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# Virtual image and pupils' conceptual difficulties in the first year of Baccalaureate Experimental Sciences

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## ABSTRACT

This paper presents a research on the pupils' conceptual difficulties in the first year of Baccalaureate Experimental Sciences ES during the geometrical construction of the virtual image.

The experimentation realized in this research takes into account the reality of the teaching in the classroom. It was conducted towards the end of the school year 2012/2013 among a group of learners consisting of 54 pupils. These pupils must only use the traditional method paper, pencil, ruler and protractor for doing tests.

By analyzing the conceptual difficulties proven in the false geometrical constructions produced by the pupils, we have marked that the first variant sub-tests do not allow the emergence of the conceptual difficulty associated with the tracing of the construction ray extension. The construction of the virtual image through the second variant sub-tests has shown that about 32 % of pupils face against this conceptual difficulty, which is related to an incorrect status that the pupil attributes to the construction ray extension.

After checking the conceptual difficulty related to the correspondence image object (punctual and global) and the conceptual difficulty associated with the minimum number of rays departing from the same point of the luminous object and also the difficulty in tracing a construction ray, it seems that the both variants don't allow the emergence of these conceptual difficulties.

## Indexing terms/Keywords

Virtual image, construction ray, construction ray extension, geometrical optics, conceptual difficulties

## Academic Discipline and Sub-Disciplines

Education, Didactic of Physical Sciences

## SUBJECT CLASSIFICATION

Innovation in education

## INTRODUCTION AND PROBLEM

Much research in didactics of geometrical optics has proven that the learner comes up against a lot of conceptual difficulties during the representation of certain concepts.

In connection with the subject of geometrical construction of the real image and that of the vision of the virtual image, Galili (1996) examined the students' explanations associated with the formation of a real image through a lens and those associated with the vision of virtual image through a plane mirror. The students' knowledge facets are presented through two models: the holistic model (pre-teaching) and the hybrid model (post-teaching) "Image Projection Conceptualization IPC".

In the students' schemas related the holistic model, the "lines" do not represent the construction rays and the image of the luminous object appears "to travel" to the optical system studied.

In the students' schemas related to the hybrid model IPC, the "lines" represent the construction rays. These construction rays are traced according to the laws of refraction, but with only one construction ray joining the object point with the corresponding image point, and the image of the luminous object through the optical system is reconstructed entirely.

(Galili and Hazan, 2000) presented models that illustrate the use of construction rays by the students during the study of light sources. They compared the use of construction ray according to the cactus model (scientifically correct) with its use according to the hybrid model (post-teaching) "Image Projection Conceptualization IPC".

According to the cactus model, the light source is a set of points and each of them distributes the luminous rays in all directions in space. However, according to the hybrid model (IPC), the light source is considered by students as a set of points and each of them sends only one luminous ray carrying all the information of the source point. The analysis of students' knowledge facets, before and after teaching, revealed that a little students offer compatible explanations with the cactus model.

The geometrical optics can explain and analyze some optical phenomena, such as the formation of images and the vision. However, a large part of geometrical optics cannot be assimilated without mastering the geometrical construction of optical image.

Fawaz and Viennot (1986) analyzed the comprehension of Kepler schema, among the first year Lebanese students, using converging lenses. The results show that the students encounter difficulties in the transition from discontinuous to continuous and from punctual to global. According to the students it suffices to manipulate two construction rays to predict the nature of the formed optical image (blocking some construction rays with an obstacle implies blocking all construction rays and consequently the optical image disappears).

In an investigation, Goldberg and McDermott (1987) studied the students' understanding of the images produced by converging lenses and concave mirrors, before and after teaching the geometrical optics. These authors showed that participants do not assimilate the unique character of the relation between the optical components: the function of the lens, the mirror and the screen. This study also showed the students' poor understanding of the tracing of construction rays and it extensions.

Concerning the image formation, an important question arises: why do the "real" and "virtual" worlds engage in the geometrical construction similar construction tools for their properties different?

This question is answered in the field of vision. This fertile field has enriched the didactic of the physical sciences in general and the didactic of the geometrical optics in particular, through research carried out in this domain and which contributed to numerous reflections about the teaching objectives. Such research has created awareness among teacher concerning the concepts taught.

Viennot (1996) has written: "Thus, a light ray is not a material object. It is a mode of representation, it is often called "model" used to express in a symbolic language the propagation of light. A luminous ray does not have the status of an object that is simply defined as a table for example. In particular, we cannot see the luminous rays and those that are believed to be seen, be they the "sun" or "laser", are in fact diffused particles that the light illuminates independently from one another. The "optical image" can be observed, but its rules of formation are surprising and are far removed from those governing the ordinary material objects".

(Benjelloun, Alami and Rebmann, 2003) showed that using Java Software of Geometrical Optics JSGO in a situation of problem solving enables to identify the learners who do no conceptualize correctly the correspondence image object.

Mistrioti (2003) examined the tracing of construction ray extension for the vision of a virtual image among the students of CAPES and the DEUG. The results showed that the converging of construction rays extensions is less controlled than the tracing of one construction ray, which respects, according to the schemas analyzed, the refraction laws of Descartes. Also, the results indicated that only 31% of students presented in their schemas a construction ray extended in a straight line.

The research cited above enabled us to obtain an analysis, which is at the same time of epistemological (the status of construction ray), and didactic (the use of construction ray and it extension by students) and in order to contribute to the geometrical optic didactics, we have chosen to explore the "virtual" part of the formed optical image. For this, we designed written tests which allowed obtaining more responses in a relatively short period and allowed highlighting the role of the construction ray extension in the geometrical construction of the virtual image. For this aim we are interested in studying

the conceptual difficulties encountered in the false constructions produced by the pupils during the geometrical construction of the virtual image.

## RESEARCH FRAMEWORK

### 1. Description of tests and learners' corpus

During this research we developed within the framework of Gauss conditions, two tests of the geometrical construction of the virtual image. Each test consists of two sub-tests. A first variant sub-test and a second variant sub-test as described below:

The first variant sub-tests: 1-1; 2-1 (Appendix 1) are simple and classical exercises of the construction of the virtual image that we can find in the school textbooks.

The second variant sub-tests: 1-2; 2-2 (Appendix 1) are classical exercises of the construction of the virtual image which we have modified to make them less stereotyped and less unusual than the exercises often studied in the classroom.

The tests are similar in content but they differ in the schemas. Indeed, the sub-tests of each variant have almost equal difficulty indices. These indices are calculated from an external learners' corpus who worked with a traditional method.

The tests bring into play, exercises clearly designed in reference to the conceptual difficulty of tracing the construction ray and its extension. More specifically, Such test have as objective the study of status that the learner attributes to the construction ray extension, namely the influence attributed to the supposed possibility that the medium "refract" or "stop passing" the construction ray extension. The participants are from the first year of Baccalaureate, between 16 and 18 years old, option: Experimental Sciences ES.

**Geometrical optics syllabus taught**

The learner corpus with whom we have worked during this research has already received a classical teaching of geometrical optics for a period of 24 hours.

### 2. Taking place of experimentation

The experimentation realized, took into account, the reality of the teaching in the classroom. It was conducted towards the end of the school year 2012/2013 among a group of learners consisting of 54 pupils. These pupils had to use only the traditional method, paper, pencil, ruler and protractor, for doing tests.

Among the instructions that were given to participants is that once tracing the construction rays and it extensions they must place the virtual images formed in their position. The time given to participants is 40 minutes (20 minutes for each test).

Once the collection of pupils' copies was completed, we set up an evaluation grid to analyze the constructions produced.

## ANALYSIS AND DISCUSSION OF RESULTS

### 1. Influence of variant nature on the success of geometrical constructions produced.

The results of pupils' tests are presented in table 1 below:

**Table 1: Number of correct constructions, false constructions and no of construction produced by the pupils**

| Sub-tests | Nature of geometrical construction | | |
|---|---|---|---|
| | C.C | F.C | C.W.C |
| Sub-test 1-1 | 33 | 18 | 2 |
| Sub-test 1-2 | 21 | 25 | 7 |
| Sub-test 2-1 | 31 | 20 | 2 |
| Sub-test 2-2 | 19 | 26 | 8 |

**Codification of notations**

**C.C** = Correct Construction. **F.C** = False Construction. **C.W.C** = Copy without any Construction.

We noted a remarkable success of the geometrical construction produced by the pupils for the first variant sub-tests compared with the second variant sub-tests. Indeed, the pupils scored respectively: 33 and 31 correct constructions for the sub-tests: 1-1 and 2-1, against: 21 and 19 correct constructions for the sub-tests: 1-2 and 2-2.

This result shows that the presence of the opaque medium and the plane diopter in the respective schemas associated with the second variant sub-tests: 1-2 and 2-2 makes, for the pupils, the construction of the virtual image more difficult than the construction of the virtual image when solving the first variant sub-tests: 1-1 and 2-1.

### Analysis of the results using the Chi-square of Statistical Test

To get an idea about the importance of difference between the pupils' results related to the first variant sub-test and those related to the second variant sub-test of same test, we studied such difference using the Chi-square statistical test, called test of independence: Chi 2. The theoretical numbers calculated are greater than or equal to 5. The calculation of the Chi-square was carried using the predefined functions of Excel statistical software of Microsoft Office.

### Both hypotheses emitted to study the difference between the pupils' results related to the both sub-tests of test 1

**Null hypothesis (H0):** "The sub-test is of the first variant or the second variant" and "the success, or not, of a sub-test of test 1 by the pupils" are independent.

**Alternative hypothesis (H1):**"The sub-test is of the first variant or the second variant" and "the success, or not, of a sub-test of test 1 by the pupils" are not independent.

### Both hypotheses emitted to study the difference between the pupils' results related to the both sub-tests of test 2

**Null hypothesis (H' 0):** "The sub-test is of the first variant or the second variant" and "the success, or not, of a sub-test of test 2 by the pupils" are independent.

**Alternative hypothesis (H' 1):"**The sub-test is of the first variant or the second variant" and "the success, or not, of a sub-test of test 2 by the pupils" are not independent.

The results of Chi-square statistical test are presented in table 2 below:

**Table 2: The value of Chi-square, the interval of the critical probability p and the accepted hypothesis, associated to sub-tests of the same test.**

| Tests | Value of Chi-square (Chi- square) | Interval of critical probability: p | Accepted hypothesis |
|---|---|---|---|
| **Test 1** | **5,453** | **p< 0,05** | **$H_1$** |
| **Test 2** | **5,451** | **p< 0,05** | **$H'_1$** |

For test 1, where the critical probability is less than 5%, we can reject the null hypothesis ($H_0$) and accept the hypothesis ($H_1$). For test 2, where the critical probability is less than 5%, we can reject the null hypothesis ($H'_0$) and accept the hypothesis ($H'_1$). In other words, the results show a significant influence of the second variant subtests on the geometrical constructions success in relation to the first variant sub-tests.

According to the results presented in table 1, it can be concluded that the second variant sub-tests have a significant and negative influence on the geometrical constructions success in relation to the first variant sub-tests.

### 2. Pupils' conceptual difficulties proven in the false constructions

We analyzed the geometrical constructions produced by classifying the false geometrical constructions according to the conceptual difficulties below:

**CD 1** = Conceptual difficulty related to the correspondence image object (punctual and global).

**CD 2** = Conceptual difficulty associated with the minimum number of rays departing from the same point of luminous object.

**CD 3** = Conceptual difficulty related to the tracing of construction ray.

**CD 4** = Conceptual difficulty associated with the tracing of construction ray extension.

The results of pupils' difficulties proven in the false constructions are presented in table 3 below:

**Table 3: Numbers of pupils' difficulties proven in the false constructions.**

| Sub-tests | Nature of difficulties | | | |
|---|---|---|---|---|
| | CD 1 | CD 2 | CD 3 | CD.4 |
| Sub-test 1-1 | 4 | 7 | 6 | 4 |
| Sub-test 1-2 | 5 | 4 | 7 | 14 |
| Sub-test 2-1 | 6 | 7 | 5 | 5 |
| Sub-test 2-2 | 5 | 6 | 8 | 16 |

Before we start our discussion, we note that some false constructions have more than one conceptual difficulty.

## Discussion

For the first variant sub-tests, the pupils scored about 5 difficulties related to the tracing of construction ray extension, while the number of the constructions produced is of about 51 (table 1). This result shows that the geometrical construction associated with the first variant sub-tests do not allow the emergence of the conceptual difficulty related to the construction ray extension tracing. (About 10 % of pupils encountered this conceptual difficulty).

For the second variant sub-tests, the pupils scored about 15 difficulties associated with the tracing of construction ray extension, while the number of the construction produced is about 45 (table 1). Because of this, it can be concluded that the tracing of construction ray extension while solving the second variant sub-tests presents a real difficulty for about 32 % of pupils.

This result joined that of (Mistrioti, 2003) concerning the emergence of this conceptual difficulty even for university students when working with an optical system formed of a plane diopter.

In connection with this conceptual difficulty, and in the false schemas corresponding to the sub-test 1-2, about 32 % of pupils consider that the opaque medium "prevents" the formation of the virtual image (Figure 9, Appendix 2). In this respect we can say that about 32 % of pupils consider that the opaque medium "blocks" the construction ray extension. In the false schemas corresponding to the sub-test 2-2, about 32 % of pupils consider that the plane diopter has an "effect" on the formation of the image (Figure 10, Appendix 2). About 32 % of pupils consider that the construction ray extension "undergoes" refraction in relation to the axis of construction ray, modeling, the luminous ray reflected on the plane mirror.

So, if about 32 % of pupils consider in their construction that the medium "refracted" or "prevents from passing" the construction ray extension, we can conclude that 32 % of the learners affect to the construction ray extension characteristics that the construction ray possess (the fact to be "refracted" or being "stopped" by a medium). This result shows that about 32 % of pupils have a misconception associated with the role of the construction ray extension.

For all sub-tests, the pupils produced about 6 difficulties associated respectively with the minimum number of rays departing from the same point of the luminous object, and with the correspondence object-image. This result illustrates that just about 12 % of pupils encountered this conceptual difficulties. In the false constructions associated with these conceptual difficulties, we note that a one construction ray departing from a point of the luminous object has been traced, or a lot of construction rays have been traced, but each of them departs from a different point of the other of luminous object.

For each sub-test, the pupils have proven approximately 7 difficulties associated with the tracing of construction ray. So, we can say that approximately, just 14 % of pupils come up against this conceptual difficulty.

## CONCLUSION

Through this work we have studied the conceptual difficulties encountered by the pupils during the geometrical construction of a virtual image among the pupils in the first year of Baccalaureate Experimental Sciences ES.

The analysis of the results using the Chi-square of Statistical Test has shown that the second variant sub-tests have a significant and negative influence on the success of geometrical construction of virtual image in relation to the first variant sub-tests.

By analyzing the difficulties proven in the false geometrical constructions produced by the pupils, we have found that the first variant sub-tests do not allow the emergence of the conceptual difficulty associated with the tracing of construction ray extension. The geometrical construction of the virtual image through the second variant sub-tests has shown that about 32 % of pupils have a misconception associated with the role of the construction ray extension when solving the second

variant subtests. This result joined that of (Mistrioti, 2003) concerning the emergence of this conceptual difficulty, even for university students, by working with an optical system formed of a plane diopter.

After checking the conceptual difficulty related to the correspondence image object (punctual and global) and the difficulty associated with to the minimum number of rays departing from the same point of the object and also the conceptual difficulty in tracing a construction ray, it seems that the geometrical construction through the both variant have not allowed the emergence of these conceptual difficulties. Just about 12 % of pupils come up against these conceptual difficulties for each sub-test.

We scored a difference between our results associated with the sub-test 1-2 and those of (Mistrioti, 2003) concerning the schema given to the students to complete. Indeed, 38 % of pupils have provided a correct construction for the sub-test 1-2, while just 11% of multidisciplinary students scored a correct construction. This difference can be justified by the fact that the mechanism of the vision of an image is more difficult than a simple geometrical construction of the virtual image. In fact, the study of the mechanism of the vision of a virtual image involves a “double geometrical construction” The geometrical construction of the optical image of the luminous object through the optical system, and the geometrical construction of the image of the formed optical image through the “eye” that constitutes another independent optical system.

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## Appendix 1

### Test 1:

**Sub-test 1-1**

**Enunciated:** A luminous object of small dimensions in the form of the letter F is placed on the principal optical axis of a convergent lens (L), between the principal focal object and the principal optical center (Figure 1). Construct, geometrically, the image $F_1$ of the luminous object F through the convergent lens (L).

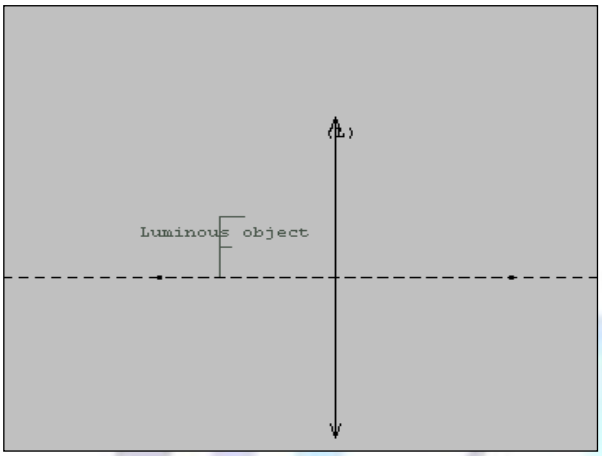


**Figure 1:** Schema of sub-test 1-1

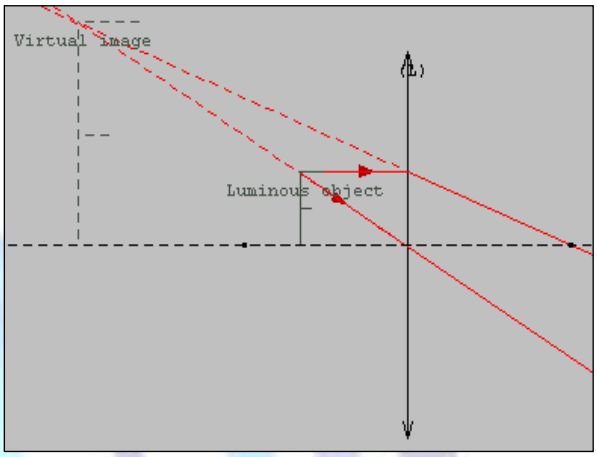


**Figure 2:** correct construction of sub-test 1-1

**Sub-test 1-2**

Enunciated: Now, we place an opaque medium tangent on the left side of the principal optical axis (Figure 3). Construct, geometrically the image $F_2$ of the luminous object F through the system: {(L) + opaque medium}.

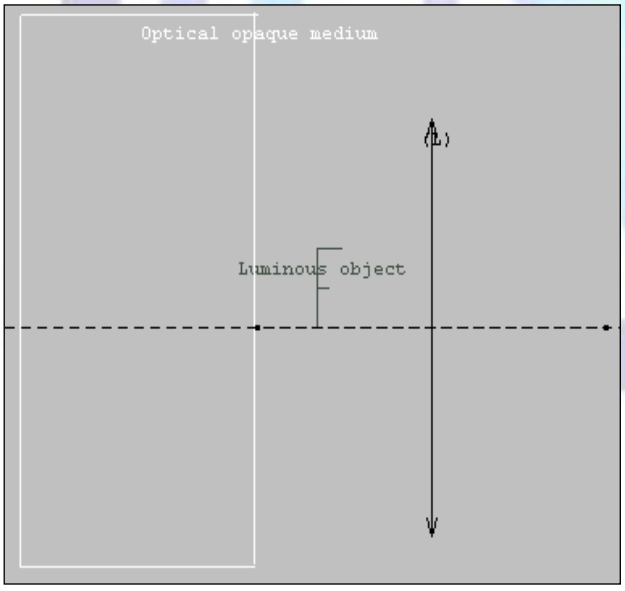


**Figure 3:** Schema of sub-test 1-2

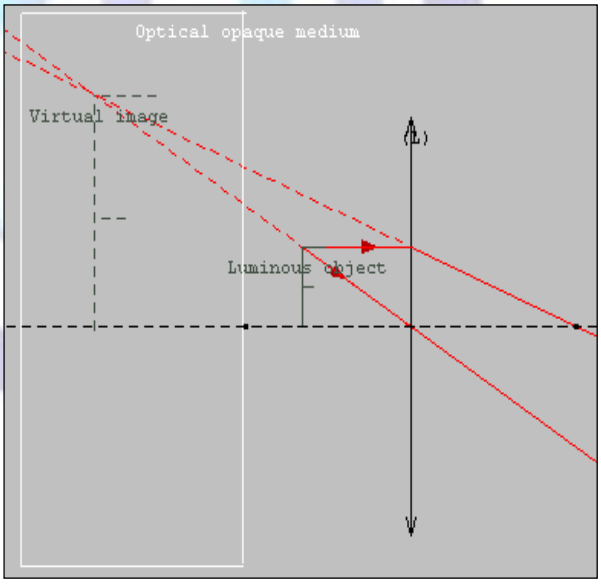


**Figure 4:** correct construction of sub-test 1-2

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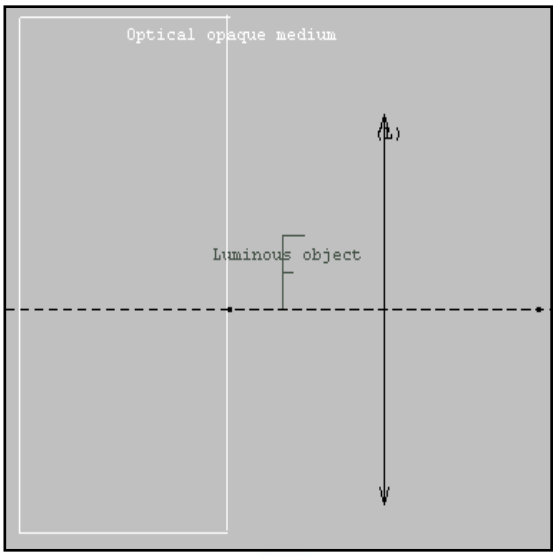


**Test 2:**

**Sub-test 2-1**

**Enunciated:** A luminous object of small dimensions, in the form of the letter F is placed vertically in vacuum (the index of refraction of vacuum is n=1) in front of a plane mirror (PM) (Figure 5). Construct, geometrically the image $F_3$ of the luminous object F through the plane mirror (PM).

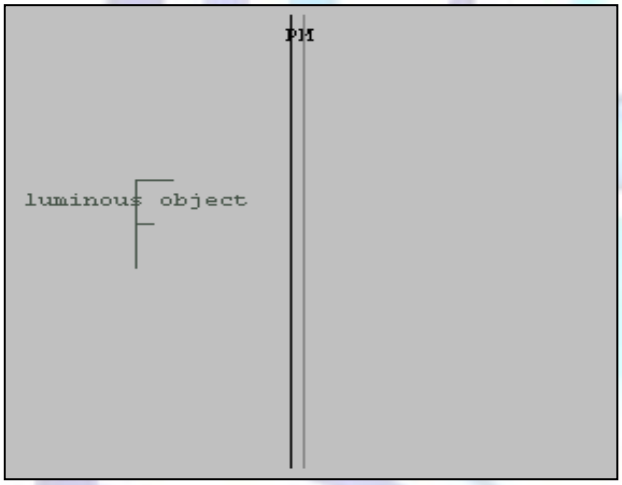


**Figure 5:** schema of sub-test 2-1

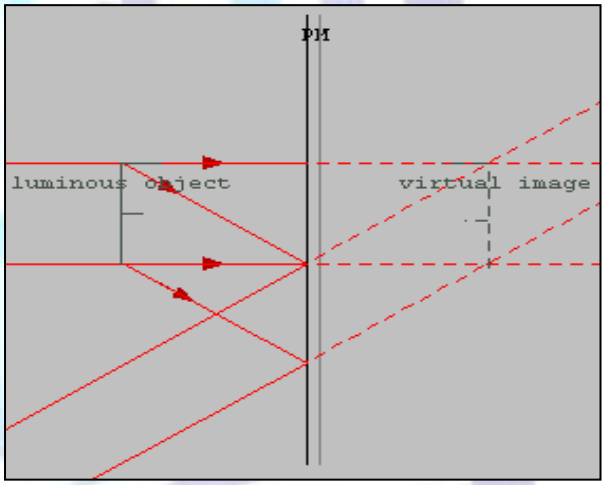


**Figure 6:** correct construction of sub-test 2-1

**Sub-test 2-2**

**Enunciated:** Now, we place a refracting medium (the refraction index of this medium is n = 1.5) tangent on the right side of plane mirror (PM) (Figure 7). Construct, geometrically the image $F_4$ of the luminous object F through the system: {(PM) + refracting medium}.

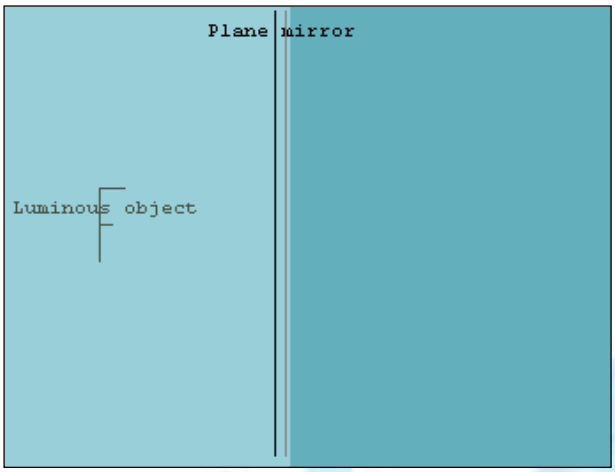


**Figure 7:** schema of sub-test 2-2

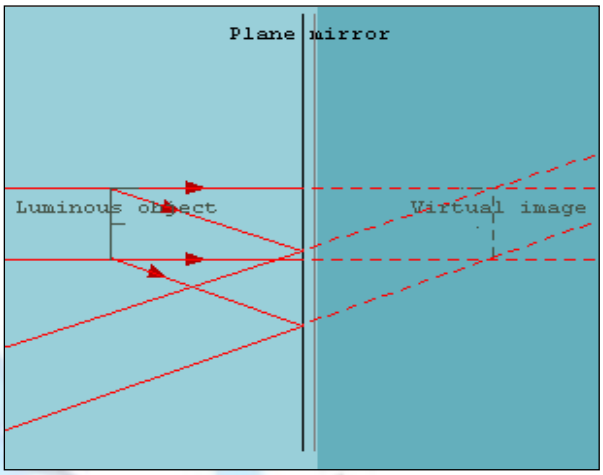


**Figure 8:** correct construction of sub-test 2-2

## Appendix 2

False geometrical constructions related to the sub-tests: 1-2 and 2-2.

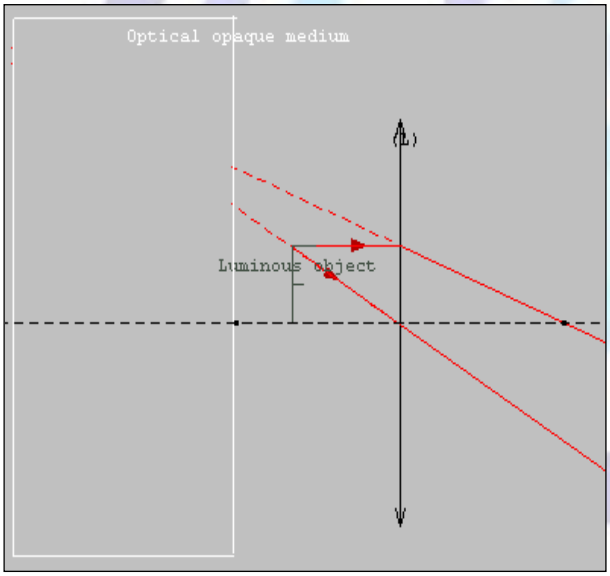


**Figure 9:** A false geometrical construction in which the construction rays extensions are “blocked” by the opaque medium.

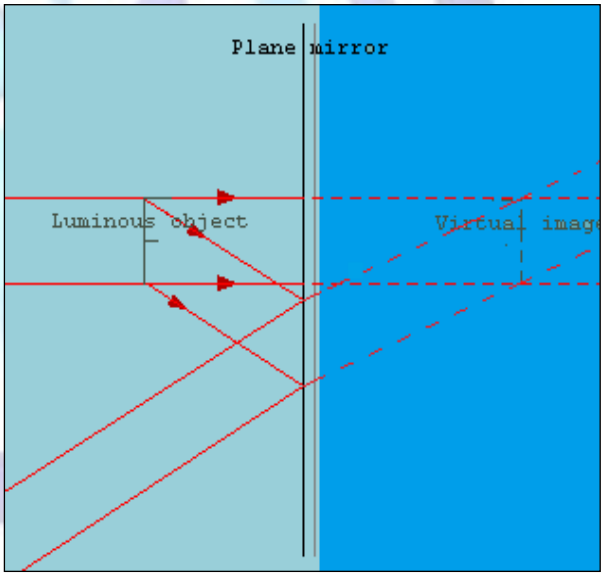


**Figure 10:** A false geometrical construction in which the construction rays extensions have “undergo” refraction by the refracting medium.