	0.191	1	0.035	0.451	0.191	*
					2	0.965	-0.451	-0.191	
					Other	0.000	-9.000	-9.000	
12	0-12	0.284	0.519	0.390	1	0.284	0.519	0.390	*
					2	0.716	-0.519	-0.390	
					Other	0.000	-9.000	-9.000	
13	0-13	0.035	0.597	0.252	1	0.035	0.597	0.252	*
					2	0.965	-0.597	-0.252	
					Other	0.000	-9.000	-9.000	
14	0-14	0.305	0.681	0.518	1	0.305	0.681	0.518	*
					2	0.695	-0.681	-0.518	
					Other	0.000	-9.000	-9.000	
15	0-15	0.128	0.843	0.528	1	0.128	0.843	0.528	*
					2	0.872	-0.843	-0.528	
					Other	0.000	-9.000	-9.000	
16	0-16	0.064	0.356	0.182	1	0.064	0.356	0.182	*
					2	0.936	-0.356	-0.182	
					Other	0.000	-9.000	-9.000	

Mean P	0.13
Mean Item-Tot.	0.34

In the TTGOMT wrong answers are more important than true answers and it has very strong distracters. Therefore, most of the items were very difficult and had small difficulty levels. The average value of item difficulty was 0.13 and ranged from 0.01 to 0.31.

The average value of the point-biserials, which are the item discrimination indexes, on the TTGOMT was 0.34 with a maximum value of 0.54 and a minimum value of 0.06. According to Gregory's criteria the item with average discrimination index requires little or no revision. So, the average item on the test was discriminatory.

4.3.4 Descriptive Statistics

Table 4.10 summarizes the results of the general descriptive statistics which were estimated by using SPSS program for the TTGOMT. The mean of the scores was found 2.14 and with a 95 % confident true mean of the scores is between 1.83 and 2.45. The standard deviation was found 1.88. It is a small value considering a test with a possible maximum score 16. As it is seen, since the standard deviation which shows how the scores spread throughout the distribution was a small value, the reliability of the test for the correct answers was also a little bit small value.

A positive and great value of skewness indicates that most of the students' scores are low. A positive value of kurtosis shows that the distribution of the scores corresponds to a peak distribution.

Table 4.10 Descriptive Statistics

# of Students		141
# of Items		16
Mean		2.14
Standard Deviation		1.88
Standard Error of the Mean		0.16
95 % Confidence Interval for Mean	Lower	1.83
	Upper	2.45
Variance		3.52
Skewness		0.90
Kurtosis		0.46
Minimum		0.00
Maximum		8.00
Median		2.00
Mode		1.00
Reliability (Coefficient Alpha)		0.55
Standard Error of the Measurement		1.58

Figure 4.2 shows the histogram of score-3. It is seen most of the scores are at the low end which means the items were generally difficult for most of the students.

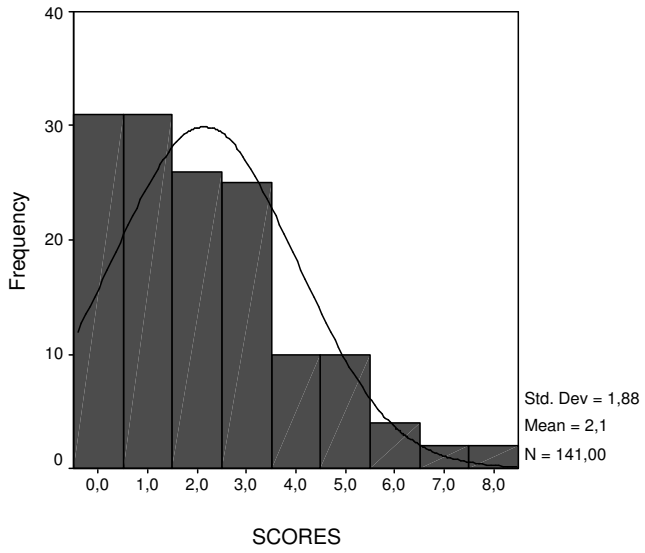


Figure 4.2 Histogram for the Students' Scores

4.3.5 Other Test Results

If Figure 4.3 is examined carefully, the proportion of each misconception gradually decreases when the tiers of the test are increased from one to three one by one. It is understood from Figure 4.3 that the first tiers overestimate the proportion of the misconceptions. And also first two tiers, not as much as first tiers, overestimate the proportion of the misconceptions. The percentages of the misconceptions are given in Table 4.9. How these values were obtained was mentioned in Section 3.5.

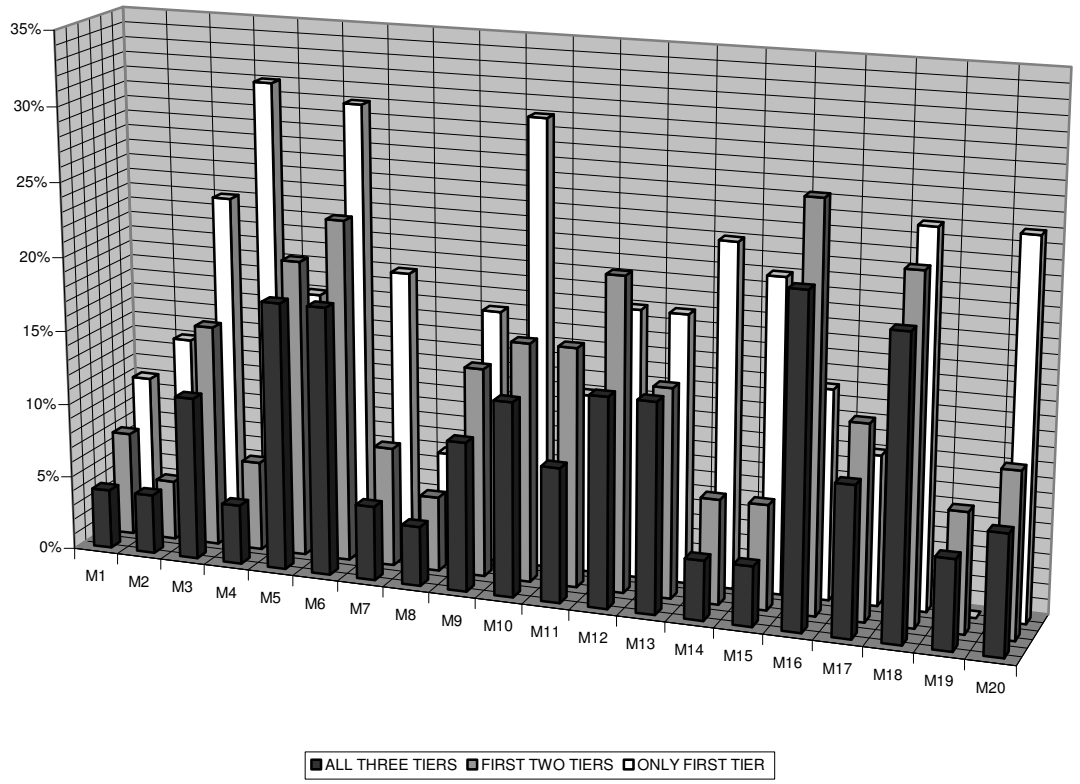


Figure 4.3 Proportions of the Misconceptions in terms of Type of the Test

Table 4.11 Proportions of the Misconceptions Considering the Tiers of the Test

	ALL THREE TIERS (Misconception-1)	FIRST TWO TIERS (Misconception-2)	ONLY FIRST TIERS (Misconception-3)
M1	4%	7%	10%
M2	4%	4%	13%
M3	11%	15%	23%
M4	4%	6%	31%
M5	18%	20%	17%
M6	18%	23%	30%
M7	5%	8%	19%
M8	4%	5%	7%
M9	10%	14%	17%

Table 4.11 (continued)			
M10	13%	16%	30%
M11	9%	16%	12%
M12	14%	21%	18%
M13	14%	14%	18%
M14	4%	7%	23%
M15	4%	7%	21%
M16	22%	27%	14%
M17	10%	13%	10%
M18	20%	23%	25%
M19	6%	8%	29%
M20	8%	11%	25%
AVERAGE	10%	13%	19%

Table 4.11 shows the proportions of the misconceptions appearing in the first tiers, first two tiers and all three tiers. It is necessary to say that some items' first tiers indicated the some misconceptions even if they were correct. Therefore, the researcher assumed half proportions of correct answers of these items as misconceptions. The items in which the first tiers indicating misconceptions even if they were correct are 1, 6, 7, 8, 10, 11, and 15. On the other hand, some of the misconceptions' proportions for the first two tiers were higher than for the first tiers which was an unacceptable result. While calculating the proportions of the misconceptions, the item choice selections were used (see Appendix E). Since some item choice selections for the first tiers were measuring one more misconceptions, the researcher assumed the proportion of each misconception by dividing the total proportion of the item choice selection to the number of the misconceptions sharing that total proportion. This assumption was done for the misconceptions 5, 11, 12, 16, and 17. Although some misconceptions' proportions for the first two tiers were higher than for the first tiers, the proportions of the misconceptions for the first tiers are generally higher than first two tiers (See Figure 4.3). If it is looked at the average proportions, 6 % proportion of the

misconceptions disappeared as the tier was increased from one tier to two tiers. 3.4 % of the 6 % is the proportion of false negatives. The remaining 2.6 % is the result of inconsistent answers. Similarly, 3 % proportion of the misconceptions disappeared as the tiers of the test were increased from two tiers to three tiers. This proportion stems from lack of knowledge. Because, in misconception-3, a misconception is not accepted even if the answer of the student to the first two tiers shows a misconception unless the student clarifies his/her confidence in the third tier.

Figure 4.4 shows the proportion of the correct answers to each item in terms of the tiers of the test. In fact, these proportions are the difficulty levels. Table 4.12 shows the proportions of the correct answers for the score-1, score-2 and score-3. How these values were obtained was mentioned in section 3.5

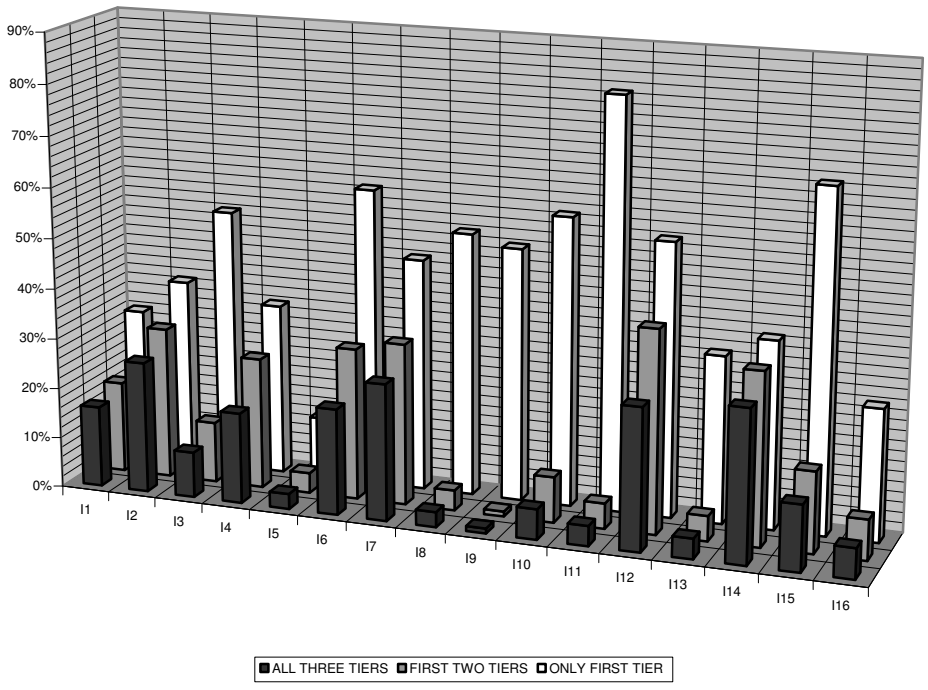


Figure 4.4 Proportions of the Correct Answers in terms of Type of the Test

Table 4.12 Proportions of the Correct answers Considering the Tiers of the Test

	ALL THREE TIERS (Score-3)	FIRST TWO TIERS (Score-2)	ONLY FIRST TIER (Score-1)
I1	16%	18%	30%
I2	26%	30%	37%
I3	9%	12%	52%
I4	18%	26%	34%
I5	3%	4%	12%
I6	21%	30%	59%
I7	27%	32%	46%
I8	3%	4%	52%
I9	1%	1%	50%
I10	6%	9%	57%
I11	4%	5%	81%
I12	28%	40%	54%
I13	4%	5%	33%
I14	30%	34%	37%
I15	13%	16%	67%
I16	6%	8%	26%
AVERAGE	13%	17%	45%

The average values are 45 % for the first tiers, and 17 % for the first two tiers. The gab, 28 %, between the first tiers and first two tiers is due to false positives. Besides, 4 % of the correct answers disappear when the tier of the test was increased from two to the three. This proportion shows the lack of knowledge of the students.

4.3.6 Summary of the Results

- In the interviews, the students showed in ability using the terminology. For example, some of the students used refraction to mean reflection.
- In the interviews and open-ended test some new misconceptions were found. These misconceptions are:
  - ✓ Students believe that they can see the light colored objects in the total darkness. Because, they emit light by themselves.
  - ✓ Students claim that there will be black rays in the total darkness.
  - ✓ Students think that the shadows of the objects are clearer when the bigger bulb is used as a light source.
  - ✓ Students claim that there will be no shadow even if a light source and a non- transparent object exist together.
  - ✓ Students think that shadow is black color and light is white color. When they overlap, they mix and form the grey color. In a similar way, they think when the shadow and light overlap, the shadow reduce the brightness of the light.
- It was found that there was a significant correlation between the score-2 and confidence levels. It means that high scorer students were more confident than low scorer students in the TTGOMT.
- There was a factor analysis conducted for the score-3 and 5 factors were found with reliabilities 0.58, 0.44, 0.47, 0.48 and 0.43.
- There was also a factor analysis conducted for the misconception-3 and one factor was found with a reliability of 0.75.
- The proportion of the false positives was estimated 28.2 % and the proportion of the false negatives was estimated 3.4 %.
- The reliability of the score-3 was estimated by using Cronbach alpha and found 0.55. It means 55 % of variance in the total scores is due to the variance in the true scores.
- The reliability of the misconception-3 was estimated by using Cronbach alpha and found 0.28. It means 28 % of variance in total misconception-3 scores is due to the variance of true student misconceptions.

- The average item discrimination index on TTGOMT was 0.34 with a maximum 0.54 and a minimum 0.06. Item 5 with a discrimination index of 0.056 can be removed from the test. Because, its discrimination index was too small.
- The average value of item difficulty was 0.13 ranged from 0.01 to 0.31.
- Histogram of the score-3 was right-skewed. It means the items of TTGOMT were difficult for the students.
- The mean of the misconceptions' discrimination indexes was found 0.01. It means the high scorer students and the low scorer students had nearly same proportion of misconceptions.
- The proportions of the misconceptions among the students decreased as the tier of test was increased. The proportions of the misconception for one-tier, two-tier and all three-tier of the TTGOMT were 19 %, 13 % and 10 % respectively. The difference between the mean misconception proportion of the one tier test and two-tier test was 6 % and the difference between the mean misconception proportion of the two-tier test and three-tier test was 3 %. 3.4 % of 6 % was false negatives and remaining 2.6 % was inconsistent student answers. The 3 % difference between the two-tier test and three-tier test was due to lack of knowledge.
- The proportions of the correct answers of the students also decreased as the tier of the test was increased. The proportions of the correct answers for one-tier, two-tier and all three-tier of the TTGOMT were 45 %, 17 % and 13 % respectively. The difference between the mean proportions of the correct answers to the one-tier test and two-tier test was 28 % which was false positives. And, the difference between the mean proportions of the correct answers to the firs two-tier and all three-tier was 4 % due to lack of knowledge.
- It was found that misconception 16 (M16) (see Appendix E) was the most frequent misconception among the students with 22 % of proportion. Moreover, it was seen that the students gave most wrong answers due to lack of knowledge for Misconception 12. 7 % of proportion of the misconception disappeared since the students did not show their confidence in the third tier.

CHAPTER 5

CONCLUSIONS, DISCUSSIONS AND IMPLICATIONS

This chapter consists of seven sections. The first section is the summary of the study. The second section includes the conclusions based on the results. The third section is the discussion of the results. Internal and external validities of the study are given in the fourth and fifth sections respectively. The sixth section presents the implications of the study. Finally, the last section presents the recommendations for the further studies.

5.1 Summary of the Research Study

This study included development process of a three-tier test and assessment of the misconceptions of 11^{th} grade students about geometric optic with this three-tier test. Research design of the study is a cross-sectional survey study.

Firstly, the literature was reviewed to investigate the students' conceptions about geometric optic. Second, interviews were conducted with 11^{th} grade students in the light of the literature review. Third, open-ended test was constructed based on the interview and literature review results and administered to 114 the students. Fourth, the TTGOMT was developed mainly based on the open-ended test results. Interview results and literature review were also considered in the construction of the test. Fifth, the test was administered to the 141 students and the results were analyzed.

5.2 Conclusions

For establishing validity of the test two quantitative techniques were used. First, the scores of the students for the first two tiers and the confidence levels of the students for the third tiers were correlated and a positive correlation was found to be 0.33. It shows students with high scores for the first two tiers of the test had

high confidence and students with low scores for the first two tiers had low confidence. This indicates the students answered the test items sincerely and the test functioned properly. It is important to say that three-tier tests have an advantage over the two-tier tests in terms of discriminating students' lack of knowledge from their misconceptions by means of the third tier items which assess how confident the students are about their responses for the first and second tiers. It is known that misconceptions do not stem from lack of knowledge. Since, this correlation deals with confidence levels of the students which is a physiological construct, it can be attributed to the construct validity of the test. Second, factor analyses were conducted by means of students' scores (score-3) and students' misconceptions (misconception-3) so that similar items or misconceptions formed acceptable factors. Items 13 and 16, 7 and 15, 3 and 4, 2 and 14, 1 and 12 formed factors based on the correct answers which are expected except the factor formed by 2 and 14. In fact, it is expectable that items 8 and 9 to form a factor together. Because, both items ask what would happen to image position or image size when the bulb was raised. They mainly focus on the whether the students confuse image formation with shadow formation. Also, item 10 can be expected in the factor formed by the items 13 and 16. Because, both items mainly focus on whether the image position depends on the observer's position. Since, the item 10 also focus on whether image position or size depends on the observer's position, item 10 can be expected in that factor. The reliabilities of the factors were estimated 0.58, 0.44, 0.47, 0.48 and 0.43 respectively for the first, the second, the third, the fourth and the fifth factors. And, the correlation coefficients between the items were found 0.42, 0.30, 0.32, 0.32 and 0.28 respectively for the items 13 and 16, 7 and 15, 4 and 3, 14 and 2, 12 and 1. It is seen that the reliabilities of the factors are generally small values. That can be attributed to two reasons. First, it is normal to have low value reliability with two items. The reliability is increased with the number of the items. Second, since the most of the items in the test were very difficult for the students, the score of the students were not spread and thus created low reliability.

Since the items asking similar concepts formed factors which also had been expected before conducting the factor analysis that can be attributed to the content validity of the test. Moreover, a factor analysis was done for the misconceptions and only one factor was found. Misconception 12 and 18 formed a

factor together with a reliability of 0.75 and correlation of 0.60. In fact, it is expectable that the students who had the misconception 12 also had the misconception 18. Because, both misconceptions mainly focus on that the image position of the any object in the plane mirror depends on the position of the observer.

The proportion of the false positives was estimated 28.2 %. This value is not a too big value. Because, students have a chance to give responses randomly in all multiple choice tests. In fact, powerful distracters of the TTGOMT which were created based on the interview and open-ended test results may also appear reasonably to the students causing the false positives. The proportion of the false negatives was estimated 3.4 %. The probability of the false negatives can be attributed to the carelessness or inattention of the students. This shows the TTGOMT has items with good format and understandable language that prevent students from fall in inattention or carelessness.

Two reliabilities were estimated by using Cronbach alpha. Reliability of the test based on the correct answers was found 0.55 which is a little low value. There were many items in the test with low item difficulties which caused the reliability to be a little low. However, it is normal to have difficult items in a misconception test. Because, the items had very strong distracters. It is possible to increase reliability by removing difficult items. However, misconception tests are criterion-referenced; therefore objective of an item is more important than its difficulty level. This reliability shows us that the students understand the geometric optic qualitatively with 0.55 reliability. Also, since the distracters of the TTGOMT were created based on the interviews and open-ended test results, they seemed reasonable to the students. Therefore, the items with powerful distracters were very difficult for the students. That lowered the reliability of the test for the correct answers. On the other hand, since the TTGOMT is a misconception test and it focuses on the misconceptions, other reliability was also calculated based on the misconceptions for all three-tiers. The reliability for the misconceptions was found 0.28 which is smaller than the reliability of the correct answers. This low value may stem from that the students with higher scores also have as many misconceptions as low scorers have. Therefore, a discrimination index was conducted to explain the reason of that result. 27 % of the students who have the

highest score on the test and 27 % of the students who have the lowest score on the test were compared considering the misconceptions that they possess. The mean of the discrimination index was found 0.01. It shows that students who have high scores on the test have as many misconceptions as the students who have low scores. Therefore, there was no difference among the students in terms of the misconceptions and the sample was a homogenous group as considering the misconceptions. It is known that the more diverse the group, the more reliable the exam i.e. if the sample is diverse, the variance of the observed scores will be greater.

The mean of the item difficulty levels of the TTGOMT was 0.13. It shows that the test was very difficult for the students. The reliability of the test for the score-3 was a bit low since the scores of the students were not spread due to difficult items. To improve the reliability of the test difficult items can be removed. However, since this test is a misconception test it is not necessary to eliminate difficult items. In misconception test wrong answers are more important than the correct answers. On the other hand, the mean of the discrimination index of the items was 0.34. It shows that an average item on the test is discriminatory.

When the changes in the proportion of the misconceptions were examined, the proportions of the misconceptions were observed to lessen gradually as the tiers of the test were increased one by one. It is observed that 6 % of the misconceptions disappear when the tier of the test changed from one tier to two tiers. And, 3.4 % of the 6 % was calculated as the false negatives. The remaining 2.6 % is the inconsistent answers. However, this value is not a big value. Because, some items have many distracters and since the test is a misconception test the items of the test have powerful distracters. Therefore, students might have fallen in inconsistency due to many and powerful distracters. It is also observed that 3 % of the misconceptions disappeared when the tier of the test changed from two tiers to three tiers. It is important to say that even if a student holds a misconception for the first two tiers, it is not accepted as a misconception if the confidence is not stated in the third tier. Therefore, that 3 % of decreasing proportion in the misconceptions can be attributed to the students' lack of knowledge. To sum up, multiple-choice tests and two-tier tests over estimate the proportion of the misconceptions. They do not take into account wrong answers due to mistakes or lack of knowledge.

When the changes in the proportions of the correct responses to each item were examined, they were also observed to lessen gradually when the tiers of the test were increased one by one. There was 28 % of a decreasing proportion when the tier of the test changes from one tier to two tiers and 4 % when the test changes from two tiers to three tiers. That 28 % decreasing was false positives. And, 4 % can be attributed to the lack of knowledge. Because, the correct answers were not accepted unless the students clarified their confidence in the third tier. These results showed that the first tier of the test and even first two tiers overestimate the proportion of students who have the correct conceptual understanding.

Finally, proportions of the misconceptions measured by each item were calculated. Some misconceptions were measured by two or more items. However, some misconceptions were measured by only one item. It is desired that each misconception is measured by two or more items. However, even if these items measure one misconception, their measuring proportions are very high (see Table 4.11).

In this study, besides the misconceptions found from the literature review, some misconceptions were found that were not discussed before. It is important to say that these misconceptions may have been studied. But the researcher could not see them in the literature review. These new misconceptions are:

- Students believe that they can see the light colored objects in the total darkness. Because, they emit light by themselves.
- Students claim that there will be black rays in the total darkness.
- Students think that the shadows of the objects are clearer when the bigger bulb is used as a light source.
- Students claim that there will be no shadow even if a light source and a non- transparent object exist together.
- Students think that shadow is black color and light is white color. When they overlap, they mix and form the grey color. In a similar way, they think when the shadow and light overlap, the shadow reduce the brightness of the light.

5.3 Discussion of the Results

The validity of the test was estimated by three quantitative techniques. According to Çataloğlu (2002) there should be a positive correlation between students' scores for the first two tiers and confidence levels for the third tier which shows the construct validity of the test. The correlation was found for the TTGOMT 0.33 which is a positive and significant value. According to Eryılmaz and Sürmeli (2002) to accept a misconception of any student it is important that the student must show his or her confidence. Because, the answer of the student for the first two tiers may stem from lack of knowledge. Therefore, even if an item choice selection points out a misconception for the first two tiers, it is not accepted as a misconception without showing the confidence in the third tier. They said that three-tier tests have an advantage over the two-tier tests in terms of discriminating the students' lack of knowledge. Huffmann and Heller (as cited in Hestenes and Halloun, 1995) investigated the content validity of the FCI by conducting a factor analysis. As Huffman and Heller did, a factor analysis was conducted to estimate the content validity of the TTGOMT. There were 5 factors found in the TTGOMT and 4 of 5 were expected. Items 13 and 16, 7 and 15, 3 and 4, 2 and 14, 1 and 12 formed factors which are expected, except the factor formed by 2 and 14. The reliabilities of these factors were a bit small values. However, according to Marx (1988) reliability can be influenced by the number of the items and item difficulties. The greater the number of the items, the more reliable test and if a test has too difficult or too easy items, the reliability will be low. Therefore, low reliabilities of the factors can be attributed to these two reasons.

Hestenes and Halloun (1995), however, established the content validity of the test by estimating the probabilities of false positives and false negatives instead of conducting a factor analysis. In the TTGOMT the proportions of the false positives and false negatives were found 28.2 % and 3.4 % respectively. These values are satisfactory according to Hestenes and Halloun. According to them false negatives can be attributed to the carelessness or inattention of the students. For the false positives students have a chance to give responses randomly in all multiple choice tests. However, they also emphasized that powerful distracters may also appear reasonably to the students causing the false positives.

The reliability of the test for the correct answers of the all three tiers was found 0.55 by using Cronbach alpha. The reported reliability coefficients for the achievement tests are typically 0.90 and for classroom tests are 0.70. In general it is acceptable that reliability should be at least 0.70 (Fraenkel & Wallen, 1996, p. 163). It was found that most items were difficult for the students. Since the items were very difficult, the scores of the students did not spread, thus lowering the reliability. However, Gronlund, and Linn (1990) stated that in norm-referenced tests it is necessary to avoid from too difficult and too easy items to spread the scores of the students for the discrimination. Spreading the scores of the students causes high reliability. But, for criterion-referenced tests it is not necessary to avoid from too difficult or too easy items. The important thing is not spreading the scores of the students but the content in interest. Therefore, the reliability of the criterion-referenced tests can be lower as compared to the norm referenced tests. The skewness was found 0.90 which shows the items were generally difficult for the students. Kurtosis was found 0.46 which shows a peak distribution. A peak distribution shows most of the students' scores are nearly similar, thus the scores do not spread widely. Since the items were very difficult in the TTGOMT, the scores did not spread, thus a low reliability. However, the TTGOMT is a criterion-referenced test and having too difficult items is not concern.

The reliability for the misconceptions was found 0.28. It is important to say that there is no reported acceptable reliability coefficient for the misconception tests in the literature. Therefore, determining whether the 0.28 reliability is good or bad is difficult. According to Marx (1988) group homogeneity influences the reliability. It was found that the mean of the discrimination index for the misconceptions was 0.01. This low value indicates that the students with higher scores have as many misconceptions as the students with lower scorers. And, that shows the homogeneity of the sample in terms of possessing the misconceptions which may be attributed to cause of low reliability.

One findings of the study showed that multiple-choice tests and two-tier tests overestimate the proportion of the misconceptions as Griffard and Wandersee (2001) found. In the TTGOMT, the proportion of the misconceptions decreased gradually when the type of the test was changed from a multiple-choice test to

a two-tier test in which if the first tiers were accepted as a multiple-choice test and the first-two tiers were accepted as a two-tier test. It is understood that multiple-choice tests can not measure the students' minds deeply as Rollnick and Mahooana (1999) stated. In multiple-choice tests, if the student's answer is wrong it is accepted as a misconception. Even though two-tier tests measure the proportion of the misconceptions better than multiple-choice tests, they also overestimate the proportion of the misconceptions. Because, some wrong answers may arise from lack of knowledge. Even if a student holds a misconception for the first two tiers, it can not be accepted as a misconception unless the student expresses his confidence Eryılmaz and Sürmeli (2002). In the TTGOMT, the proportion of the misconceptions decreased 6 % when the tier of the test changed from one tier to two tiers and 3 % when the tier of the test changed from two tiers to three tiers. If the first tiers of the test are accepted as a multiple choice test and the first two tiers are accepted as a two tier test, third tier tests have advantage over multiple-choice tests and two-tier tests in terms of estimating the proportions of the misconceptions. Eryılmaz and Sürmeli (2002) investigated the students' misconceptions about heat and temperature with a three tier test. They found that the students in their study had misconceptions with a mean of 46 % for the first tiers. This value was similarly decreased to 27 % for the first two tiers and 18 % for all of the three tiers as in the TTGOMT. They stated that there were some students in the percentage of the misconceptions measured by the first tiers giving wrong answers by mistake or lack of knowledge. They found that 19 % of the students fell in the mistakes in the first tiers. Because, their answers for the second tiers were not consistent with the first tiers i.e. that students did not choose the reasons that support their mistake in the first tiers. They also found that 9 % of the students selected misconceptions for the first two tiers without expressing their confidence in the third tier. Eryılmaz and Sürmeli said that these students' wrong answers were due to lack of knowledge in which they did not show their confidence in the third tier. According to them, a misconception is not a mistake or a wrong answer due to lack of knowledge. They expressed the misconceptions as the conceptions in the students' minds that are incorrect scientifically. If someone has a misconception, it is necessary for him/her to say the reason of the mistake and say his/her confidence. They concluded that misconceptions can be distinguished from

mistakes and lack of knowledge with three-tier tests. Therefore, it can be said that three-tier tests measure the misconceptions more reliable than multiple-choice tests and two-tier tests.

5.4 Internal Validity

Internal validity means that observed differences on the dependent variable are directly related to the independent variable, and not due to some other unintended variable (Fraenkel & Wallen, 1996, p. 241). In this section, possible threats to internal validity and methods to deal with them were discussed.

The selection of the classes for the administration of the open-ended test and the TTGOMT was convenience sampling, thus a threat for the internal validity. And also, the students interviewed were selected by convenience sampling.

Location in which the students were interviewed and administered open-ended test and the TTGOMT may affect the students' responses. Therefore, students were interviewed in the schools' laboratories and provided comfortable conditions.

The open-ended test and the TTGOMT were administered in the same type of the classrooms. The classrooms had a board, a table and chair for the teachers, desks for the students about the same wideness, the same heating and lighting conditions, etc.

Instrument decay can be a threat to the internal validity. Because, scoring the 141 open-ended test results was long and difficult to score, thereby resulting in fatigue of the scorer. To avoid fatigue, scoring was done by the same scorer and students' responses were categorized systematically.

Data collector characteristics were also a threat to internal validity especially for the interviews. However, since the interviews were conducted by only the researcher, this threat was avoided.

Data collector bias could be a threat to internal validity for the interviews. Because, the data collector could lead the student responses in the purposes of desired outcomes from the interviews. However, a complete attention was paid to avoid the use of leading questions.

Testing could be a threat to internal validity. Because, in the interviews the students' responses were recorded by an audio-recorder. Therefore, students might have been alerted. However, when the students were informed why the audio-recorder was used they got relaxed.

Mortality and maturation could not be a threat to internal validity. Because, the data collection procedures for the interviews, open-ended tests and the TTGOMT were at just one point in time and the time took 40-45 minutes for the interviews and 30-35 minutes for the open-ended tests and the TTGOMT.

Also, confidentiality was not a threat to internal validity. Because, the names of the students were not taken in any part of the study.

5.5 External Validity

External validity is the extent to which the results of the study can be generalized. There are two types of external validity: population genaralizability and ecological genaralizability. Population generalizibility refers to the degree to which a sample represents the population of interest and ecological generalizability refers to the degree to which results of the study can be extended to other settings or conditions (Fraenkel & Wallen, 1996, p. 106).

The number of the 11^{th} grade science students in Bayrampaşa was approximately 900 students. The TTGOMT was administered to 141 students which is more than 15 % of the accessible population. Therefore, the results of the study can be generalized the accessible population, which covers all 11^{th} grade science students.

The administration of the TTGOMT occurred in ordinary classrooms during regular class hours. However, some variables such as region, socio-economic statues, ethnicity, education facilities, father's occupation etc. can affect the results of the study. Since these variables were not taken into account in the study, the generalizibility of the results is doubtful.

5.6 Implications of the Study

According to the results of the study and findings of the previous studies, following suggestions can be offered:

1. The results of the study and the previous studies showed that students have misconceptions and these misconceptions resist to change and obstructing the learning process. The teachers should take students' misconceptions into account. The more teachers know about theirs students' misconceptions, the more they will be able to provide them to learn.
2. In the study, it was found that the students who had higher scores on the test have as many misconceptions as the students who had lower scores. Therefore, the teachers should consider that even if the students have high scores on the exams, they may have as many misconceptions as the students who have low marks.
3. In the interviews, it was seen that even if the students were above average, the students had little or no understanding of a conceptual understanding of a physical phenomenon. For example, when the students were asked to explain seeing process of an image of any object in a plane mirror, most of the students could not explain the process. In fact, they complained that their teachers do not ask such questions asking conceptual understanding of the subject. They stated that this question is very simple and they had solved more difficult and complex questions for the plane mirrors. They concluded that they learn the types of questions and they resort to rote memorization of formulae and procedures but they do not understand the concepts scientifically. Therefore, teachers should emphasize on the conceptual understanding of the students.
4. Teachers can use the TTGOMT for formative evaluation to assess the misconceptions of the 11^{th} grade students about geometric optic. Therefore, it can be needed for them to use different methods or instruments in the lecture to make the concepts more clear and understandable.

5. The findings of the study show that multiple-choice tests and also two-tier tests overestimate the misconception of the students. Because, they do not take into account the mistakes of the students and lack of knowledge of the students. Moreover, both types of tests also overestimate the correct answers of the students. Therefore, to avoid from mistakes and lack of knowledge causing the wrong answers of the students teachers should use three-tier tests to investigate the misconceptions of the students. They should consider that the results of the multiple-choice tests or even if two-tier tests can be misleading while investigating the misconceptions of the students.
6. Identifying the students' misconceptions in geometric optic by the TTGOMT can give some feedback to the textbook editors. They can use more examples and simple questions dealing with the misconceptions instead of complex situations and questions.

5.7 Recommendations for Further Research

The recommendations for further studies can be as the followings:

1. This study was done for assessing the misconceptions of the students about geometric. The other physics topics can be studied and students' misconceptions can be investigated by a three-tier test that will have been developed in the study. It is also important to say that in the literature some concepts studied too much, whereas some concepts studied a few. Therefore, it is worth working with the concepts which were studied a few.
2. The TTGOMT was administered to 141 11^{th} grade students. However, the independent variables such as school type, gender, socio-economic statue etc. did not take into account. Therefore, a study that investigates the effects of these independent variables to the students' misconceptions about geometric optic can be studied.
3. In the study it was found that reliability of the misconceptions was lower than reliability of the correct answers. Consistency of conceptions and misconceptions can be investigated.
4. The TTGOMT was administered to 141 students. For ecological validity concerns, it can be administered to larger samples.

REFERENCES

Al-Rubayea, A. A. M. (1996). An analysis of Saudi Arabian high school students' misconceptions about physics concepts. Kansas State University. *Dissertation Abstracts International* (University Microfilms No. 9629018).

Beichner, R. J. (1994). Testing student interpretation of kinematics graphs. *American Journal of Physics, 62 (8)*, 750-762.

Bendall, S., Goldberg, F., & Galili, I. (1993). Prospective Elementary Teachers' Prior Knowledge about Light. *Journal of Research in Science Teaching, 30 (9),* 1169-87.

Çataloğlu, E. (2002). *Development and Validation of an Achievement Test in Introductory Quantum Mechanics: The Quantum Mechanics Visualization Instrument.* The Pennsylvania State University.

Chapter 2 Review of the Literature.(n.d.), http://webphysics.davidson.edu/faculty/mhd/dissertation/dissertation1/chaptwo.pdf, Last accessed date March 2004

Chapter 4. Multiple-Choice Concept Tests: The Force Concept Inventory. (n.d.), http://www.physics.umd.edu/perg/dissertations/saul/Chapter4.PDF, Last accessed date February 2004

Chen, C. C., Lin, S. H., & Lin, M. L. (2002). Developing a Two-Tier Diagnostic Instrument to Assess High School Students' Understanding - The Formation of Images by a Plane Mirror. *Proc. Natl. Sci. Counc. ROC(D), 12 (3),* 106-121.

Dupin, J. –J. & Johsua, S. (1987). Conceptions of French pupils concerning electric circuits: Structure and evolution. Journal of Research in Science Teaching, 24(9), 791-806.

Eryılmaz, A. & Sürmeli, E. (2002). *Üç-aşamalı Sorularla Öğrencilerin Isı ve Sıcaklık Konularındaki Kavram Yanılgılarının Ölçülmesi*, http://www.fedu.metu.edu.tr/ufbmek-5/, Last accessed date March 2004

Feher, E. & Rice, K. (1988). Shadows and Anti-Images : Children's Conceptions of Light and Vision. 2. *Science Education, 72 (5),* 637-649.

Fetherstonhaugh, T., & Treagust, D. F. (1992). Students' understanding of light and its properties: Teaching to engender conceptual change. *Science Education, 76,* 653-672.

Fraenkel, J. R., & Wallen, N. E. (1996). *How to design and evaluate research in education.* (3rd ed.). New York: McGraw-Hill.

Gee, J. K. (1988). The myth of lateral inversion. *Physics Education, 28,* 300-301

Goldberg, F., & McDermott, L. C. (1986). Student difficulties in understanding image formation by a plane mirror. *The Physics Teacher, 24,* 472-480.

Gredler, M. E. (n.d.). *Learning and Instruction Theory Into Practice. Newyork:* Macmillan Publishing Company.

Griffard, P. B., & Wandersee, J. H. (2001). The Two-Tier Instrument on Photosynthesis: What Does It Diagnose? *International Journal of Science Education, 23 (10),* 1039-52.

Gronlund, N. E. & Linn, R. L. (1990). *Measurement and evaluation in teaching*. New York: Mac Millian Publishing.

Hestenes, D. & Halloun, I. (1995). Interpreteting the Force Concept Inventory. A response to Huffman and Heller. *The Physics Teacher, 33,* 502-506.

Hestenes, D., Wells, M. & Swackhamer, G. (1992). Force Concept Inventory. *The Physics Teacher, 30,* 141-158.

Klammer, J. (1998). *An Overview of Techniques for Identifying, Acknowledging and Overcoming Alternative Conceptions in Physics Education*, http://www.klingenstein.org/html/research/projects/1998/klammer.htm, Last accessed date January 2004

Langley, D., Ronen, M., & Eylon, B. (1997). Light Propagation and Visual Patterns: Preinstruction Learners' Conceptions. *Journal of Research in Science Teaching, 34 (4),* 399-424.

Marx, J. D. (1988). Creation of a diagnostic exam for introductory, undergraduate electricity and magnetism. Rensselaer Polytechnic Institute, Troy, New York. *Dissertation Abstracts International* (University Microfilms No.9908686).

Mcleod, G., (n.d.). *Learning theory and Instructional Design*, http://courses.durhamtech.edu/tlc/www/html/Resources/learningmatters/learningtheory.pdf, Last accessed date January 2004

Mergel, B. (1998). *Instructional Design & Learning Theory*, http://www.usask.ca/education/coursework/802papers/mergel/brenda.htm, Last accessed date February 2004

Odom, A. L., & Barrow, L. H. (1995). Development and Application of a Two-Tier Diagnostic Test Measuring College Biology Students' Understanding

of Diffusion and Osmosis after a Course of Instruction. *Journal of Research in Science Teaching, 32 (1),* 45-61.

Osborne, R. J. & Gilbert, J. K. (1980). A technique for exploring students' views of the world. *Physics Education, 15,* 376-379

Reiner, M., Slotta, J. D., Chi, M. T. H., & Resnick, L. B. (2000). Naïve Physics Reasoning: A commitment to Substance Based Conceptions. *Cognition and Instruction, 18 (1),* 1-34.

Rollnick, M. & Mahooana, P. P. (1999). A quick and effective way of diagnosing student difficulties: two tier from simple multiple choice questions. *S. African Journal of Chemistry., 52 (4),* 161-164

Savinainen, A. & Scot, P. (2002). The Force Concept Inventory: a tool for monitoring student learning. *Physics Education, 37 (1),* 45-52.

Schwab, A. J. (2002). *Course Materials- Current semester*, http://www.utexas.edu/courses/schwab, Last accessed date February 2004

Steinberg, R. N. & Sabella, M. S. (1997). Performance on Multiple-Choice Diagnostics and Complementary Exam Problems. *Physics Teacher, 35,* 150-155.

The Free Dictionary (2005), http://www.thefreedictionary.com/conception, Last accessed date September 2005

Tsai, C. C., & Chou, C. (2002). Diagnosing students' alternative conceptions in science. *Journal of Computer Assisted Learning, 18,* 157-165.

Watts, D. M. (1985). Student Conceptions of *Light*: A Case Study. *Physics Education, 20 (4),* 183-87.

Zeilik, M. (n.d.). *Conceptual Diagnostic Tests*, http://www.flaguide.org/extra/download/cat/diagnostic/diagnostic. PDF, Last accessed date March 2004

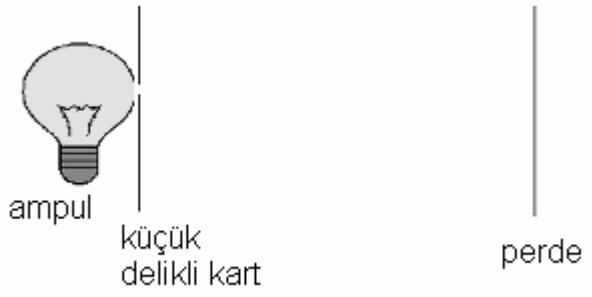
APPENDIX A

INTERVIEW GUIDE

1. Dışarıdan ışığın hiçbir durumda giremeyeceği yalıtılmış bir odada, vazo içinde çiçekler bulunmaktadır. Tamamen karanlık olan bu odada mum yakan birisi, vazonun beyaz; vazo içinde bir kırmızı, bir sarı, bir mor, bir pembe çiçeği ve bu çiçeklerin yeşil yapraklarının olduğunu görmektedir. Eğer mum söndürülürse, bu kişi neler görebilecektir? Açıklayınız.

2. Işığın aldığı mesafe gündüz ve geceleyin farklılık gösterir mi? Açıklayınız.

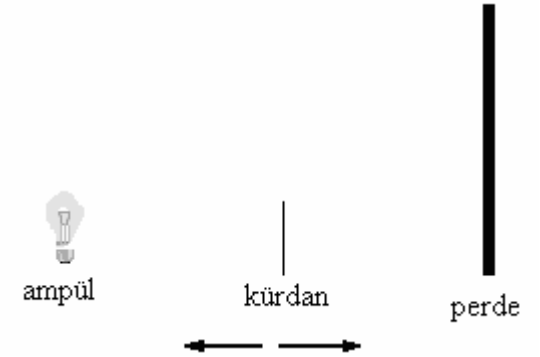
3. Şekil 1'de görüldüğü gibi, küçük delikli kart ampulün ortasına delik olan kısmı gelecek şekilde yerleştirilirse perdede ne görürsün? Açıklayınız.



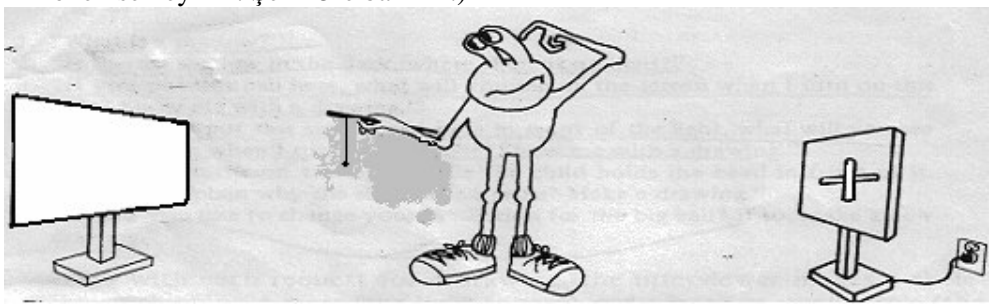
Şekil 1

4. Bir önceki soru için, perde ampulden uzaklaştırılırsa, perdede herhangi bir şey değişir miydi? Açıklayınız.

5. Şekil 2'de görüldüğü gibi ampul ile perdenin arasına bir kürdan konmuş ve kürdan ekrana yaklaştırılıp uzaklaştırılmaktadır. Kürdan ekrana yaklaştırıldığında gölge daha net olurken ekrandan uzaklaştırıldığında dağılmaktadır. Bu durumu açıklayabilir misiniz?



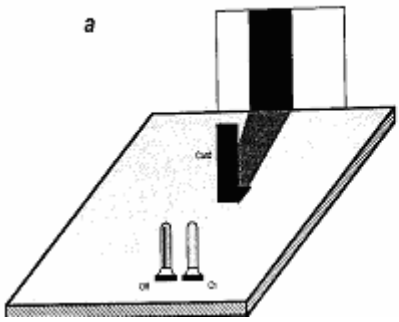
6. Eğer küçük yuvarlak boncuğu artı şeklindeki ışık kaynağının önüne koyarsak, ışık yandığında perdede ne görürsün? Açıklayınız. (Boncuğun asılı olduğu ipi önemsemeyiniz. Şekil 3'e bakınız.)



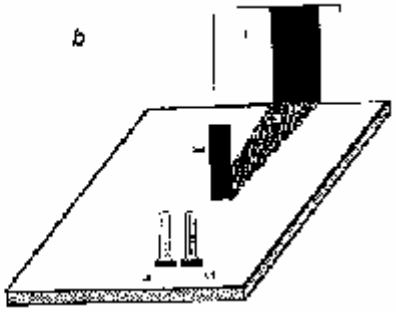
Şekil 3

7. Bir önceki soru için, yapılan deneyde gölgenin artı bir işaret olduğu gözlenmiştir. Gölgenin niçin artı bir işaret olduğunu açıklayabilir misiniz?

8. Şekillerde görüldüğü gibi tek düzeneğin üzerine iki ışık kaynağı yan yana konmuştur, önlerine bir kart ve kartın arkasına bir ekran yerleştirilmiştir. Işık kaynaklarından ilk önce sağdaki açılmış ve perdede şekil 4'de olduğu gibi gölge oluşmuştur. Daha sonra soldaki ışık kaynağı açılmış ve şekil 5'de olduğu gibi gölge şekil 4'da oluşan gölgeye göre biraz daha sağa kaymıştır. Farzedin ki her iki kaynak aynı anda açılırsa ekranda ne görürdünüz? Açıklayınız.

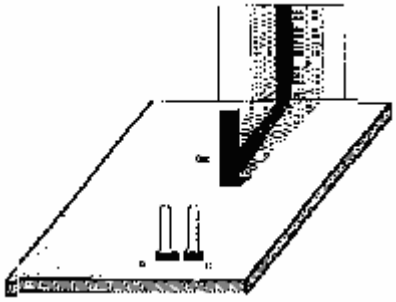


Şekil 4



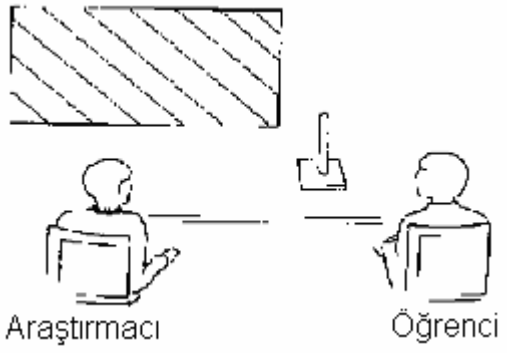
Şekil 5

9. Bir önceki soru için, yapılan deneyde ekranda aşağıdaki şekle benzer bir şekilde gölge oluştuğu gözlenmiştir. Gölgedeki açık ve koyu bölgeleri açıklayınız. Bu durumu şekil çizerek gösteriniz.



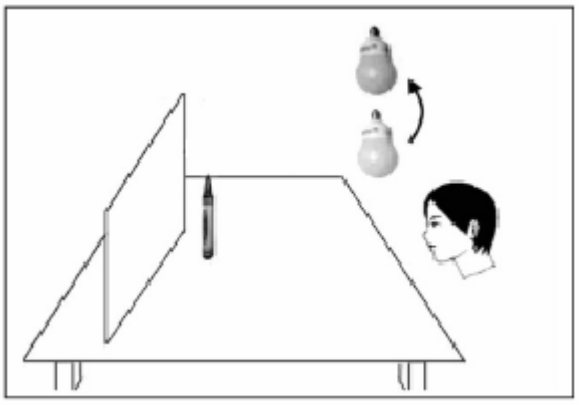
Şekil 6

10. Bir araştırmacı ve bir çocuk bir düz aynanın önüne şekil 7'de olduğu gibi oturmaktadırlar. Araştırmacı aynayı bir örtü ile kapamış ve aynanın ön cephe sınırlarının dışında, biraz daha sağ tarafına tahta bir çubuk koymuştur. Aynanın üzerindeki örtü olmasa, öğrenci cismin görüntüsünü aynada görür mü? Araştırmacı cismin görüntüsünü görür mü? Açıklayınız.



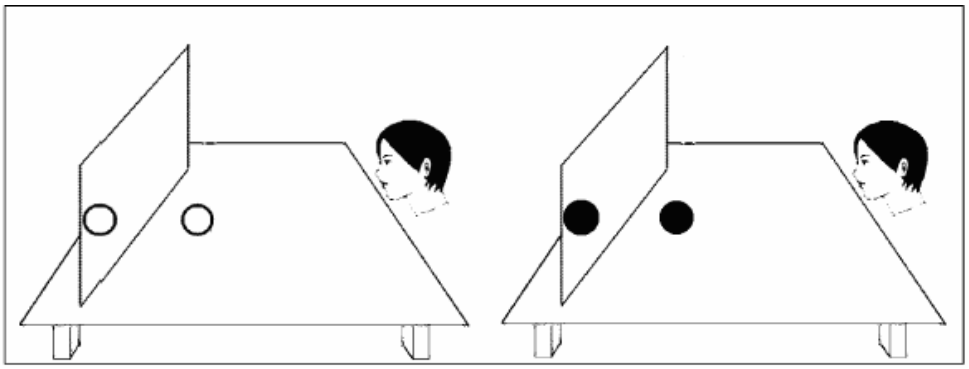
Şekil 7

11. Bir düz ayna ve kalem, masanın üzerine şekil 8'de olduğu gibi yerleştiriliyor. Bir gözlemci kalemin görüntüsünü görebilmek için aynaya bakmaktadır. Ortamdaki tek ışık kaynağı bir ampuldür. Eğer ampul biraz daha yukarı kaldırılacak olursa, kalemin aynadaki gözlemci tarafından görülen görüntüsünün yerinde ne değişiklik olur? Açıklayınız.



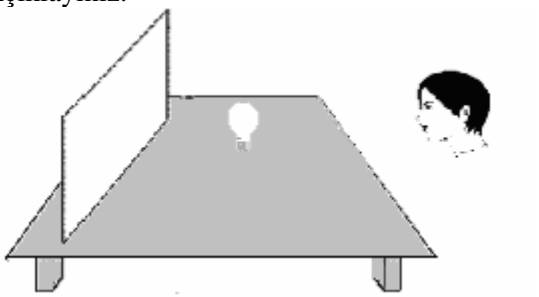
Şekil 8

12. Şekil 9'da görüldüğü gibi, beyaz bir top düz aynanın önüne konmuştur. Bir gözlemci bu topu görebilmektedir. Daha sonra, beyaz top siyah bir topla değiştirilmiştir.Her iki durumda da aynadaki görüntü oluşum işlemini ve bu görüntülerin nasıl görüldüğünü açıklayabilir misiniz?



Şekil 9

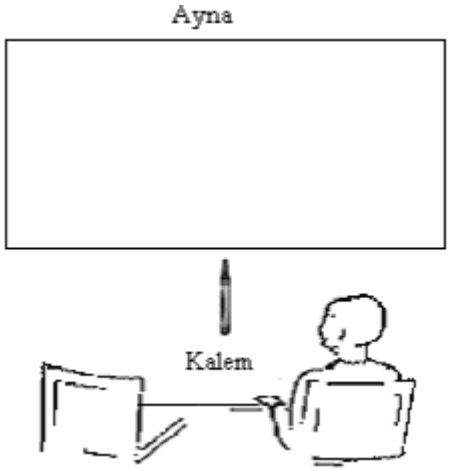
13. Dışarıdan ışığın hiçbir durumda giremeyeceği yalıtılmış bir odadaki bir düz ayna önünde, beyaz bir lamba bulunmaktadır. Lamba açıkken aynaya bakan bir çocuk, aynada lambanın görüntüsünü görebilmektedir. Odadaki diğer ışıklar ve lamba kapatılırsa çocuk hala aynada lambanın görüntüsünü görebilir mi? Açıklayınız.



Şekil 10

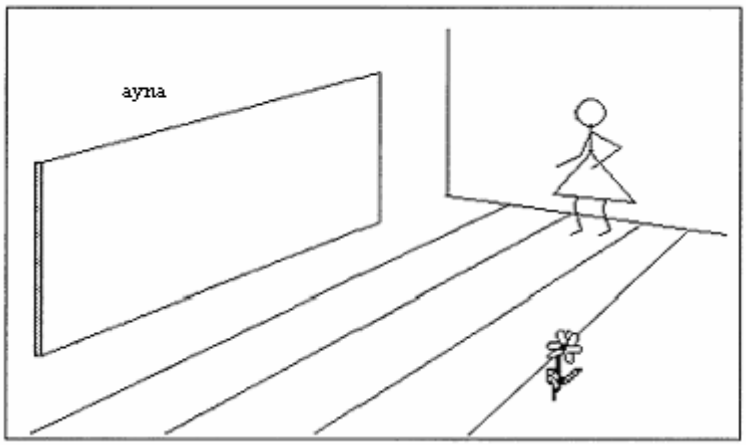
14. Bir önceki soru için, aynada çocuk göremese de hala lambanın bir görüntüsü oluşur mu? Açıklayınız.

15. Bir çocuk bir düz aynanın karşısına oturup aynanın karşısında durmakta olan kalemin görüntüsüne bakmaktadır. Eğer çocuk, solundaki boş sandalyeye geçerse görüntünün yeri değişir mi? Açıklayınız.



Şekil 11

16. Odanın bir tarafında ayakta duran kız aynaya bakmaktadır. Kız aynada çiçeğin görüntüsünü görebildiğini söylemektedir.
    a) Kızın çiçeği aynada nasıl görebildiğini açıklayınız.
    b) Şekli kızın aynada çiçeği nasıl gördüğünü açıklayan çizimle tamamlayınız.

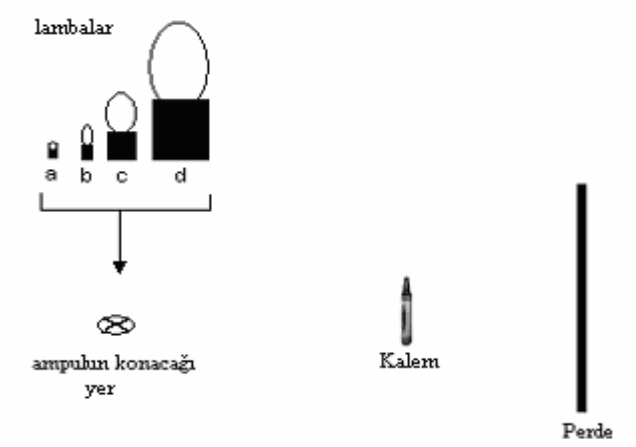


Şekil 12

APPENDIX B

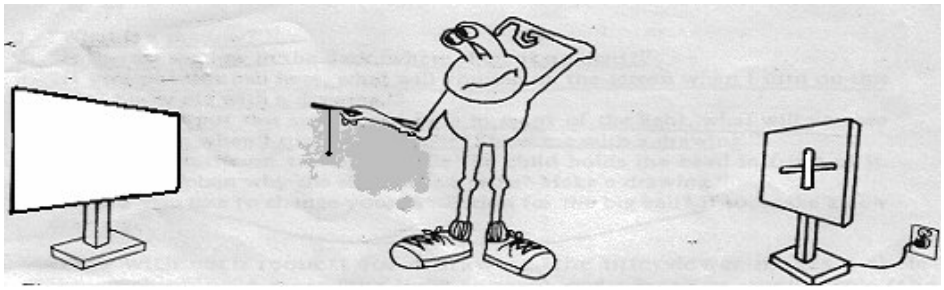
OPEN-ENDED TEST

1. Dışarıdan ışığın hiçbir durumda giremeyeceği yalıtılmış bir odada, vazo içinde çiçekler bulunmaktadır. Tamamen karanlık olan bu odada mum yakan birisi, vazonun beyaz; vazo içinde bir kırmızı, bir sarı, bir mor, bir pembe çiçeği ve bu çiçeklerin yeşil yapraklarının olduğunu görmektedir. Eğer mum söndürülürse, bu kişi neler görebilecektir? Açıklayınız.
2. Işığın aldığı mesafe gündüz ve geceleyin farklılık gösterir mi? Nedenini kısaca açıklayınız.
3. Şekilde 1'de farklı büyüklükte özdeş dört ampul verilmiştir. Bu ampullerin her biri şekilde belirtilen yere ayrı ayrı konulup kalemin ve perdenin yerleri sabit tutulursa, her bir ampul için perdede gölge oluşmaktadır. Gölgeleri netlik açısından karşılaştırınız. Nedenlerini açıklayınız.



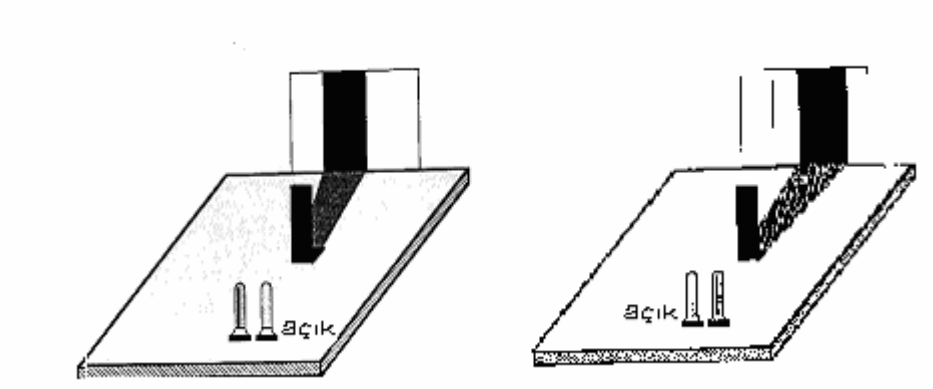
Şekil 1

4. Eğer bu küçük yuvarlak boncuğu artı şeklindeki ışık kaynağının önüne koyarsak, ışık yandığında perdede ne görürsün? (Boncuğun asılı olduğu ipi önemsemeyiniz.) Nedenini açıklayınız.



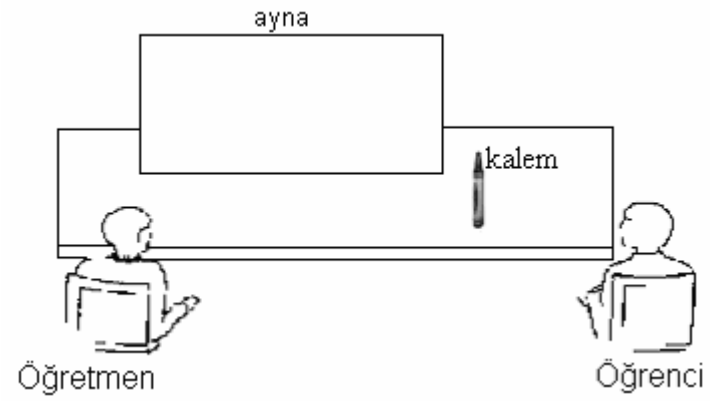
Şekil 2

4. Şekillerde görüldüğü gibi tek düzeneğin üzerine iki ışık kaynağı yan yana konmuştur, önlerine bir kart ve kartın arkasına bir ekran yerleştirilmiştir. Işık kaynaklarından önce sağdaki açılmış ve perdede şekil 3' de olduğu gibi gölge oluşmuştur. Daha sonra soldaki ışık kaynağı açılmış ve şekil 4'de olduğu gibi gölge şekil 3'de oluşan gölgeye göre biraz daha sağa kaymıştır. Farzedin ki her iki kaynak aynı anda açılırsa ekranda ne görürdünüz? Nedenini açıklayınız.



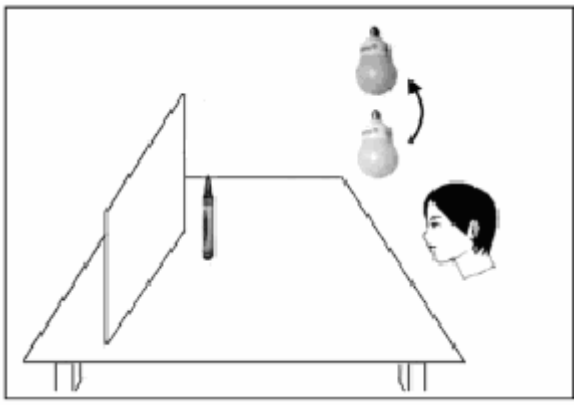
Şekil 3 Şekil 4

6. Aşağıdaki şekilde bir öğretmen ve öğrenci üzerinde ayna ve kalem konulmuş masanın etrafına oturuyorlar. Kalem aynanın ön cephe sınırlarının dışına konuluyor ve öğrenci kalemin biraz daha sağında oturuyor (şekle bakınız). Sizce, öğrenci cismin görüntüsünü aynada görür mü? Öğretmen, cismin görüntüsünü aynada görür mü? Şekil çizerek nedenlerini açıklayınız.



Şekil 5

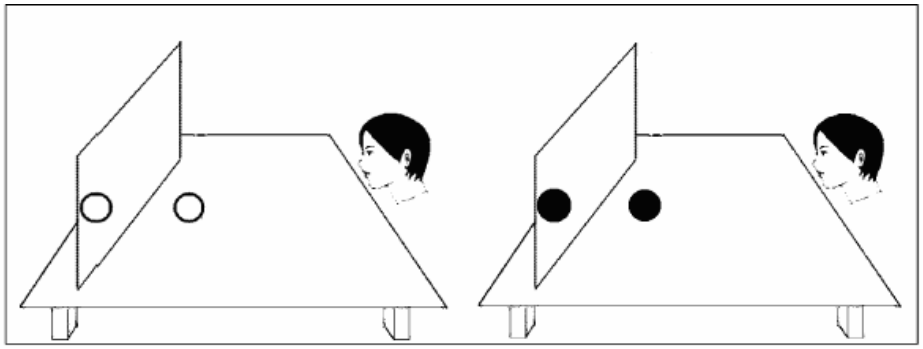
7. Bir düz ayna ve kalem, masanın üzerine şekil 6'da olduğu gibi yerleştiriliyor. Bir gözlemci kalemin görüntüsünü görebilmek için aynaya bakmaktadır. Ortamdaki tek ışık kaynağı bir ampuldür. Eğer ampul biraz daha yukarı kaldırılacak olursa, kalemin aynadaki gözlemci tarafından görülen görüntüsünün yerinde ne değişiklik olur? Sebebini açıklayınız.



Şekil 6

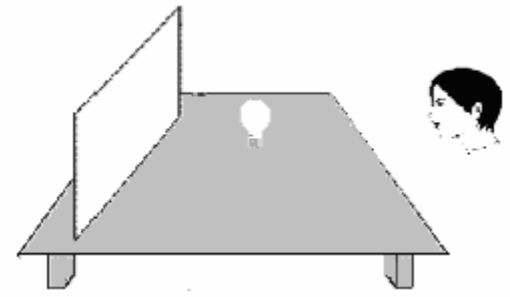
8. Ayna karşısında durmakta olan Ali, aynada vücudunun üst yarısını görebilmektedir. Ali'nin vücudunun tamamını görebilmesi için yapabileceği bir şey var mı? Varsa nedenini kısaca açıklayınız.

9. Şekil 7'de beyaz bir top, görüldüğü gibi düz aynanın önüne konmuştur. Bir gözlemci bu topu aynada görebilmektedir. Daha sonra, beyaz top siyah bir topla değiştirilmiştir.Her iki durumda da aynadaki görüntü oluşumunu ve bu görüntülerin nasıl görüldüğünü açıklayabilir misiniz?



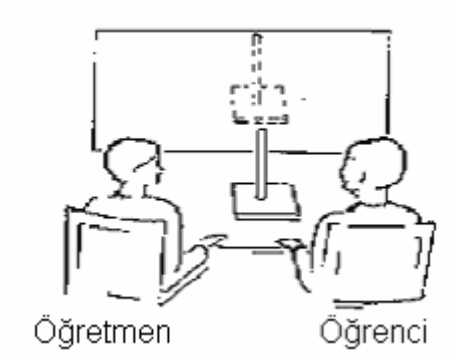
Şekil 7

10. Dışarıdan ışığın hiçbir durumda giremeyeceği yalıtılmış bir odadaki bir düz ayna önünde, beyaz bir lamba bulunmaktadır. Lamba açıkken aynaya bakan bir çocuk, aynada lambanın görüntüsünü görebilmektedir. Odadaki diğer ışıklar ve lamba kapatılırsa aynada ampulün görüntüsü oluşur mu? Nedenini açıklayınız.



Şekil 8

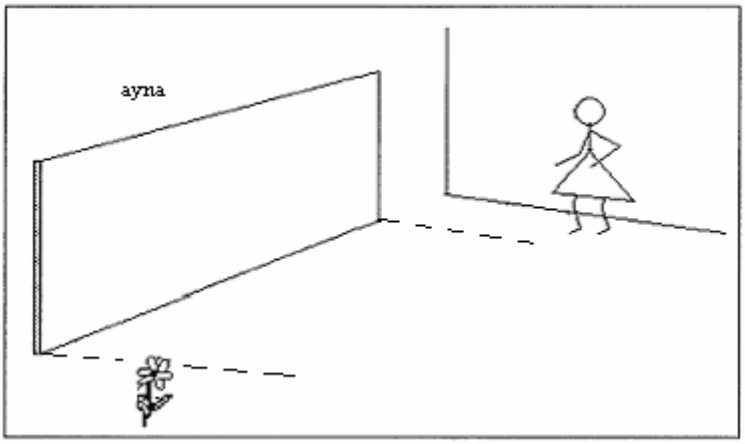
11. Bir öğretmen ile bir öğrenci bir düz aynanın karşısına oturmuşlardır. Öğretmen, aynanın karşısına öğrencinin görebileceği bir tahta çubuk koymuştur. Eğer öğrenci iki adım solunda olan öğretmeninin yerine geçerse öğrencinin görmüş olduğu cismin görüntüsünün yeri değişir miydi? Nedenini kısaca açıklayınız.



Şekil 9

12. Geceleyin uyumakta olan Mustafa, çenesini ısıran bir sivrisinek tarafından uyandırılmıştır. Karanlık odasında, çenesindeki ısırığı görmek isteyen Mustafa eline ayna ve elfeneri almıştır. Çenesini aynada görmek isteyen Mustafa, el fenerinin ışığını nereye tutmalıdır? Nedenini açıklayınız.

13. Aşağıdaki şekilde odanın bir tarafında ayakta duran kız, aynaya bakmaktadır. Kız, aynada çiçeğin görüntüsünü görebilir mi? Şekil üzerinde çizimle gösteriniz ve nedenini açıklayınız.



Şekil 10

APPENDIX C

THREE-TIER GEOMETRIC OPTIC MISCONCEPTION TEST

GEOMETRİK OPTİK

OKULUNUZ	: ☐Anadolu Lisesi	☐ Düz Lise	☐Süper Lise
CİNSİYETİNİZ	: ☐ Erkek	☐ Kız	

Yönergeler

1. Sınava başlamadan önce yukarıda verilen kısma **okulunuzun türünü** ve **cinsiyetinizi** işaretleyiniz.
2. Testte 16 soru vardır. Her bir sorunun üç alt aşamalı sorusu vardır. Birinci aşamada fiziksel bir olay ya da fiziksel bir olayın sonucu sorulmuştur. İkinci aşamada, birinci aşamada verilen cevabın nedeni sorulmuştur. Üçüncü aşamada ise bir ve ikinci aşamalarda verilen cevaplardan emin olunup olunmadığı sorulmuştur.
3. Bu testtin sonuçları Ortadoğu Teknik Üniversitesi'nde Orta Öğretim Fen ve Matematik Eğitimleri Bilimi Alanı'nda yüksek lisans yapan araştırmacının tezinde veri olarak kullanılacaktır.
4. Bütün sorulara cevap vermek için gayret gösteriniz. Cevap vermek istediğiniz şıkkı yuvarlak daire içine alınız.
5. Bu bir bilimsel çalışmadır. Sizde şu an bilimsel bir çalışmanın parçasısınız. Gerekli ilgiyi gösterdiğiniz için teşekkür ederim.

IŞIK

1.1. Dışarıdan ışığın hiçbir durumda giremeyeceği yalıtılmış bir odada, vazo içinde çiçekler bulunmaktadır. Tamamen karanlık olan bu odada mum yakan birisi, vazonun beyaz; vazo içinde bir kırmızı, bir sarı, bir mor, bir pembe çiçeği ve bu çiçeklerin yeşil yapraklarının olduğunu görmektedir. Eğer mum söndürülürse, bu kişi neler görebilecektir?

a) Beyaz vazoyu ve açık renkli çiçekleri görebilir.
b) Vazoyu da çiçekleri de göremez.
c) Net olmasa da cisimleri yine görebilecektir.
d) Cisimlerin rengini net göremese de karartılar halinde şekillerini görebilir.

1.2. Yukarıdaki seçeneği seçmemin sebebi;

a) Mum söndüğü zaman ortamda siyah ışın olduğu için cisimler siyah yansıyacaktır.
b) Mum söndükten bir süre sonra göz, karanlıkta görmeye alışacaktır.
c) Mum söndüğünde ortamda cisimlerin renklerini yansıtacak ışık olmayacağı için cisimleri karartılar halinde görecektir.
d) Mum söndüğünde ortamda cisimlere çarpıp yansıyacak ışık olmayacaktır.
e) Mum söndüğünde açık renkli cisimlerin yaydığı ışık olacağı için, açık renkli cisimler kendilerini karanlıkta belli ederler.

1.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz?

a) Eminim. b) Emin değilim.

2.1. Işığın aldığı mesafe gündüz ve geceleyin farklılık gösterir mi?

a) Gösterir, ışık gece daha çok yol alır.
b) Gösterir, ışık gündüz daha çok yol alır.
c) Göstermez, ışık gece ve gündüz eşit yol alır.

2.2. Yukarıda seçeneği seçmemin sebebi;

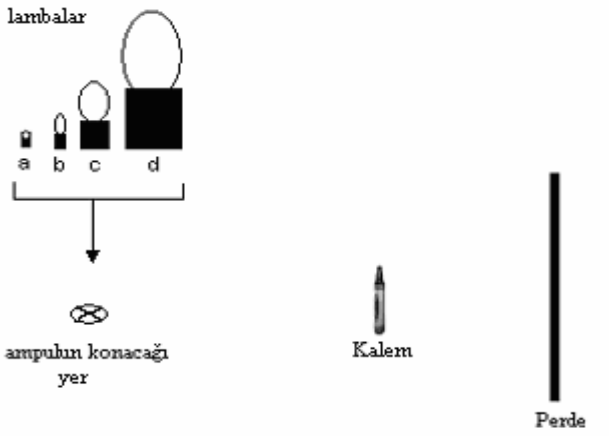
a) Geceleyin ortam karanlık olduğundan yansıma en azdır.
b) Gündüz görünen uzaktaki cisimler, gece görünmeyebilir.
c) Gündüz ortamdaki güneş ışığı ışığın ilerlemesini kolaylaştırır.
d) Işık hızı ortamın yoğunluğuna bağlıdır.
e) Işık, gücünü gece hem ilerlemek hem de etrafını aydınlatmak için kullanır.
f) Gündüz, ışık her tarafa yayılırken gece sabit bir noktaya odaklanır.
g) Gündüz ortamdaki güneş ışığı, ışığın ilerlemesini engeller.

2.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz?

a) Eminim. b) Emin değilim.

GÖLGE

3.1. Şekil 1'de, farklı büyüklükte parlaklık olarak özdeş dört ampul verilmiştir. Bu ampullerin her biri şekilde belirtilen yere ayrı ayrı konulup kalemin ve perdenin yerleri sabit tutulursa, her bir ampul için perdede gölge oluşmaktadır. Gölgeleri <u>netlikleri</u> açısından karşılaştırınız.



Şekil 1

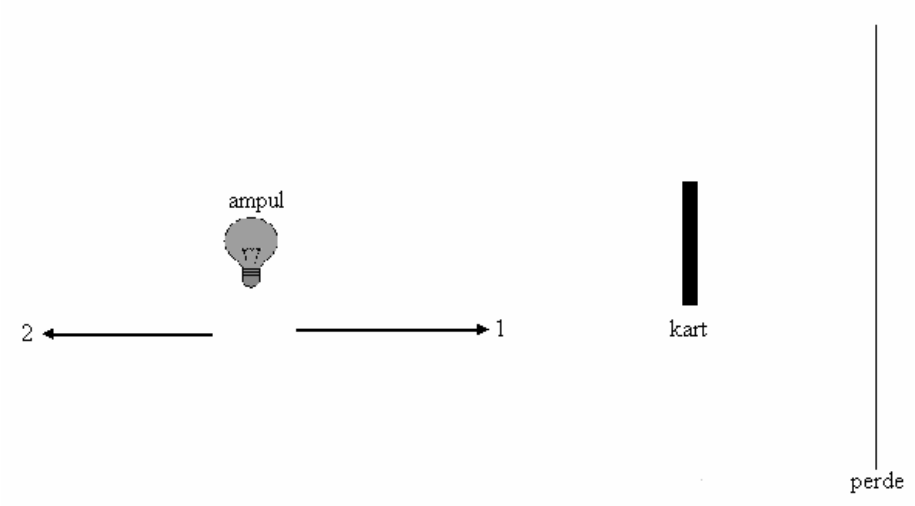
a) a >b>c>d
b) a<b<c<d
c) a=b=c=d

3.2. Yukarıdaki seçeneği seçmemin sebebi;
a) Ampul büyüdükçe daha güçlü ışık verir.
b) Ampul büyüdükçe gölgenin boyu küçülür.
c) Ampuller küçülerek noktasal ışık kaynağına benzedikçe daha az yarı gölge oluşur.
d) Ampullerin kaleme olan uzaklıkları ve kalemin boyu hepsi için sabittir. Ampul büyüklüklerinin gölgenin netliğine etkisi yoktur.

3.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz?
a) Eminim. b) Emin değilim.

4.1. Aşağıdaki şekilde bir perde ile yanmakta olan ampul arasına bir kart konulmuştur. Ampul hangi yönde hareket ettirilirse perdedeki gölgenin netliği daha belirgin olur?

a) 1 yönüne
b) 2 yönüne
c) Hiçbiri



Şekil 2

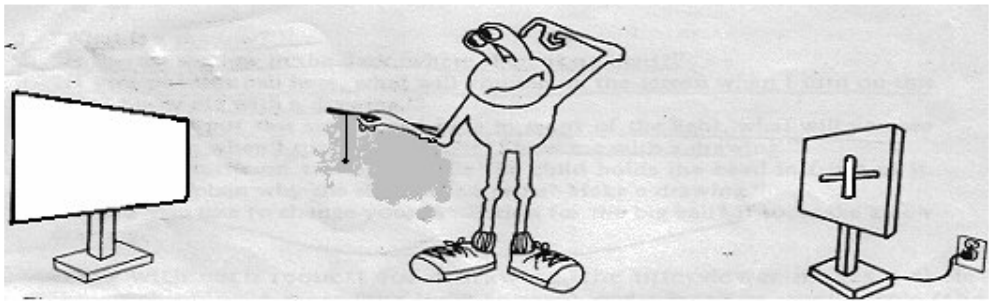
4.2. Yukarıdaki seçeneği seçmemin sebebi;

a) Ampulün yerinin önemi yoktur, kart ile perde arasındaki uzaklık önemlidir.
b) Ampul yaklaştıkça karta daha güçlü ışık gelir.
c) Ampul karttan uzaklaşırken noktasal ışık kaynağına benzediği için daha az yarı gölge oluşur.

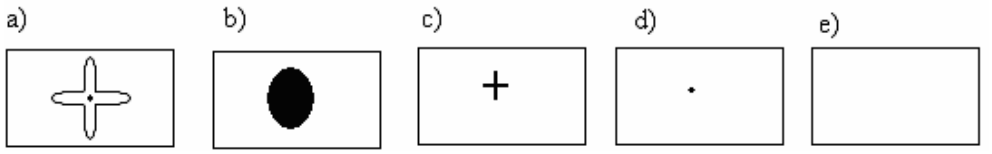
4.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz?

a) Eminim. b) Emin değilim.

5.1. Eğer bu küçük yuvarlak boncuğu artı şeklindeki ışık kaynağının önüne koyarsak, ışık yandığında perdede ne görürsün? (Boncuğun asılı olduğu ipi önemsemeyiniz.)



Şekil3



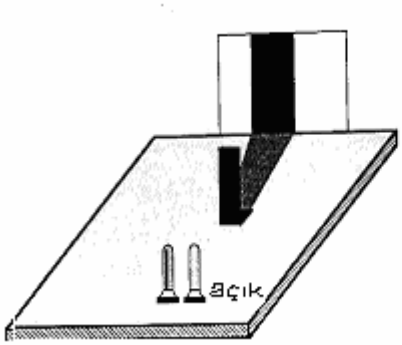
5.2. Yukarıdaki seçeneği seçmemin sebebi;

a) Işık kaynağı boncuğa göre çok büyük olduğu için perdenin her yerine ışık gönderebilir.
b) Işık kaynağından çıkan ışınlar perdeye doğrusal gittiği için perdede artı şekinde bir aydınlanma olur. Boncuğun üzerine gelen ışınları engellemesiyle artı şeklindeki aydınlanmanın ortasında noktasal bir gölge oluşur.
c) Işık kaynağının şeklinin gölge oluşumunda etkisi yoktur. Önemli olan ışığı engelleyen cismin şeklidir.
d) Işık kaynağının bir noktasından her yöne dağılan ışınlardan bir tanesi boncuk tarafından engellenir. Artı ışık kaynağının her bir noktasının perdede gölgesi olur. Bu gölgelerin perde üzerinde yan yana bulunmasıyla artı şekli olur.

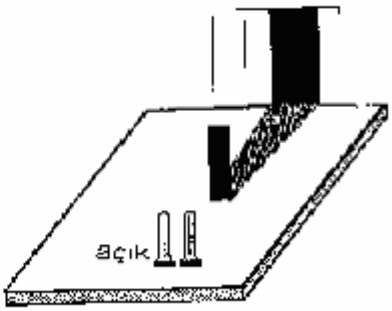
5.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz?

a) Eminim. b) Emin değilim.

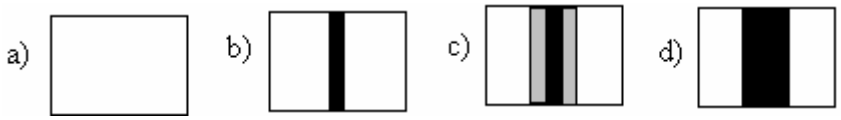
6.1. Şekillerde görüldüğü gibi tek düzeneğin üzerine iki ışık kaynağı yan yana konmuştur, önlerine bir kart ve kartın arkasına bir ekran yerleştirilmiştir. Işık kaynaklarından ilk önce sağdaki açılmış ve perdede şekil 4'de olduğu gibi gölge oluşmuştur. Daha sonra soldaki ışık kaynağı açılmış ve şekil 5'de olduğu gibi gölge şekil 4'de oluşan gölgeye göre biraz daha sağa kaymıştır. Farzedin ki her iki kaynak aynı anda açılırsa ekranda ne görürdünüz?



Şekil 4



Şekil 5



6.2. Yukarıdaki seçeneği seçmemin sebebi;

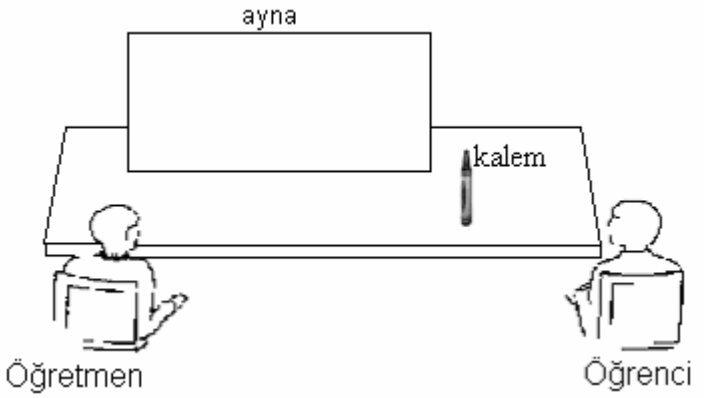
a) Her iki ışık kaynağından çıkan ışınların kart tarafından engellenmesiyle perdede iki gölge oluşur. Bu iki gölge perdede birleştiği için koyu büyük bir gölge oluşur.
b) Her iki kaynağın ışığının gidemediği yerde küçük koyu bir gölge oluşurken diğer yerler her bir ışık kaynağı tarafından aydınlatıldığı için aydınlık olur.
c) Her iki ışık kaynağının kart tarafından engellediği bölgede küçük koyu bir gölge olur. Yan taraflarında birinin aydınlatıp diğerinin aydınlatamadığı yeler, her ikisinin aydınlattığı yerlere göre daha az aydınlık olur.
d) Her iki kaynaktan ışık almayan orta kısımda koyu bir gölge oluşur. Koyu gölgenin yan taraflarında bir kaynağın engellenmesiyle oluşan gölge ile diğerinin oluşturduğu aydınlığın birleşmesi ile daha açık bir gölge oluşur.
e) Her bir kaynağın ışık gönderemediği yerlere diğer kaynak ışık gönderdiği için perde aydınlık olur.

6.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz?

a) Eminim. b) Emin değilim.

Düz Ayna

7.1. Aşağıdaki şekilde bir öğretmen ve öğrenci üzerinde ayna ve kalem konulmuş masanın etrafına oturuyorlar. Kalem aynanın ön cephe sınırlarının dışına konuluyor ve öğrenci kalemin biraz daha sağında oturuyor. Sizce, öğrenci cismin görüntüsünü aynada görür mü? Öğretmen, cismin görüntüsünü aynada görür mü?



Şekil 6

a) Sadece öğrenci görür.
b) Sadece öğretmen görür.
c) Her ikisi de göremez.
d) Her ikisi de görür.

7.2. Yukarıdaki seçeneği seçmemin sebebi;

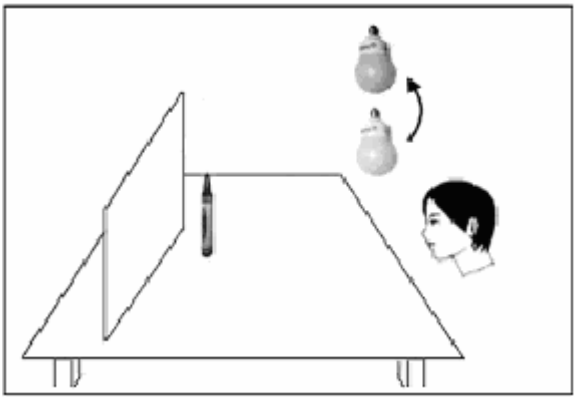
a) Öğretmenin kaleme baktığı doğrultu aynanın dışında kalırken, öğrencinin kaleme baktığı doğrultu ayna ile kesişmektedir.
b) Kalemden aynaya yansıyan ışınlar aynadan öğretmene yansımaktadır. Fakat, kalemden aynaya yansıyan ışınların aynadan öğrenciye yansıma ihtimali yoktur.
c) Her iki gözlemci, kalem aynanın yansıtıcı ön cephe sınırları içersine girmediği için göremez.
d) Kalem her iki gözlemcinin görüş alanları içersindedir.
e) Öğretmenin gözünden çıkan ışınlar aynaya gelip aynadan cismin üzerine yansır. Öğrencinin gözünden çıkan ışınların aynadan yansıyıp kalemin üzerine gelme ihtimali yoktur.
f) Kalemin aynada bir görüntüsü oluşur. İki gözlemci de bakış açıları uygun olduğu için görebilirler.

7.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz?

a) Eminim. b) Emin değilim.

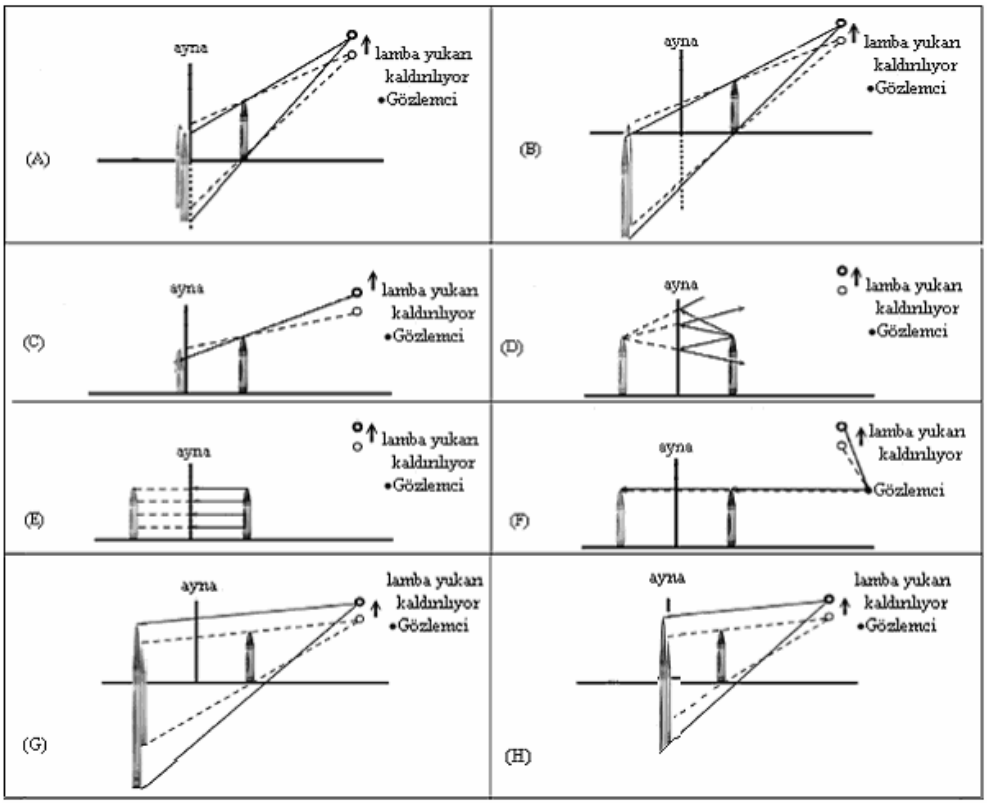
8.1. Bir düz ayna ve kalem, masanın üzerine şekilde olduğu gibi yerleştiriliyor. Bir gözlemci kalemin görüntüsünü görebilmek için aynaya bakmaktadır. Ortamdaki tek ışık kaynağı bir ampuldür. Eğer ampul biraz daha yukarı kaldırılacak olursa, kalemin aynadaki gözlemci tarafından görülen görüntüsünün yerinde ne değişiklik olur?

a) Yukarı çıkar.
b) Aşağı kayar.
c) Görüntünün yeri değişmez.



Şekil 7

8.2. Yukarıdaki seçeneği seçmemin sebebi;



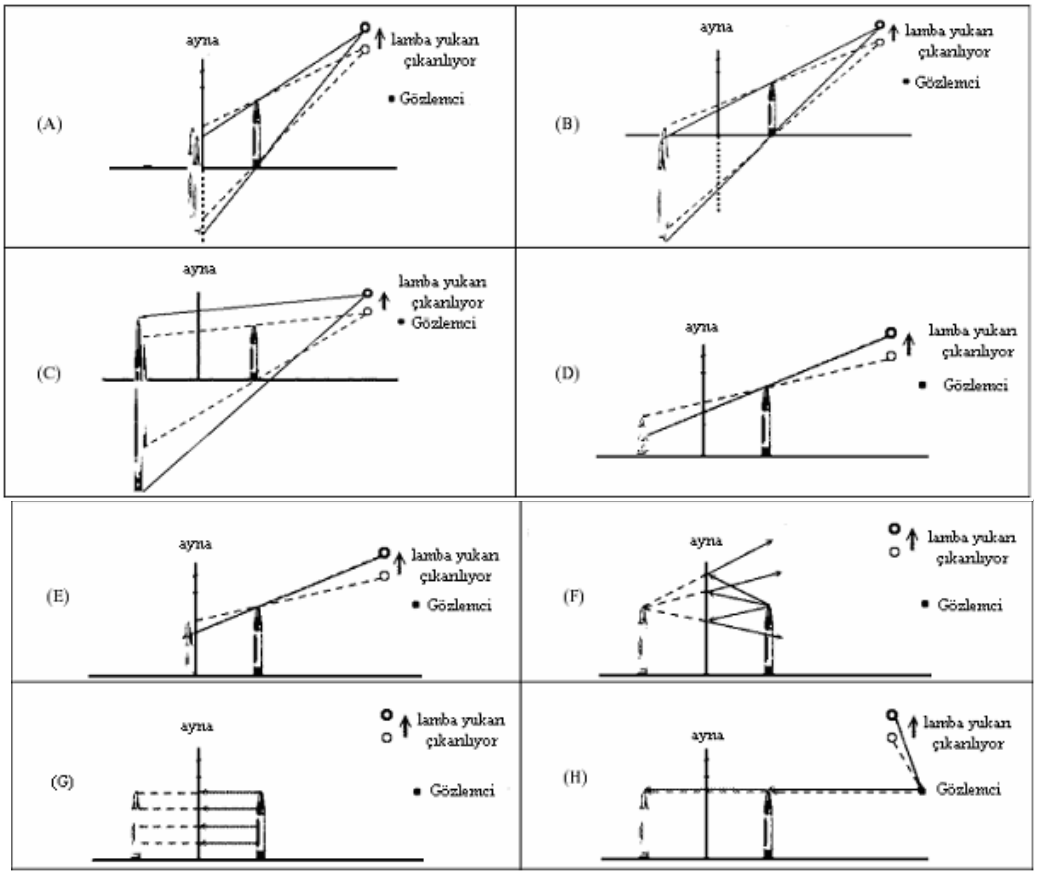
8.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz?

a) Eminim. b) Emin değilim.

9.1. (Bir önceki soru için) Eğer ampul yukarı kaldırılırsa görüntünün <u>boyunda</u> ne değişiklik olur?

a) Görüntünün boyu büyür.
b) Görüntünün boyu küçülür.
c) Görüntünün boyu değişmez.

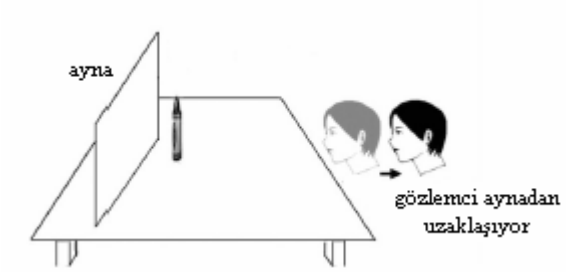
9.2. Yukarıdaki seçeneği seçmemin sebebi;



9.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz

a) Eminim. b) Emin değilim.

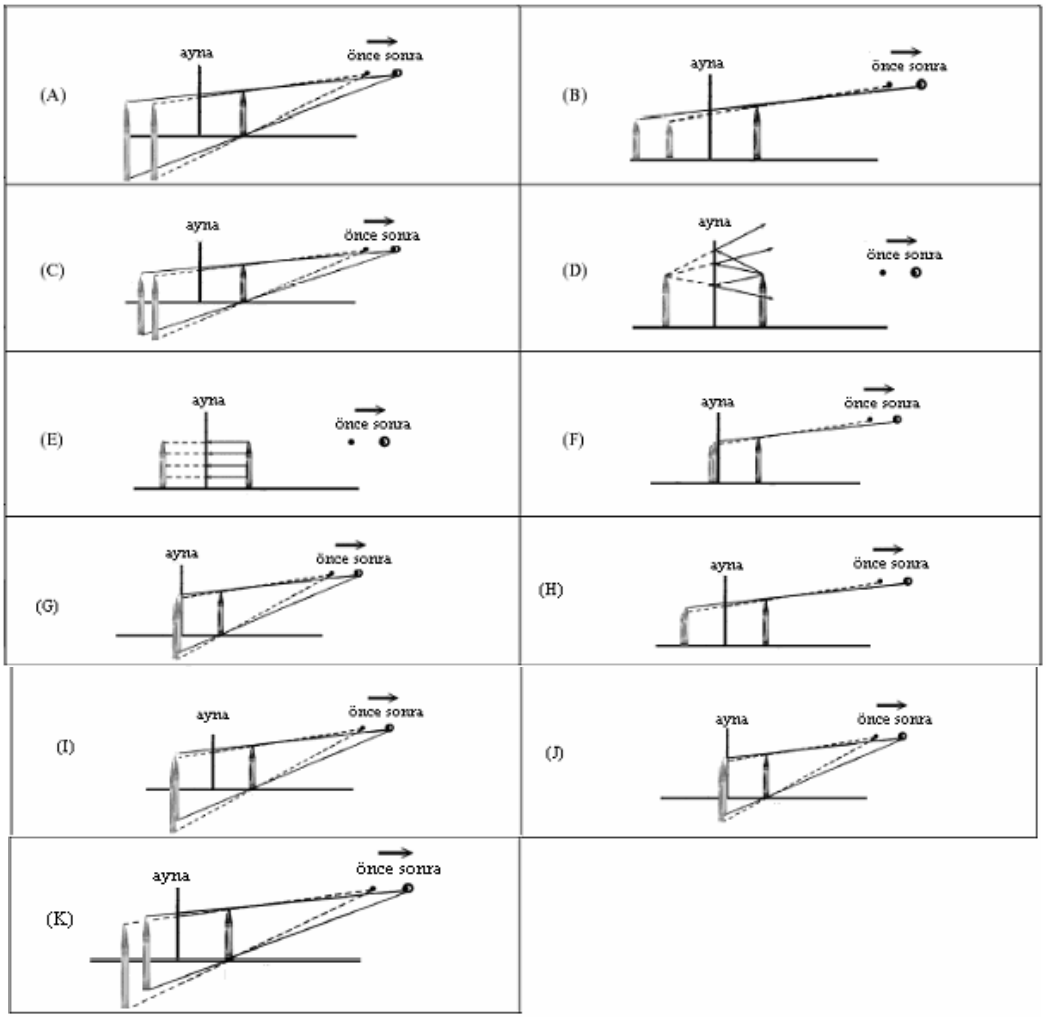
10.1. Aşağıdaki şekilde bir çocuk bir düz aynanın önünde duran kalemin aynadaki görüntüsüne bakmaktadır. Eğer çocuk aynadan geri geri giderek uzaklaşırsa aynadaki cismin görüntüsünün yerinde ne değişiklik olur?



Şekil 8

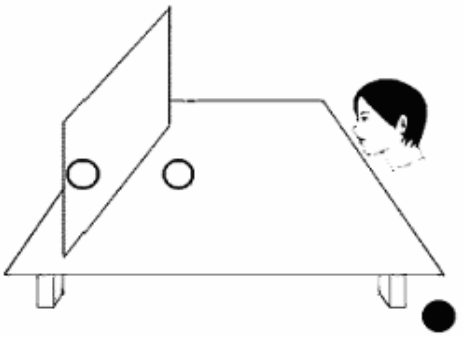
a) Görüntü aynadan uzaklaşır.
b) Görüntünün yeri değişmez.
c) Görüntü aynaya yaklaşır.

10.2. Yukarıdaki seçeneği seçmemin sebebi;



10.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz?
a) Eminim. b) Emin değilim.

11.1. Şekil 9'da beyaz bir top, görüldüğü gibi düz aynanın önüne konmuştur. Bir gözlemci beyaz topu aynada görebilmektedir. Daha sonra beyaz top kaldırılıp yerine aynı büyüklükte siyah bir top konmuştur.



Şekil 9

Aşağıdakilerden hangisi doğrudur?

a) Gözlemci siyah topu aynada görebilir.
b) Gözlemci siyah topu aynada göremez.

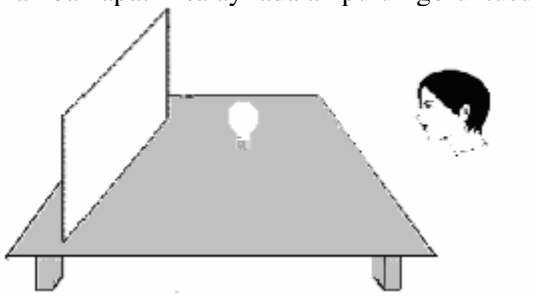
11.2. Yukarıdaki seçeneği seçmemin sebebi;

a) Siyah top üzerine gelen ışığı aynaya yansıtıp, aynadan yansıyan ışınlar gözlemcinin gözüne gelir.
b) Gözlemcinin gözünden çıkan ışınlar aynadan yansıyarak, siyah topun üzerine gelir.
c) Siyah topun yaydığı siyah ışınlar, aynadan yansıyarak gözlemcinin gözüne gelir.
d) Topun renginin siyah olmasının önemi yoktur. Siyah top çocuğun aynaya baktığı doğrultuda olduğundan aynadaki görüntüyü görür.
e) Siyah topun etrafındaki yerlerden ışınlar aynaya yansıyıp gözlemcinin gözüne gelirken siyah toptan ışın yansımayacağı için gözlemci orayı karartı görecektir.
f) Siyah top ne üzerine gelen ışığı yansıtır ne de kendisi ışık yayar.

11.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz?

a) Eminim. b) Emin değilim.

12.1. Dışarıdan ışığın hiçbir durumda giremeyeceği yalıtılmış bir odadaki bir düz ayna önünde, beyaz bir lamba bulunmaktadır. Lamba açıkken aynaya bakan bir çocuk, aynada lambanın görüntüsünü görebilmektedir. Odadaki diğer ışıklar ve lamba kapatılırsa aynada ampulün görüntüsü oluşur mu?



Şekil 10

a) Oluşur.

b) Oluşmaz.

12.2. Yukarıdaki seçeneği seçmemin sebebi;

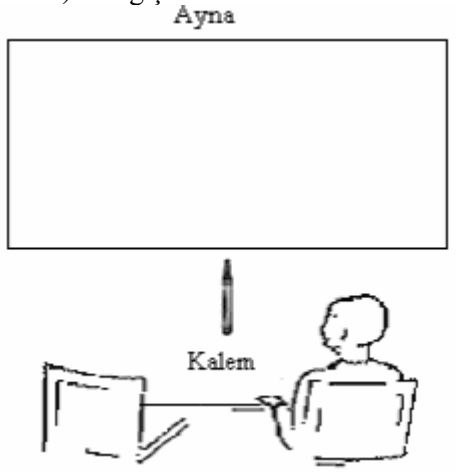
a) Odada ışık olmadığı için aynada görüntü oluşmaz.
b) Lamba beyaz olduğu için kendinden ışın yollayarak görüntü oluşturur.
c) Ampulün ve aynanın yeri değiştirilmediği sürece aynanın kendi iç yapı özelliğinden görüntü oluşur; fakat çocuk, ışık olmadığı için görüntüyü göremez.
d) Karanlık olduktan bir süre sonra göz uyumu olur. Çocuk lambanın görüntüsünü çok net olmasa da aynada görebilir.
e) Oda karanlık olduğu için ampulden aynaya siyah ışın yansır. Aynaya yansımaların tümü siyah ışın olduğu için çocuk görüntüyü fark edemez.

12.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz?

a) Eminim. b) Emin değilim.

13.1. Bir çocuk bir düz aynanın karşısına oturup aynanın karşısında durmakta olan kalemin görüntüsüne bakmaktadır. Eğer çocuk, solundaki boş sandalyeye geçerse görüntünün yeri değişir mi?

a) Değişmez.
b) Değişir.



Şekil 11

13.2. Yukarıdaki seçeneği seçmemin sebebi;

a) Çocuğun bakış açısı değiştiği için, çocuk kalemin görüntüsünü ayna üzerinde sağ tarafta görür.
b) Çocuk sol tarafa kaydığı için görüntü de aynanın arkasında sol tarafa kayar.
c) Kalemin yeri sabit kaldığı için görüntü her iki durumda da ayna üzerinde, aynı yerdedir.
d) Çocuğun bakış açısı değiştiği için çocuk kalemin görüntüsünü aynanın arkasında sağ tarafta görmektedir.
e) Kalemin yeri sabit kaldığı için, her iki durumda da görüntü aynanın arka tarafında aynı yerdedir.
f) Çocuk sol tarafa kaydığı için, görüntünün yeri de ayna üzerinde sol tarafa kayar.

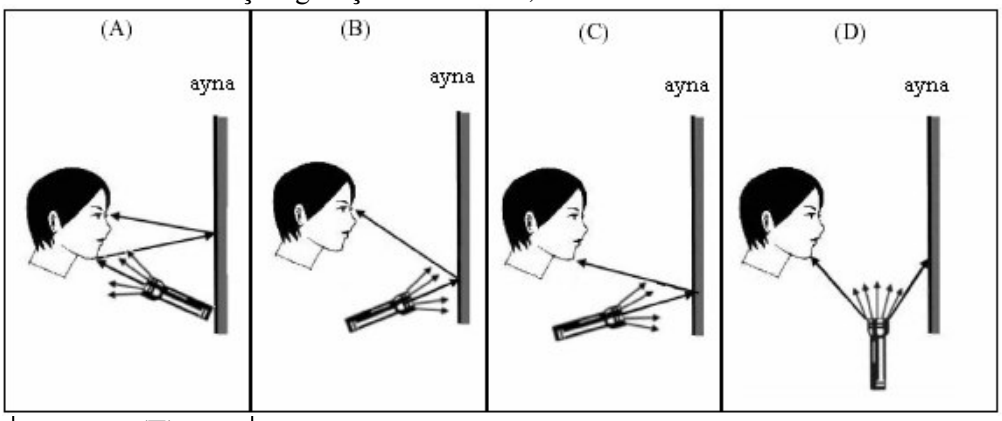
13.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz?

a) Eminim. b) Emin değilim.

14.1. Geceleyin uyumakta olan Mustafa, çenesini ısıran bir sivrisinek tarafından uyandırılmıştır. Karanlık odasında, çenesindeki ısırığı görmek isteyen Mustafa eline ayna ve el feneri almıştır. Çenesini aynada daha net görmek isteyen Mustafa, el fenerinin ışığını nereye tutmalıdır?

a) El fenerini çenesine tutmalıdır.
b) El fenerini aynaya tutmalıdır.
c) El fenerini ışığının hem aynaya hem de çenesine gelecek şekilde tutmalıdır.
d) El fenerini nereden tuttuğu önemli değildir.

14.2. Yukarıdaki seçeneği seçmemin sebebi;

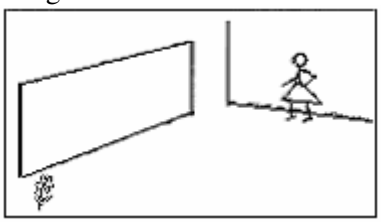


(E)

14.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz?

a) Eminim. b) Emin değilim.

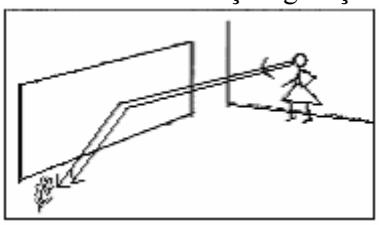
15.1. Aşağıdaki şekilde, ayakta durmakta olan kız aynaya bakmaktadır. Kız aynanın diğer tarafında aynanın ön cephe sınırlarının dışında olan çiçeği görebilir mi?



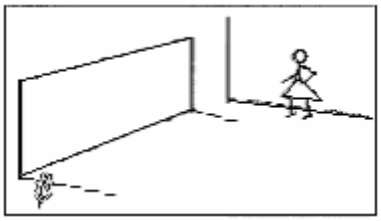
Şekil 12

a) Görebilir.
b) Göremez.

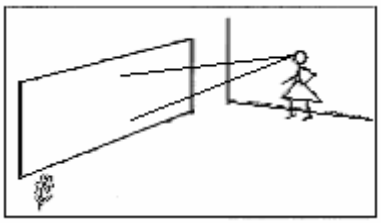
15.2. Yukarıdaki seçeneği seçmemin sebebi;



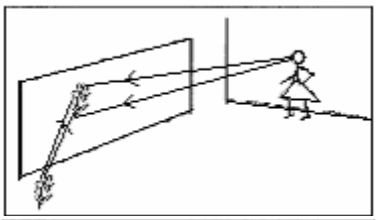
a) Kızın gözünden çıkan ışınlar aynadan yansıyarak çiçeğe gelir.



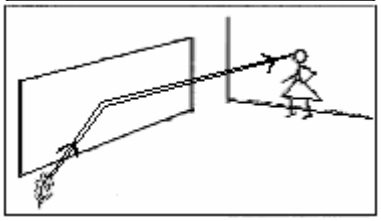
b) Çiçek aynanın yansıtıcı ön cephe sınırlarının dışarısında kalmaktadır.



c) Çiçek kızın aynaya baktığı doğrultuda değildir.



d) Çiçekten yansıyan ışınlar aynada görüntü oluşturur. Kızın gözünden çıkan ışınlar aynaya giderek görüntüyü algılar.

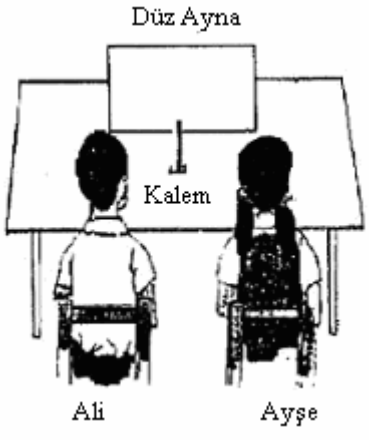


e) Çiçekten yansıyan ışınlar aynadan yansıyarak kızın gözüne gelir.

15.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz?

a) Eminim. b) Emin değilim.

16.1. Aşağıdaki şekilde görüldüğü gibi bir düz ayna ve kalem masanın üzerine yerleştirilmiştir. Ali ve Ayşe yan yana oturup aynaya bakmaktadırlar.



Şekil 12

Aşağıdakilerden hangisi doğrudur?

a) Kalemin aynadaki görüntüsünü aynı yerde görürler.
b) Kalemin aynadaki görüntüsünü farklı yerde görürler.

16.2. Yukarıdaki seçeneği seçmemin sebebi,

a) Ali ve Ayşe farklı yerde oturmaktadırlar. Ali kalemin görüntüsünü aynanın üzerinde sol tarafta görür. Ayşe yine ayna üzerinde fakat sağ tarafta görür.
b) Ali ve Ayşe'nin oturdukları yerlerin önemi yoktur. İkisi de aynanın üzerinde, aynı yerde görüntüyü görürler.
c) Ali ve Ayşe'nin bakış açıları farklıdır. Ali görüntüyü aynanın arkasında sağ tarafta görür. Ayşe ise aynanın arka tarafında sol tarafta görür.
d) Ali ve Ayşe'nin oturdukları yerin önemi yoktur ikisi de aynanın arkasında aynı yerde görür.
e) Ali ve Ayşe'nin bakış açıları farklıdır. Ali görüntüyü aynanın üzerinde sağ tarafta görür. Ayşe ise aynanın üzerinde sol tarafta görür.
f) Ali ve Ayşe farklı yerde oturmaktadırlar. Ali kalemin görüntüsünü aynanın arkasında sol tarafta görür. Ayşe ise yine aynanın arkasında fakat sağ tarafta görür.

16.3. Yukarıdaki iki soruya verdiğiniz cevaptan emin misiniz?

a) Eminim. b) Emin değilim.

APPENDIX D

ANSWER KEY OF THE THREE-TIER GEOMETRIC OPTIC MISCONCEPTION TEST

1.1) B	5.1) C	9.1) C	13.1) A
1.2) D	5.2) D	9.2) F	13.2) E
1.3) A	5.3) A	9.3) A	13.3) A
2.1) C	6.1) C	10.1) B	14.1) A
2.2) D	6.2) C	10.2) D	14.2) A
2.3) A	6.3) A	10.3) A	14.3) A
3.1) A	7.1) B	11.1) A	15.1) A
3.2) C	7.2) B	11.2) E	15.2) E
3.3) A	7.3) A	11.3) A	15.3) A
4.1) B	8.1) C	12.1) B	16.1) A
4.2) C	8.2) D	12.2) A	16.2) D
4.3) A	8.3) A	12.3) A	16.3) A

APPENDIX E

ITEM CHOICES INDICATING THE MISCONCEPTIONS

Misconception	Item Choices	Number of Item Choices
M1 Students believe that they can see the light colored objects in the total darkness. Because, they emit light by themselves.	(1.1.a, 1.2.e, 1.3.a) (12.1.a, 12.2.b, 12.3.a)	2
M2 Students claim that there will be black rays in the total darkness.	(1.1.b, 1.2.a, 1.3.a) (12.1.a, 12.2.e.12.3.a)	2
M3 For seeing in the darkness, significant numbers of the students expressed that eyes can get used to seeing in total darkness.	(1.1.c, 1.2.b, 1.3.a) (1.1.d, 1.2.b, 1.3.a) (12.1.a, 12.2.d, 12.3.a)	3
M4 Students think that light travels a different distance depending upon whether it is day or night.	(2.1.a.,2.2.a, 2.3.a) (2.1.a, 2.2.f, 2.3.a) (2.1.a, 2.2.g, 2.3.a) (2.1.b, 2.2.b, 2.3.a) (2.1.b, 2.2.c, 2.3.a) (2.1.b, 2.2.e, 2.3.a)	6
M5 They think of light as emanating in only one direction from each source, like flash light beams.	(3.1.b, 3.2.b, 3.3.a) (5.1.a, 5.2.b, 5.3.a)	2

M6 Students think that the shadows of the objects are clearer when the bigger bulb is used as a light source.	(3.1.b, 3.2.a, 3.3.a) (4.1.a, 4.2.b, 4.3.a)	2
M7 Children have an idea that shadow belongs only to the non-luminous object and it always looks like the object.	(5.1.b, 5.2.c, 5.3.a) (5.1.d, 5.2.c, 5.3.a) (5.1.a, 5.2.c, 5.3.a)	3
M8 Students claim that there will be no shadow even if a light source and a non- transparent object exist together.	(5.1.e, 5.2.a, 5.3.a) (6.1.a, 6.2.e, 6.3.a)	2
M9 Most of the students reasoned that in the region of geometrical overlap there would be either lightness (full illumination) or darkness (shadow). They did not consider semi darkness. Students treated the shadow as the presence of something i.e. they gave material characteristics to the shadow, rather than absence of the light.	(6.1.b, 6.2.b, 6.3.a) (6.1.d, 6.2.a, 6.3.a)	2

M10 Students think that shadow is black color and light is white color. When they overlap, they mix and form the grey color. In a similar way, they think when the shadow and light overlap, the shadow reduce the brightness of the light.	(6.1.c, 6.2.d, 6.3.a)	1
M11 Some students think that to see an image of any object, it should be inside the front region straight ahead of the mirror.	(7.1.c, 7.2.c, 7.3.a) (15.1.b, 15.2.b, 15.3.a)	2
M12 Students think that an image in a plane mirror lies behind the mirror along the line of sight between a viewer and the object.	(7.1.a, 7.2.a, 7.3.a) (11.1.a, 11.2.d, 11.3.a) (13.1.b, 13.2.a, 13.3.a) (15.1.b, 15.2.c, 15.3.a) (16.1.b, 16.2.c, 16.3.a) (16.1.b, 16.2.e, 16.3.a)	6
M13 Students believe that an observer see the object because the observer directs sight lines toward it, with light possibly emitted from the eyes.	(7.1.b, 7.2.e, 7.3.a) (11.1.a, 11.2.b, 11.3.a) (15.1.a, 15.2.a, 15.3.a) (15.1.a, 15.2.d, 15.3.a) (8.1.a, 8.2.f, 8.3.a)	5

M14 Students confuse image formation with shadow formation. They believed that in the presence on an illuminant the position and size of the image of an illuminated object depends on the illuminant. For example, they think image size of an object gets longer when the illuminant is gotten closer to the object	(8.1.a, 8.2.g, 8.3.a) (8.1.a, 8.2.h, 8.3.a) (8.1.b, 8.2.a, 8.3.a) (8.1.b, 8.2.b, 8.3.a) (8.1.b, 8.2.c, 8.3.a) (8.1.c, 8.2.c, 8.3.a) (9.1.a, 9.2.a, 9.3.a) (9.1.a, 9.2.b, 9.3.a) (9.1.a, 9.2.c, 9.3.a) (9.1.b, 9.2.d, 9.3.a) (9.1.b, 9.2.e, 9.3.a)	11
M15 Some of the students think that the position and size of the image of any object depend on the location of the observer. They think when the observer retreats size and position of the observer is changed.	(10.1.a, 10.2.a, 10.3.a) (10.1.a, 10.2.b, 10.3.a) (10.1.a, 10.2.c, 10.3.a) (10.1.c, 10.2. k, 10.3a)	4
M16 Students claim that image of a black object on the mirror was due to black rays bouncing off the black object.	(11.1.a, 11.2.a, 11.3.a)	1

M17 Students think that creating images is an inherent attribute of the silvery mirror material, rather than the product of the reflection process. The students say that "The mirror reflects and so the person sees".	(12.1.a, 12.2.c, 12.3.a)	1
M18 Students have a misconception that while watching an object its position also shifted as they viewed it from different perspectives. They misunderstand that the absolute position of the object remains the same as an observer moves. Only change is its apparent position relative to the background).	(13.1.b, 13.2.a, 13.3.a) (13.1.b, 13.2.d, 13.3.a)	2
M19 Some of the students believe that image of any object is located right ahead of the observer.	(13.1.b, 13.2.b, 13.3.a) (13.1.b, 13.2.f, 13.3.a) (16.1.b, 16.2.a, 16.3.a) (16.1.b, 16.2.f, 16.3.a)	4
M20 Students think that if a person wants to see him or herself in a dark room, he or she should illuminate the mirror rather than himself or herself.	(14.1.b, 14.2.b, 14.3.a) (14.1.b, 14.2.c, 14.3.a)	1

APPENDIX F

RAW DATA

	ITEMS																						
	1.1.	1.2.	1.3.	2.1.	2.2.	2.3.	3.1.	3.2.	3.3.	4.1.	4.2.	4.3.	5.1.	5.2.	5.3.	6.1.	6.2.	6.3.	7.1.	7.2.	7.3.	8.1.	8.2.	8.3.
1	A	E	B	B	A	A	A	B	A	A	B	A	E	A	B	B	B	A	D	D	B	B	C	B
2	A	E	B	C	D	B	B	B	B	B	C	A	C	A	A	C	D	B	D	A	B	B	B	B
3	D	B	A	B	A	A	B	C	A	A	B	A	B	B	A	D	A	A	C	C	A	B	C	A
4	C	B	A	B	D	B	C	B	A	A	A	A	A	C	B	B								
5	C	B	A	A	E	A	A	B	A	A	B	B	A	B	A	A	B	A	D	F	A	B	B	A
6	D	C	A	C	D	B	A	B	B	B	B	A	B	A	A	B	B	A	A	A	B	A	B	A
7	A	C	A	A	G	B	C	D	A	B	B	B	E	A	A	B	A	B	D	D	B	C	H	B
8	D	B	A	C	D	A	B	C	B	C	A	B	E	A	B	D	A	B	D	D	B	C	E	A
9	B	C	B	A	G	B	A	C	A	B	C	A	D	C	A	C	C	A	B	B	B	C	F	B
10	B	A	A	A	A	A	B	A	A	A	B	A	E	A	A	D	A	A	B	B	A	C	G	A
11	D	E	A	B	A	A	A	B	A	A	B	A	D	A	A	C	C	A	B	E	B	C	F	A
12	D	B	A	C	A	B	A	B	A	A	B	A	C	A	B	C	D	A	B	B	A	C	E	A
13	B	D	A							A	B	A	B	B	B	A	C	A	B	B	A	B	B	A
14	D	B	B	C	D	A	A	B	A	A	B	A	E	A	A	C	C	A	B	B	A	C	E	A
15	C	B	A	B	G	A	B	B	A	B	B		C	D	A	C	D	A	A	D	A	B	A	A
16	C	B	A	C	D	A	A	B	A	C	A	A	D	C	A	C	D	A	A	A	A	C	E	B
17	D	B	A	C	D	A	B	A	A	A	B	A	A	B	A	C	C	A	B	B	A	C	E	A
18	D	B	A	A	E	A	B	C	A	A	B	A	A	D	A	B	B	A	D	D	A	B	C	A
19	C	C	A	A	G	A	B	B	A	C	A	A	B	B	A	C	C	B	C	C	B	C	C	B
20	B	D	A	A	G	A	B	A	A	C	B	B	B	D	B	C	C	A	D	C	A	B	H	B
21	D	B	B				B	C	A	A	C	A	A	B	A	D	C	B	A	A	A	C	E	B
22	D	C	A	B	C	A	B	B	A	A	B	B	B	C	B	C	C	B	A	C	A	B	C	A
23	D	C	A	C	E	B	A	B	A	A	B	A	A	B	A	C	A	A	D	F	A	B	A	A
24	B	D	A	B	C	A	B	A	B	A	B	A	B	B	B	D	A	B	D	F	A	B	B	B
25	B	D	A	C	D	A	A	B	A	A	B	B	A	B	A	C	D	A	B	E	A	B	C	A
26	D	C	A	B	C	A	B	A	A	A	B	A	A	B	A	D	A	A	D	F	A	C	F	B
27	D	C	A	C	D	A	A	B	A	C	A	A	A	B	A	D	A	A	B	E	A	B	A	B
28	B	A	A	B	C	B	B	A	A	A	B	A	D	C	A	C	C	A	B	B	B	B	B	A
29	B	A	B	A	F	A	B	A	A	A	B	A	E	A	A	C	D	A	B	B	A	B	A	A
30	A	E	A	C	D	A	A	C	A	B	C	B	D	D	B	C	C	B	B	B	A	C	D	A
31	D	C	A	A	E	A	A	B	A	B	C	A	D	C	B	B	B	A	C	C	A	C	F	A
32	B	D	A	A	G	B	A	C	A	B	C	B	E	A	A	C	B	A	B	C	B	C	F	A
33	B	D	A	A	F	A	A	C	B	B	C	A				B	B	A	C	C	B	B	C	A
34	A	E	A	B	E	B	A	B	A	B	C	A	A	B		C	D	A	A	A	A	C	E	A
35	B	D	A	B	C	B	A	A	A	C	A	A	D	A	A	C	C	A	B	E	A	B	C	A
36	D	C	B	B	F	A	A	B	B	B	C	B	D	C	B	D	A	A	B	E	A	B	D	B
37	B	D	A	B	F	B	A	A	A	C	A	A	A	B	B	C	D	A	B	B	A	C	F	A
38	C	B	B	C	D	B	B	C	A	C	A	A	D	C	A	D	A	A	A	A	A	C	F	B
39	A	E	A	B	B	A	A	B	A	A	B	B	B	C	B	C	D	B	B	B	A	C	E	A
40	D	B	A	B	A	B	A	B	A	A	B	A	E	C	B				A	A	A	C	G	B
41	D	C	A	A	E	B	A	B	A	A	B	A	D	B	A	B	B	A	C	C	A	C	F	B

	ITEMS																							
	1.1.	1.2.	1.3.	2.1.	2.2.	2.3.	3.1.	3.2.	3.3.	4.1.	4.2.	4.3.	5.1.	5.2.	5.3.	6.1.	6.2.	6.3.	7.1.	7.2.	7.3.	8.1.	8.2.	8.3.
42	A	E	B	B	C	A	B	A	A	A	B	A	C	D	A	D	A	B				B	A	A
43	B	D	A	C	D	A	A	B	A	A	B	A	E	A	A	D	A	A	D	D	A	C	E	B
44	C	B	A	B	B	B	B	B	A	C	A	A	D	A	B	D	A	B	D	D	A	C	D	B
45	D	B	A	C	D	A	C	D	A	C	A	A	A	B	A	C	B	A	D	D	A	C	E	A
46	D	C	A	A	G	B	B	B	A	B	C	A	A	B	A	D	A	A	B	A	A	C	E	A
47	B	D	A	C	D	A	A	C	B	B	C	B	B	C	A	C	D	A	B	B	A	C	E	A
48	D	C	A	B	G	B	A	B	A	B	C	A	D	C	A	C	D	A	D	F	B	C	C	B
49	B	D	A	B	D	B	A	B	A	B	C	A	D	C	A	D	A	B	A	A	B	B	B	B
50	D	B	A	C	D	A	C	D	A	A	B	A	D	C	B	C	C	A	B	B	A	B	B	A
51	B	D	A	C	D	A	A	B	A	A	B	A	C	D	A	C	C	A	B	B	A	B	A	A
52	B	D	A	C	D	A	A	C	A	B	C	A	A	B	A	C	D	A	B	B	A	C	F	B
53	A	E		B	B	B	B	A	A	C	A	A	A	B	A	D	D	B	C	C	B	B	F	B
54	C	E	B	A	G	B				A	B	A							D	F	B			
55	D	B	A	A	E	A	B	B	A	A	C	B	C	A	B	A	C	A	B	D	A	A	C	A
56	A	E	A	A	E	B	A	B	A	C	A	A	D	D	B	C	C	B	D	D	B	C	E	B
57	D	B	A	C	D	A	C	D								C	C	A	B	B	A	C	E	A
58	D	C	A	C	E	B	B	A	A	A	B	A	A	C	A	C	E	B	D	D	A	A	D	B
59	D	C	A	B	C	B	A	C	A	A	B	A	A	A	A	C	D	A	D	F	B	C	C	B
60	B	D	A	C			A	C	A	A	B	B	E	A	A	C	B	B	B	B	A	C	F	A
61	D	C	B	A	D	A	A	A	A	A	B	A	C	C	B	C	C	B	A	A	A	B	D	B
62	B	C	A	C	E	B	A	B	A	A	B	A	D	C	A	C	C	A	B	B	A	C	E	B
63	D	B	A	A	G	A	A	B	A	C	A	A	A	C	A	D	A	A	A	A	A	C		A
64	A	E	A	A	F	A	A	B	A	A	B	A	A	B	A	C	D	A	B	B	B	B	B	B
65	B	D	A	C	D	A	C	D	A	B	C	B	B	B	A	C	C	A	D	D	A	C	E	A
66	D	C	A	B	C	B	A	B	A	B	C	A	A	B	B	C	C	A	B	B	A	B	A	A
67	D	B	A	C	D	B	B	A	A	A	A	A	A	B	A	C	C	A	B	D	B	B	B	A
68	C	C	A	C	E	B	A	B	A	A	C	A	B	D	B	D	A	A	B	B	A	B	B	A
69	D	A	A	C	D	B	A	B	A	C	A	A	B	C	B				D	D	A	B	B	A
70	D	B	A	B	C	A	A	B	A	A	B	A	D	B	A	D	A	B	B	A	A	C	E	B
71	B	D	A	A	G	A	A	C	A	B	C	A	D	B	A	D	A	A	A	A	A	C	E	B
72	D	B	A	C	D	A	A	B	A	A	B	A	A	B	A	D	A	A	B	A	A	C	E	B
73	B	C	A	A	D	A	A	C	A	C	A	B	A	B	A	C	C	A	A	A	A	C	F	A
74	C	C	A	B	B	B	A	A	B	A	C	A	A	C	B	D			B	E	A	B	A	B
75	B	A	A	A	A	A	B	A	A	A	A	A	D	D		B	D	B	B	B	B	A	C	A
76	C	B	A	A	E	A	B	B	A	A	B	B	C	A	B	C	D	A	C	E	A	B	D	B
77	B	A	A	C	B	B	C	C	B	C	C	B	D	C	B	C	E	B	C	C	B	B	B	B
78	D	B	A	C	D	A	A	D	A	B	A	A	A	D	A	C	B	A	B	B	A	B	D	A
79	D	C	A	B	E	A	A	C	A	B	C	A				C	C	A	B	B	A	C	F	B
80	D	C	A	B	C	A	A	B	A	A	B	A	A	B	A	C	C	A	B	E	B	B	B	B
81	B	D	A	C	D	A	A	C	A	B	C	A	D	C	B	C	D	A	B	E	A	C	F	A
82	B	C	A	A	B	A	B	A	A	A	B	A	D	D	A	B	B	A	D	D	A	A	G	A
83	D	B	A	A	F	A	A	B	A	A	B	B	A	B	A				B	B	A	B	A	A
84	D	C	A	C	F	A	B	B	A	C	A	B	D	C	A	C	C	B	D	D	A	B	B	A
85	B	D	A	C	D	A	C	D	A	C	A	A	E	A	A	C	C	A	B	B	A	C	E	A
86	D	B	A	C	D	B	C	D	A	A	B	A	D	C	A	C	B	A	D	D	A	B	A	A
87	D	B	A	A	A	A	A	B	A	A	B	A	B	B	A	C	C	A	D	B	A	C	F	A
88	D	B	A	B	A	A	B	A	A	A	B	A	C	A	A	B	D	A	D	C	A	B	A	A
89	D	E	B	A	G	B	B	C	A	A	B	B	A	B	A	C	A	A	B	B	A	C	E	B
90	C	B	A	B	D	B	A	B	A	B	B	A	A	B	A	C	E	B	C	C	B	C	F	A
91	D	C		B	A	B	A	B	B	A	B	A	B	B	B	C	C	A	B	B	A	B	B	A
92	D	B	A	C	D	A	C	B	B	A	C	A	C	C	A	D	A	A	B	B	A	B	B	A
93	D	B	A	B	E	A	A	B	A	A	A	B	B	C	A	C	C	B	B	E	A	C	D	B
94	D	C	A	A	G	A	A	D	A	C	A	A	C	A	B	C	C	B	D	D	A	C	C	A

	ITEMS																							
	1.1.	1.2.	1.3.	2.1.	2.2.	2.3.	3.1.	3.2.	3.3.	4.1.	4.2.	4.3.	5.1.	5.2.	5.3.	6.1.	6.2.	6.3.	7.1.	7.2.	7.3.	8.1.	8.2.	8.3.
95	B	A	A	C	D	A	A	A	A	C	A	A	B	C	B	D	A	A	D	F	A	C	F	A
96	B	D	A	C	D	A	A	C	B	C	A	B	E	A	A	B	D	B	B	B	A	B	C	B
97	A	E	A	A	F	A	C	D	A	C	A	A	C	D	A	A	E	A	B	E	A	B	A	B
98	B	D	A	C	D	A	B	C	A	A	A	B	A	B	A	C	C	A	B	B	B	B	C	B
99	D	C	A	C	D	A	C	D	A	C	A	A	D	C	A	B	B	A	B	E	A	C	F	B
100	B	D	A	C	D	A	A	C	A	B	C	A	A	B	A	A	E	A	B	B	A	C	E	B
101	C	B	A	A	G	A	A	B	B	B	C	B	A	B	B	C	B	B	D	D	A	C	A	B
102	C	B	A	A	G	A	A	B	B	B	C	B	A	B	A	D	A	A	B	B	A	C	A	B
103	D	C	A	B	F	A	C	D	A	C	A	B	C	A	B	C	D	B	D	F	A	C	F	B
104	D	C	A	B	C	A	B	B	A	C	B	A	A	D	A	B	D	B	C	C	A	A	H	A
105	D	E	A	B	E	A				B	C	A	B	C	A	C	A	A	B	E	A	C	E	A
106	D	E		B	E	A	B	B		B	C	A	B	C	A	C	A	A	D	E	A	C	E	A
107	D	C	A	A	G	A	C	D	A	C	A	A	D	C	A				C	C	A	B	B	A
108	D	B	A	C	D	A	C	D	B	A	C	B	A	B	A	D	A	B	D	D	B	C	F	B
109	D	B	A	C	D	A	C	D	A	B	C	B	A	B	A	D	A	B	D	D	A	C	F	A
110	B	D	A	C	D	A	B	B	A	A	C	B	A	B	A	C	C	A	D	D	A	B	A	A
111	D	C	A	B	C	B	A	A	B	B	C	A	C	C		C	C	B	D	F	A	C	E	B
112	B	D	A	B	A	B	B	A	B	A	C	A	A	B	A	C	D	B	D	D	A	B	D	B
113	D	A	A	A	D	A	B	C	A	B	C	A	C	C	A	C	B	B						
114	D	E	A	A	E	A	B	C	B	B	A	B	C	C	A	C	C	B	C	E	B	B	D	A
115	A	E	B	A	B	A	A	B	A	C	A	A	D	C	A	C	D	B	D	F	A	B	B	A
116	B	D		C	D	A	C	B		C	C	A	B	C	A	C	C	A	C	E	B	C	G	B
117	D	C	B	A	D	A	B	A	B	A	B	B	A	C	B	C	C	B	D	D	B	B	D	A
118	D	C	B	A	B	B	B	C	B	B	B	A	D	A	B	C	B	B	C	C	A	C	H	B
119	A	B	A	B	F	B	A	B	A	B	B	A	A	B	A	D	A	A	D	F	A	C	E	A
120	A	B	B	B	D	A	B	A	B	A	B	A	A	B	A	C	C	B	B	B	A	A	G	B
121	C	B	B	A	E	A	C	D	B	B	C	B	B	A	A	D	A	B	D	A	A	C	C	B
122	D	C	A	C	G	B	A	A	A	B	B	A	A	B	A	D	A	A	D	F	B	C	D	A
123	D	C	A	A	G	B	A	A	A	B	B	A	A	B	A	D	A	A	D	F	B	C	D	A
124	D	B	B	C	D	A	C	D	A	A	B	A	A	B	A	C	C	A	B	B	A	B	C	A
125	D	C	A	A	D	A	C	D	A	B	C	B	A	B	A	C	D	A	B	B	A	C	E	A
126	D	C	A	A	D	A	C	D	A	B	C	A	A	B	A	C	D	A	B	B	A	C	E	A
127	D	C	A	A	D	A	C	D	A	B	C	A	A	B	A	C	D	A	B	B	A	C	E	A
128	D	C	A	A	G	B	B	B	A	B	C	A	D		A	C	B	A	B	B	A	C	D	A
129	D	B	A	B	F	A	A	B	A	B	B	A	B	B	A	C	C	A	B	B	A	B	C	A
130	C	C	A	A	G	B	B	B	A	B	C	B	D	C	B	C	C	A	B	A	A	B	A	B
131	B	A	A	C	D	A	A	B	A	B	C	A	D	A	A	C	C	A	B	B	A	C	F	A
132	B	A	A	C			A	B	A	A	B	A	D	C	A				D	F	B	B	G	
133	B	A	A	C	D	A	A	B	A	B	C	A	C	D	B	B	B	A	A	A	A	B	G	B
134	B	A	A	C	D	A				A	B	B		D	B	D	A	B	B	B	B	C	E	A
135	D	C	A	A	F	A	A	D	B	B	C	A	A	B	A	C	C	B	D	F	A	B	B	S
136	C	C	A	C	D	A	A	B	A	A	B	A	A	B	A	C	D	A	D	D	A	C	F	A
137	B	C	A	C	D	A	A	B	A	A	A	A	A	B	A	C	E	A	D	D	A	C	F	A
138	B	D		A	G	A	A	C	B	B	C	B	B	C		C	C	A	B	B	A	B	B	A
139	D	C	A	B	E	B	A	B	B				A	B	A	C	C	A	B	E	B	B	E	A
140	B	C	B	A	G	B	A	C	A	B	C	A	D	C	A	C	C	A	B	B	B	C	E	B
141	B	D	B	C	D	A	A	C	B	C	A	B	E	A	A	B	B	B	B	B	A	B	C	B

	ITEMS																							
	9.1.	9.2.	9.3.	10.1.	10.2.	10.3.	11.1.	11.2.	11.3.	12.1.	12.2.	12.3.	13.1.	13.2.	13.3.	14.1.	14.2.	14.3.	15.1.	15.2.	15.3.	16.1.	16.2.	16.3.
1	B	B	B	C	F	B	A	D	B	B	A	B	B	A	B	C	C	A	A	A	B	A	C	B
2	C	B	B	C	G	B	A	A	A	B	C	B	B	A	A	B	B	B	B	B	B	B	C	B
3	A	B	A	A	B	A	A	B	A	B	A	A	B	A	A	C	D	A	A	A	A	B	A	
4																								
5	A	A	A	B	A	B	A	B	B	B	A	B	B	A	B	A	A	A	A	A	A	B	A	B
6	B	B	B	A	B																			
7	C	C	B	B	A	B	A	A	B	B	A	A	A	C	A	B	B	B	A	A	B	A	B	B
8	C	G	A	B	E	A	A	D	A	B	A	A	A	C	A	A	A	A	A	D	A	B	A	A
9	C	G	A	C	B	A	B	E	B	B	A	A	B	B	A	B	C	A	A	A	A	A	B	A
10	A	C	A	B	E	A	A	A	A	B	A	A	A	C	A	B	C	A	A	A	A	B	A	
11	C	H	A	B	E	A	A	D	A	B	A	A	A	C	A	A	A	A	A	A	B	A	C	B
12	C	G	A	B	E	A	A	A	A	A	C	A	A	E	A	A	A	A	A	D	A	B	C	A
13	B	D	A	A	B																			
14	C	G	A	B	E	A	A	A		B	A	B	B	B	A	A	A	B	A	E		B	A	A
15	B	C	A	B	F	A	B	E	A	A	C	A	A	B	A	D	B	A	B	B				
16	C	A	A	A	A	A	A	B	A	A	D	B	B	A	A	B	B	A	B	B	A	B	E	A
17	C	G	A	A	B	B	A	C	B	A	E	B	B	F	A	B	B	A	A	A	A	B	B	A
18	A	B	A	B	C	A	A	D	A	A	C	A	B	B	A	B	C	A	A	B	A	A	D	A
19	B	D	B	B	C	A	B	F	B	A	C	B	A	B	B	A	A	A	B	B	B	B	C	B
20	B	D		B	F	B	B	E	B	B	C	B	B	E	B	C	C	B	B	B	B	B	C	B
21	C	A	B	B	E	A	A	E	B	B	C	A	A	B	B	B	B		A	B	A	B	C	A
22	B	B	B	B	D	B	A	C	B	A	C	A	B	C	B	C	C	B	A	A	B	A	E	A
23	B	D	A	B	F	A	A	D	A	A	D	A	B	A	A	A	A	A	A	A	A	A	D	A
24	A	C	B	A	A	B	A	A	B	A	C	B	B	A	A	C	D	A	A	E	A	B	A	A
25	B	D	A	B	B	A				B	A	A	B	A	A	B	C	A	A	A	A	B	A	A
26	B	D	B	B	B	A	A	A	A							C	D	A	B	B	A	B	C	B
27	C	A	A	B	A	A	A	D	A	A	D	A	A	B	A	A	A	A	B	C	A	B	C	A
28	C	B	A	A	A	A	A	A	A	A	D	B	B	A	A	B	B	B	A	A	A	B	A	B
29	C	A	A	B	D	A	A	A	A	B	A	B	A	C	A	C	A	A	A	A	A	A	B	A
30	C	F	A	B	D	A	A	D	A	A	D	A	B	A	A	A	A	A	A	E	A	B	C	A
31	C	H	A	C	B	A	A	D	B	B	A	A	B	A	A	B	B	A	B	B	A	B	C	A
32	A	B	A	B	D	B	A	B	A	B	A	A	B	A	B	C	D	B	A	D	A	B	E	B
33	B	C	B	A	G	A	A	A	A	B	E	A	A	E	B	B	B	A	B	B	A	A	D	A
34	A	B	B	A	E	B	A	D	A	B	C		A	C	A	C	D	A	A	B	A	A	B	A
35	B	D	A	A	B	A	A	D	A	B	A	A	B	A	A	A	B	B	B	B	A	B	C	A
36	B	D	B	C	B	B	A	D	B	B	A	B	A	C	B	C	D	B	A	A	B	A	B	B
37	C	H	A	B	H	B	A	D	A	A	C	B	B	A	A	C	D	A	B	C	B	B	C	B
38	C	D	B	B	E	B	A	D	A	B	A	A	B	A	A	C	D	A	A	A	B	B	C	A
39	C	G	A	C	C	B	A	D	A	A	B	A	B	F	A	A	A	A	A	D	A	B	A	A
40	B	A	A	B	C	B	A	A	A	A	D	B	B	A	A	A	A	B	B	B	A	B	A	A
41	C	H	B	C	B	B	A	D	A	B	A	A	B	A	A	B	B	B	B	B	A	B	C	A
42	A	B	A	A	A	B	A	E	A	A	D	A	B	A	A	C	D	A	A	D	A	B	C	A
43	B	D	B	A	B	A	A	D	A	B	A	A	B	A	A	A	A	A	A	D	A	B	A	A
44	C	B	B	B	H	A	A	D	A	B	E	A	B	A	A	C	D	A	A	D	A	B	F	A
45	C	G	A	B	E	A	A	A	A	A	C	A	A	C	A	A	A	A	B	A	A	A	D	A
46	C	H	B	B	E	A	A	A	A	B	A	A	B	C	A	C	D	A	A	A	A	B	A	A
47	C	G	A	B	E	A	A	D	A	B	A	A	B	A	A	C	D	A	A	E	A	B	A	A
48	C	A	B	B	D	A	A	E	A	B	C	A	A	C	A	A	A	B	A	A	A	A	B	A
49	C	A	B	B	E	A	A	D	A															
50	C	B	A	B	H	B	A	A	A	A	D	B	B	A	A	A	A	A	A	E	A	B	C	A
51	C	H	A	B	E	A	A	A	A	B	A	A												
52	C	H	B	B	H	A	A	D	A	B	A	A	B	B	A	A	A	A	A	E	A	B	A	A
53	C	A	B	C	E	A	A	B	A	B	A	A	A	C	A	B	C	A	A	A	A	B	C	A
54				B			A	A	B	B	A	B	B	A	A				A	A	B	B	E	A
55	B	D	A	B	B	B	B	C	A	A	B	B	A	C	A	C	B	B	A	D	B	B	C	A

	ITEMS																							
	9.1.	9.2.	9.3.	10.1.	10.2.	10.3.	11.1.	11.2.	11.3.	12.1.	12.2.	12.3.	13.1.	13.2.	13.3.	14.1.	14.2.	14.3.	15.1.	15.2.	15.3.	16.1.	16.2.	16.3.
56	C	G	B	B	E	B	A	A	B	A	B	B	B	A	A	C	D	A	A	A	A	A	E	B
57	C	G	A	B	E	A	A	B	A				A	C	A	A	A	A	A	E	A	B	A	A
58	A	B	B	A	A	B	B	B	B	B	D	B	B	A	B	A	D	B	A	B	B	A	B	B
59	B	D	B	A	A	A	A	D	B	B	A	B	B	A	A	C	D	A	A	D	A	B	C	A
60	C	G	A	B	E	A	A	D	A	B	A	B	A	E	B	A		A	A	A	A	A	D	B
61	B	B	B	A	G	A	A	A	A	A	C	A	A	C	A	A	D	A	A	A	A	B	B	B
62	C	H	B	A	B	B	A	D	A	A	B	B	B	A	A	A	A	A	A	A	A	B	C	A
63	C		B	C		B	A	A	B	A	E	A	A	C	B	A	A	B	B	B	A	B	D	B
64	A	B	B	A	B	B	A	B	B	A	D	A	B	A	A	A	A	A	A	E	B	B	C	A
65	C	G	A	A	A	A	A	D	A	B	A	A	A	C	A	A	A	A	A	E	A	B	C	A
66	A	B	A	C	G	A	A	B	B	A	D	A	B	A	A	C	D	A	A	A	A	B	A	A
67	B	B	B	A	A	A	A	A	A	B	A	A	B	B	A	B	B	A	A	A	B	B	A	B
68	C	B	A	B	E	A	A	D	A	A	D	B	B	A	A	C	D	A	A	A	B	B	E	A
69	A	B	B	B	D	B	A	B	A	B	E	A	B	F	A	B	B	B	A	A	A	B	E	B
70	B	D	A	B	H	B	B	E	A	B	A	B	B	C	B	C		B	B	B	B	B	D	B
71	B	D	A	A	C	A	A	D	A	A	D	B	B	C	B	B	C	B	B	A	B	B	C	B
72	B	D	A	B	H	A	B	D	B	B	D	B	B	B	B	C	D	B	B	B	B		B	
73	C	H	A	A	K	A	A	D	A	B	A	A	B	A	A	A	A	A	B	B	A			
74	C																							
75	A	A	B	A	A	A	A	A	A	A	A	B	B	B	B	B	B	B	A	B	B	A	E	B
76	B	B	B	B	E	B	B	E	A	A	C	A	B	B	A	B	B	A	B	B	A	B	D	A
77	B	B	B	B	B	B	B	D	B	A	D	B	A	B		C	D	B	A	E	B	B	E	B
78	C	G		B	F	A	A	A	A	A	B	A	A	E	A	B	C	A	A	E	A	A	B	A
79	C	A	B	B	E	A	A	D	A				A	C	A	C	D	A	A	A	A	A	D	A
80	A	B	A	A	C	A	A	D	A	B	E	A	B	D	A	C	D	A	B	B	A	B	C	A
81	C	H	A	B	E	A	A	D	B	B	A	A	A	C	A	A	A	B	A	D	A	A	B	A
82	B	E	A	B	B	A	B	A	A	A	A	A	A	A	A	B		A	A	A	A	A	A	A
83	A	A	B	B	E	A	A	D	A				B	A	A	A	A	A				B	E	A
84	B	B	B	B	D	A	A	A	A	B	A	A	B	C	A	C	D	A	A	A	B	A	B	B
85	C	G	A	B	E	A	A	D	A	B	A	A	A	C	A	A	A	A	A	E	A	A	B	A
86	C	G	A	B	E	A	A	B	A	B	A	A	B	F	A	A	A	A	A	A	A	B	E	A
87	C	F	A	B	F	A	A	D	A	A	D	A	A	C	A	C	C	A	A	A	A	A	B	A
88	A	D	A	A	C	A	A	C	A	A	A		A	A	A	B	B	A	A	A		A	B	A
89	C	G	B	B	D	B	A	A	A	B	A	A	B	A	B	C	D	A	A	A	A	B	A	B
90	B	C	B	B	F	B	B	F	B	B	D	A	A	F	B	B	D	B	B	B	B	A	F	B
91	C	A	A	B	H	A	A	A	A	A	D	B	A	C	B	B	B	B	A	E	A	B	A	A
92	C	A	A	B	I	A	A	B	A	A	C	A	B	D	A	C	D	A	A	A	B	B	C	A
93	B	D	B	B	F	A	B	A	A	B	A	A	B	A	A	C	D	A	A	A	A	B	A	A
94	B	C	A	B	E	B	B	B	A	B	E	B	B	D	A	D		A	B	B	A	B	D	B
95	A	B	A	B	H	A	A	D	A	A	C	A	A	C	A	A	A	A	A	A	B	B	F	A
96	B	D	B	C	A	A	A	A	A	A	B	A	B	A	A	A	A	A	A	A	A	B	E	A
97	B	E	A	A	A	A	A	B	A	B	A	A	B	A	A	C	D	A	A	D	A	B	F	A
98	B	B	B	B	D	B	A	D	A	B	A	A	B	A	A	C	D	A	A	E	A	B	C	A
99	C	H	A	B	E	B	A	D	A	B	A	B	B	A	A	C	D	A	A	A		B	E	B
100	C	H	B	B	E	B	A	D	A	A	C	A	A	C	A	A	A	A	B	B	B	B	C	A
101	A	A	B	A	A	B	A	D	B	B	A	B	B	A	A	A	A	A	B	B	B	B	A	B
102	C	A	B	A	A	B	A	D	A	A	D	A	B	D	B	A	A	A	A	E	A	B	A	A
103	C	A	B	A	F	B	A	D	B	B	E	B	A	A	B	C	D	B	B	B	B	A	D	A
104	B	D	A	C	D	A	B	C	A	A	D	A	B	D	A	C	D	A	A	B	A	B	E	A
105	B	B	A	A	A	A	A	E	A	B	A	A	B	A	A	A	A	A						
106	B	B	A	C	A	A	A	E	A	B	A	A	B	A	A	A	A	A				B	A	
107	C	B	A	A	A	A	A	D	A	A	C	A	A	C	A	B	B	A	B	B	A	A	B	A
108	C	H	B	A	C	A	A	D	A	A	D	A	B	A	A	A	A	A	A	A	A	B	E	B
109	C	H	A	B	E	B	A	D	A	A	D	A	B	D	A	A	A	A	A	D	A	B	C	A
110	C	A	A	B	D	A	A	E	A	B	A	A	B	D	A	A	A	A	A	D	A			
111	A	C	B	A	B	B	A	C	A	B	A	B	A	A	B	B	B	A	A	A	B	B	F	B
112	A	B	B	C	F	A	A	A	A	B	A	A	B	A	A	A	A	A	A	A	A	B	E	A

	ITEMS																							
	9.1.	9.2.	9.3.	10.1.	10.2.	10.3.	11.1.	11.2.	11.3.	12.1.	12.2.	12.3.	13.1.	13.2.	13.3.	14.1.	14.2.	14.3.	15.1.	15.2.	15.3.	16.1.	16.2.	16.3.
113	B	F		A	E	A	B	D	A	A	D	B	B	B	A	B	B	A	B	B	A	B	C	A
114	C	B	A	B	E	A	A	E	B	A	C	B		B	B	B	C	B	B	B	A	A	D	B
115	B	B	B	A	A	B	B	E	A	B	E	B	B	A	A	A	A	A	B	B	A	B	C	A
116	C	D	B	B	D	A	A	A	A	A	A	B	B	A	B	C	D	A	A	A	B	B	A	A
117	B	B	B	B	B	B	B	F	B	A	B	A	B	B	B	C	C	B	A	A	A	B	A	B
118	B	D	B	B	B	B	A	D	B	B	D	B	B	B	B	C	D	B	B	E	B	A		B
119	C	H	A	C	A	A	A	A	A	B	C	B	B	A	A	C	D	A	B	B	A	B	C	A
120	A	C	B	A	C	B	A	D	A	B	A	B	B	B	B	C	C	B	A	A	A	B	A	B
121	C	B	B	A	C	B	A	A	A	B	A	A	B	A	A	B	B	A	A	A	A	A	B	B
122	C	G	A	B	E	A	A	A	A	A	C	A	B	A	A	A	A	A	A	E	A	B	E	A
123	C	G	A	B	E	A	A	A	A	A	C	A	B	A	A	A	A	A	A	E	A	B	E	A
124	D	B	B	C	D	A	C	D	A	A	B	A	A	B	A	C	C	A	B	B	A	B	C	A
125	D	C	A	A	D	A	C	D	A	B	C	B	A	B	A	C	D	A	B	B	A	C	E	A
126	D	C	A	A	D	A	C	D	A	B	C	A	A	B	A	C	D	A	B	B	A	C	E	A
127	D	C	A	A	D	A	C	D	A	B	C	A	A	B	A	C	D	A	B	B	A	C	E	A
128	D	C	A	A	G	B	B	B	A	B	C	A	D		A	C	B	A	B	B	A	C	D	A
129	D	B	A	B	F	A	A	B	A	B	B	A	B	B	A	C	C	A	B	B	A	B	C	A
130	C	C	A	A	G	B	B	B	A	B	C	B	D	C	B	C	C	A	B	A	A	B	A	B
131	B	A	A	C	D	A	A	B	A	B	C	A	D	A	A	C	C	A	B	B	A	C	F	A
132	B	A	A	C			A	B	A	A	B	A	D	C	A				D	F	B	B	G	
133	B	A	A	C	D	A	A	B	A	B	C	A	C	D	B	B	B	A	A	A	A	B	G	B
134	B	A	A	C	D	A				A	B	B		D	B	D	A	B	B	B	B	C	E	A
135	D	C	A	A	F	A	A	D	B	B	C	A	A	B	A	C	C	B	D	F	A	B	B	S
136	C	C	A	C	D	A	A	B	A	A	B	A	A	B	A	C	D	A	D	D	A	C	F	A
137	B	C	A	C	D	A	A	B	A	A	A	A	A	B	A	C	E	A	D	D	A	C	F	A
138	B	D		A	G	A	A	C	B	B	C	B	B	C		C	C	A	B	B	A	B	B	A
139	D	C	A	B	E	B	A	B	B				A	B	A	C	C	A	B	E	B	B	E	A
140	B	C	B	A	G	B	A	C	A	B	C	A	D	C	A	C	C	A	B	B	B	C	E	B
141	B	D	B	C	D	A	A	C	B	C	A	B	E	A	A	B	B	B	B	B	A	B	C	B