Description of Case study „Optical instruments - telescopes" - for exchange in HIPST project

1. **Title:**
   Optical instruments – telescopes
   ***Key words**: teaching, history of the telescopes, refractor, mirror telescope (reflector)*

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3. **Summary:**

The current core curriculum for upper secondary school included, inter alia, perception of the nature and structure of physics and astronomy, their development and their relationship to other natural sciences as the primary objectives. It would be difficult to find in the history of astronomy development and inventions more significant event than the use of telescope for observing the sky by Galileo in 1609. His discoveries (sunspots, mountains and craters on the Moon, phases of Venus, Saturn's rings, the separation of the Milky Way on a number of faint stars, and above all - the moons of Jupiter) were objective and irrefutable fact, which had to come out in modern science. Experience and observation came here with the help to the theory, which has been formulated almost a hundred years before by Copernicus (Comentariolus, c. 1506, and De revolutionibus... 1543). Obvious example (in the form of the moons of Jupiter) that not everything revolves around the Earth, signified an end to the geocentric model of the world's construction. The golden age of science began, which bases their theories and models not only on the direct observation, but on the proposing and verifying hypotheses.

Construction and use of binoculars and astronomical telescopes is located within the content of teaching physics both in the "Light and its role in nature" (where we excellently supplement and enrich students' knowledge on phenomena of lenses and mirrors, refraction and reflection phenomena), as well as in the section " Tools of modern physics and their role in the study of micro- and macroworld under the topic "Modern astronomical observatories." The research case described here is an attempt to combine elements of both of these issues, and refers also to the history of science, on the other hand is an attempt to sketch its current level of sophistication.

Optical telescopes give us the opportunity to meet potentially all elements of the school tasks. They assist in the contextual approach to teaching physics, based on the typical interface between nature and technology issues. They broaden the knowledge of individual student in order to deepen the understanding of science. In extremely expressive way they reveal the role of observation and theory in developing our knowledge on nature. They inspire curiosity of students and their proper attitude to research. They also acquaint them with the possibilities of modern research techniques.

The described case meets a vital role in shaping students' achievements. It clearly demonstrates the ability to observe and describe astronomical phenomena and the use of models to explain these phenomena. It enables the use of acquired knowledge in studying the construction of the optical devices.
Understanding the course requires a simple, elementary physical knowledge. Theme is so universal that it can be successfully applied not only to the lessons in the higher secondary school, but also in lower secondary school (gymnasium), especially for students who are more interested in physics, for example, during the after school courses or clubs. The subject is particularly valid in view of the celebration of International Year of Astronomy, in the 400 anniversary of Galileo's discoveries. It underlines further the historical aspect of this case study.

4. Description of Case study

The telescopes take a fundamental position among the optical devices. They are not as widespread in use as sunglasses, magnifiers and cameras, but it's hard to imagine modern astronomy without them. The story of the invention itself is not fully explained and understood.

The first well-documented historical use of lenses appears in Greek and Roman sources. As the official start of telescopic astronomy, the active living in the eleventh century Mesopotamian astronomer, Alhazen (Abu Ali Hasan Ibn al-Haysam) can be considered. He was the greatest physicist of the world in his times and he is considered to be the father of optics. He was interested in refraction and dispersion of light, and his works had a significant impact on the development of the modern telescope.
Lens were discovered in archeological stands in Visby on Gotland (in Sweden). These lenses are dated for the second half of the eleventh century. The shape of these lenses is that almost half of the ideal ellipsoid, while the other side is flat. Some of these lenses have the handle of silver and were probably used as pendants.
One of the greatest scholars of the thirteenth century in Europe, was Vitelo (historical sources indicate - he was the son of Poles and Turings). He was in the leading contemporary intellectual elite, and his works were known to Copernicus, Johannes Kepler and Leonardo da Vinci. The work "Perspectivorum libri decem" collected the state of contemporary knowledge in the field of optics. Phenomena such as: the rectilinear propagation of light, its reflection, refraction and dispersion are discussed basing most closely on mathematics and geometry.
In several studies written between 1230 and 1235 Robert Grosseteste wrote, among others: That part of optics, when we comprehend it correctly, shows us how we can make a very distant objects gave the impression of being very close, and close large objects seems to be littl , and how we can make distant objects are of the size that we want, so that it may be possible to read the smallest letters from unprecedented distances.
Robert Bacon was Grosseteste's student at Oxford, and often it is claimed that he described the telescope in the thirteenth century, although it can not be stated with certainty that he ever built a fully functional design.
We have well-documented communications providing that both lens and mirror telescopes were known in England in the second half of the sixteenth century. Writings of John Dee and Thomas Diggesa from 1570 and 1571 respectively describe the use of these optical structures by Leonard Digges, the father of Thomas.

Independent confirmation of this fact can be found in other records from that period. However, knowledge about this did not spread until the beginning of the seventeenth century (around 1608), when knowledge has become widespread in the Netherlands. Discovery - with today's historical point of view - should be attributed to three People: John Lippershey, Zacharias Janssen (who were both manufacturers of spectacles), and Jacob Adrianszoon.

The first telescopes were constructed with two lenses: focusing and diffusing - such telescopes do not invert the image, i.e. the obtained image is direct. Due to the number of practical applications of such monoculars, a significant number of them quickly spread throughout Europe. It is worth noting that the task of reconstruction of the Galileo's telescope has been developed successfully by the Department of Physics Education of Nicolaus Copernicus University in Torun; now this model is part of an interactive exhibition "FIAT LUX - from Vitelo to the optical tomograph" ***(http://dydaktyka.fizyka.umk.pl/ FIAT_LUX / html /).***

In this study we emphasise the use of the telescope by Galileo to observe the sky. This was undoubtedly the epoch-making event, which opened up a whole new world of researchers. For about two centuries the progress in developing our understanding of the universe appears to be little from today's perspective. The great step forward were spectroscopic studies of the Sun and stars. They helped to determine that the composition of cosmic matter does not differ from the earth, that in both the same basic ingredients – elements - occur. Further analysis of the spectra allowed the appointment of a whole range of physical and chemical parameters of objects in space. Another extremely important and a watershed event for astronomy was to prove an extragalactic nature of some nebulae - that is, the discovery of other galaxies, and the expansion of the universe soon after. In the longer term this has led to a huge revolution in our perception of the universe – which from the static and orderly forever has become a living, dynamic, growing and evolving.

5. Historical and philosophical background, including the Nature of Science

Already in the preceding paragraphs it was indicated how great is the importance of the telescope's invention in the development, not only of astronomy, but science in general. Confirmation of the validity of Copernican thought which abandon the geocentric point of view allowed emerging science based on observation, logical reasoning, predicting phenomena and their verification - that's the basis of modern, rational, verifiable knowledge which is also the subject to further modification. Attempt to self-statement of the lenses and the discovery of the principle of construction of telescopes is an excellent opportunity for students to find out how simple yet genius was using two lenses to obtain a zoomed image.
Galileo is given as a co-author (along with Bacon) of the scientific method of study, passing in successive stages: problem identification, hypothesis, prediction of hypothesis consequences, performing the experiment confirming the prediction, the formulating of the rule.

6. Target groups, the importance for curriculum and educational benefits

The issue has been developed for secondary school students, and it can be implemented at both basic and advanced level. Usually the telescopes are included in *the content of the lesson devoted to optical devices. We recommend selecting this theme, which allows to highlight the historical significance of Galileo's discoveries. Independently performed exercises motivate students to work more actively during the lesson. Interest and involvement of students in the learning process is growing. The lesson through the use of pre-prepared presentation goes smoothly. It may also be one of the summary lesson, extending the knowledge and skills of the geometric optics.*

7. Activities, methods and tools of learning

The beginning of the lesson is the formulation of the problem and theme. You can also use an excerpt of film, showing the discoveries made by Galileo using the telescope. The element of history might be a good mean of involving students in work during the lesson.
The primary incentive, however, is trying to get the statement of the lenses in the system by which one can obtain the magnified image. During the exercises students can independently come to the two relevant solutions - typical of Galileo (simple image) or Kepler (image reversed) system. The practical inquiry method of studies has a perfect application here. The use of worksheets permits in a clear and simply way to organise the acquired knowledge and skills.

8. Difficulties in teaching and learning

Knowing how to make the telescope image should not be superficial, based on vague, not reflecting the views of true nature. It is important that it is based on the fundamental laws of optics: the laws of reflection and refraction. Indeed, this is an excellent opportunity to illustrate the application of these laws in practice.
Encouraging students to self-experimenting is an attempt to depart from the traditional mode of giving the completed messages, which usually is not an effective method of teaching. Difficulties may appear at the stage of structuring the observations, which are concerned with the recognition of two separate optical systems used in telescopes. Diagrams displayed with the use of computer and projector should help to clarify this issue.

9. Teacher's pedagogical competencies

Information needed to carry out the activities are given in the lessons scenario. Usually the physical lab is equipped with a number of lenses, which can be used for self-testing the telescope construction. You can also ask students to bring unused spectacle lenses. Performing activities itself should not present difficulties. Through the worksheets the process of acquisition, systematizing and consolidating the acquired knowledge works smoothly and takes place mostly by an individual work of students, but only in a limited way controlled by the teacher.

10. Documentation (evidence) of studies

- *lesson's scenario: http://hipst.fizyka.umk.pl*
- *the worksheet included in the scenario*
- *optionally the excerpt of the movie „Eyes on the Skies"*

11. Further professional development of users

1. *Sierotowicz T., „Galileusz", WAM Kraków*
2. *Kreiner J. „Ziemia i Wszechświat", Wyd. Naukowe UP Kraków*
3. *North J. „Historia astronomii i kosmologii", Wyd. Książnica*
4. *Multimedia presentation: Rochowicz K. „Teleskopy optyczne" in: http://hipst.fizyka.umk.pl*

12. Written literature resources

1. *Seminar talk given at the 2-nd National Meeting of HIPST Project in Olsztyn, 11 September, 2009*
2. *Multimedia presentation at the above Seminar.*
3. *Talk at the lecture for students "Telescopes from Galileo to Hubble and beyond".*
4. *Luneta na lekcji w szkole, czyli zostań sam Galileuszem, Nauczanie Przedmiotów Przyrodniczych, 32/2009, pp. 23-28.*

Scenario of the lesson on:

Optical instruments - telescopes

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The aims of the lesson

- general (student):
  - learns about basic astronomical tools: optical telescopes
- operational (student):
  - knows, that there are two kinds of refractors, which give straight or reverse image
  - knows, that there are two kind of telescopes, refractors and reflectors

Methods

- searching: talking with students (questions and answers);
- practical: students' experiments.

Forms

- group,
- individual.

Didactical tools:

- student's textbook,
- experimental set – different kinds of lenses,
- pictures and drafts of the first telescopes on projector's screen, illustrations of spherical and chromatic aberration,
- optional: presentation "Optical Telescopes"; DVD „Eyes on the skies" (excerpt).

Lesson's scenario

TEACHER'S ACTIVITIES	STUDENTS' ACTIVITIES
1. Welcome. Introduction.	
- Today we will learn how to build one of the optical instruments, very important for astronomy. (I show the lenses). Are you aware, which instrument we can build using two lenses?	- They answer (possible answers): magnifying glass, refractor, telescope.
- (If it is necessary, I notice that magnifying glass is a single lens and it is used for observing nearby objects in close-up). Do you know, who and when pointed the telescope in the sky for the first time?	- They answer, after putting on the right track, that it was Galileo Galilei. Probably they don't know the year.
- It was exactly 400 years ago and that is why 2009 is an International Year of Astronomy. (You can show „Eyes on the skies" excerpt)	

- Introduces the lesson's subject.	- They write it down in their notebooks.
2. Lesson's ellaboration – learning the basic concept of the telescope by experimenting.	
- Distribution of the lenses among students, to look at them and study their properties	- They play with lenses, trying to get some images.
- What can you tell about these lenses?	- Possible answers: They are different in size and shape.
- What conclusion can you draw on this basis?	- Possible answers: There are two kinds of lenses; convex – focusing the light beam – and concave – spreading the light.
- Let's try to combine two lenses 20-30cm distant, to get the image.	- They try to put together the lenses in pairs and check out if an image appears; they give their propositions.
- The original Galileo's telescope was build as a system of a plano-convex object lens and plano-concave eye lens; what kind of image can we obtain this way?	- Students put together the lenses in the recommended way, they check an image characteristics; they give their propositions.
- Galilean telescope gives the straight image.	- They fill in the worksheets (p. 1 and 2).
- Let's check out if we can use two planoconvex lenses to get an image.	- Students put together two planoconvex lenses, trying to derive an image; they share their experience.
- It is the principle of Kepler telescope; his instrument gives the upside down image.	- They fill in the worksheets (p. 3 and 4).
- We say refractors or telescopes; what is the difference between them?	- They can give various answers; the teacher explains (generally there is no difference; sometimes we mean reflectors by telescopes, but it is not obvious).
- Why modern big telescopes use mirrors instead of lenses?	- They try to guess; the teacher answers.
- The short explanation of spherical and chromatic aberration based on the pictures.	
- What is the size of the world's largest astronomical telescopes?	- One student searches for this information using internet; they fill in the worksheets (p.5)
- Points out the SALT telescope, co-financed and co-used by Polish Scientific Research Committee; recommends webpage with the „Optical Telescopes" presentation	
3. Summary	
- What was today's lesson about?	- Answer: telescopes
- What kind of telescopes do you know?	- Answer: refractors and reflectors
- What kind of image do we get by Kepler's telescope?	- Answer: the reverse one
- What kind of image do we get by Galilean telescope?	- Answer: the straight one
- Makes students' work evaluation.	

Attachements:

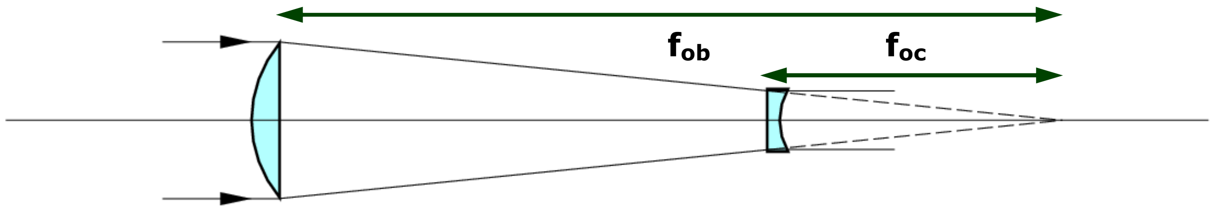
1. Worksheet
2. The pictures and drafts of the first telescopes
3. Illustrations explaining chromatic and spherical aberration

Worksheet

Firstname and surname:_______________________________ **Class** _____ **Date** _______

Subject ____

1. Describe the optical elements of the Galilean telescope marked in blue (give the name of the lenses).



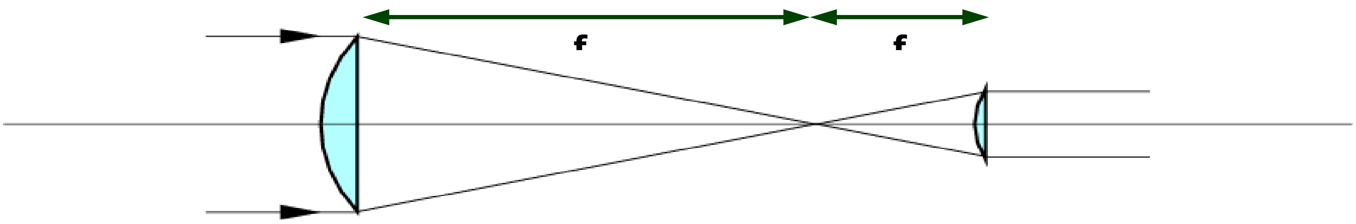
2. Complete the sentences:

Galilean telescope consists of the ______________________________________ object lens

and __________________________ eye lens. The eyepiece is located _________ the focus.

This instrument gives the _________________ image.

3. Describe the optical elements of the Kepler's telescope marked in blue.



4. Complete the sentences:

Kepler's telescope consists of the ______________________________________ object lens

and __________________________ eye lens. The eyepiece is located _________ the focus.

This instrument gives the ___________________ image.

5. Complete:

The world's largest astronomical telescopes have diameters up to _______________ metres.

These are systems with the __________________ , the so-called ______________________.

These systems are less affected or do not have the defects characteristic for lenses, including

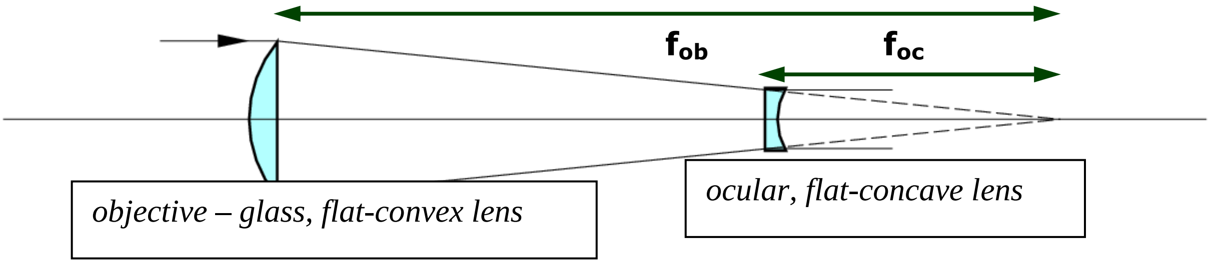
____.

Predicted right answers in the worksheet

Firstname and surname:________________________________ **Class** _____ **Date** _______

Subject: Optical instruments – telescopes _____________________________________

6. Describe the optical elements of the Galilean telescope marked in blue (give the name of the lenses).



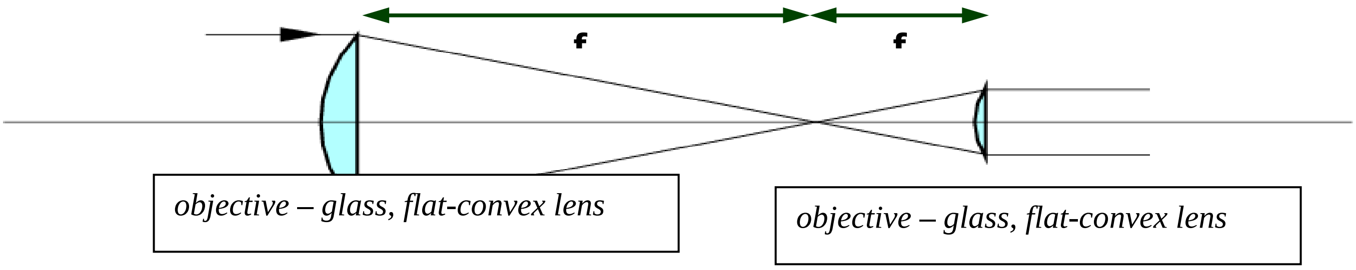
7. Complete the sentences:

Galilean telescope consists of the _______*flat-convex* _______ object lens

and ____ *flat-concave* ______ eye lens. The eyepiece is located ___*before*__ the focus.

This instrument gives the ___*direct*__ image.

8. Describe the optical elements of the Kepler's telescope marked in blue.



9. Complete the sentences:

Kepler's telescope consists of the ______________ *flat-convex* ___________ object lens

and _____*flat-convex* _______ eye lens. The eyepiece is located _after_ the focus.

This instrument gives the ___*reversed*____ image.

10. Complete:

The world's largest astronomical telescopes have diameters up to ____*10*_____ meters.

These are systems with the ____*mirrors*___ , the so-called __*reflectors*_____.

These systems are less affected or do not have the defects characteristic for lenses, including

_*spherical and chromatical aberration*_________.