Description Case study: "The contribution of Nicholas Copernicus observations to the reform of calendar"
-for exchange within the HIPST project

1. Title

"The contribution of Nicholas Copernicus observations to the reform of calendar"
***Key words**: calendar, the apparent motion of the Sun, the experiment of Copernicus, reflex gnomon*

2. Authors and Institutions

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3. Summary

In the lower secondary school teachers introduce students to the world of knowledge ... to implement their independence ... Education should mostly focus on: ... "To develop social skills through the acquisition of valid student's experience in intercourse and in a peer group."

*According to the above general objectives of teaching on the third stage of education as the Case study, we propose to carry out research **interesting physical experiment** for those **young People who want** to spend some time exploring the course of describing the fundamental physics and astronomy in nature (educational objectives in teaching of physics), and stimulate interest in the broadly defined geographic area (educational objectives in teaching geography).*

The task of the school is "to show the importance of discoveries in science for the development of civilization," ... and this can be achieved through inter-subject correlation. And all of this to the young man finishing lower secondary school could apply by geographical knowledge in life, skilfully observed and described the physical and astronomical phenomena, skilfully used the conventional inquiry methods for physics and astronomy, and operated on the basic historical categories: time ..., and variability.

Taking into account the complex development of the various issues we propose both: to equip Students with information about the physical - astronomical – geographical and historical nature as well as with the skills needed to function in society and in everyday life. Interesting experiment that combines so many elements is the experiment of Nicolaus Copernicus, who had an impact on the reform of the calendar in the sixteenth century. During repetition of observations of the famous, born in Toruń astronomer, young people learn about the gnomonic-reflection method and independently carry out lasting more than two months experiment. As a result of the observation they plot the conical curves, which are alike to the results of Nicolaus Copernicus, providing a finding of Spring equinox.

The issue raised by the above Case study is contained in the following themes of Polish core curriculum:

- *History: Europe and the Mediterranean world in the Middle Ages ...*
- *Geography: Earth as part of the Universe.*
- *Physics: Solar System ... propagation of light - phenomena of reflection and refraction of light, Nature of light.*
- *Philosophical path: The most outstanding representatives of ancient philosophy: ... Aristotle.*
- *Regional trail: Elements of the history of the Region and its most prominent representatives.*

*Interesting, not typical physical - geographic **experiment was conducted at the school** for more*

than a dozen students, as creation of opportunity for physical experience and to familiarize them with the methods of observation, research and description of the physical and astronomical phenomena, as this is a task of this institution.

At the physics lesson, after presenting the results, students lively discussed and planned to repeat the experiment willing to correct the imperfections made during the first observations.

4. Description of Case study

Physical and astronomical phenomena that are the subject of Case study are usually presented in school in isolation from history. With an "astronomical table" of Nicolaus Copernicus a common problem for physics, astronomy, geography, philosophy and history may be combined.

The purpose of Case study is to present the scientific gnomonic – reflection method, used in the castle in Olsztyn by Nicolaus Copernicus and to check whether this method can determine the solar equinox days at the present time. Due to the time duration of experiment, the following process during Case study has been planned: introductory lesson, execution of the experiment and the main lesson. During the introductory lesson, students learn about the reflective gnomon method used by Nicolaus Copernicus ***(scenario of introductory lesson),*** *and present themselves willing to work.*

Before proceeding to reproduce the experiment it is necessary to choose a place to carry out observations (in our case it was a school room), so that the windows of the rooms facing the south (northern hemisphere). You should also prepare the necessary apparatus for the experiment - the mirror on the stand, e.g. due to the activity of one of students).

Volunteers were divided into three teams and have agreed on principles for the conduct of the experiment:

- *we carried out experiment once a week (Wednesday)*
- *if in the particular day of the week the weather was not good enough we conducted observations in the first nearest sunny day (except Saturday and Sunday).*

Measurements were made a three times a day:

- *first on 8.30,*
- *second on 12.00,*
- *third at 15.00, local time.*

Then, for two months, students were marking observation points on the ceiling. After marking of the last two points, together with students and in collaboration with the Institute of Physics, NCU involved People, we "moved" the selected points on the coordinate system.

After finished observations, during the main lesson of physics, all students familiarized themselves with the results of an experiment conducted with a group of eager young People – their colleagues. Students in the classroom with the use of special experiments were acquainted with the purpose of Copernicus and volunteers observations and with the results of these observations ***(scenario of the main lesson).*** *During this lesson young People strengthened the concepts of rotational and progressive (at the orbit) motion of the Earth and found out why and what kind of conical curves appear either on the ceiling or on wall. In addition, in the next step the picture of astronomical table made by Nicolaus Copernicus in Olsztyn in 1517 (*the authenticity *of this table was confirmed in 2009) have been presented to students during the multimedia presentation.*

In our case, introductory lesson was carried out in the last week before the winter recess for students in grades second and third. The first points were marked on 18th February and the last 22 April 2009. Main lesson was conducted as the last lesson in the school year 2008/2009.

By performing the described Case study we can ask: "Are our students the first in Poland and perhaps in the world, in my care, who recreated the famous experiment of Nicolaus Copernicus?"

5. Historical and philosophical basis, including the Nature of Science (NoS)

Nicolaus Copernicus, who was born in Torun in 1473, is most known for his work published in the year of his death (1543 year) "On the Revolutions of Heavenly Spheres ..." ("De revolutionibus") containing a lecture about the heliocentric solar system of our Universe. In his time the geocentric model obeyed (in the middle of such system is the Earth and other planets - moon and sun on the third orbit in the circular motion) is described by Ptolemy in the second century. Polish astronomer argues that in the middle of the heliocentric system is the Sun and other planets, moon, and earth on the third orbit, are in the circular motion.
It turns out that Copernicus left behind also another souvenir. It is survived to our times the original astronomical instrument at the castle in Olsztyn, used to determine the day of Spring equinox, with the apparent movement of the sun observation - ***astronomical table****. It was helpful in measuring the time a complete revolution of Earth around the Sun.*
Based on archaeological research we know, that this tool set days of the Spring Equinox in 1517 on March 11 Julian calendar.

It is believed that the astronomical table is linked to the work of Copernicus on the reform of the Julian calendar, which was invited in 1513 by Pope Leo X via Bishop Paul of Middelburg.
During the time of the famous astronomer, the Julian calendar obeyed, which had an average year 365.25 days. At the Council of Nicaea in 325 year when it was decided when should be so called "movable feast". Particularly it was concerned with Easter, which are set to begin on the first Sunday after the first spring full moon, so after the spring equinox. Initially, the spring equinox were on March 21, but over the years this date began to shift. In the thirteenth century, scholars talked about the need for change, but to the time of Copernicus could not enter them. Only in 1582, Pope Gregory XIII reformed the calendar, which runs today and is called the Gregorian.

The case presents a study proposal of repetition of Nicolaus Copernicus observations, who has used his research as a first principle of reflection, which consisted in selections of successive points on the sun's rays reflected off the mirror. During the experiment, young People carry out their own experiment through the selection of points at a specified time and in accordance with their own "inventions" and jointly developed methods. Through such work they will know the difficulties of observing the sky and often also their helplessness.
The project has physics and astronomy components, but also the history (calendar) and philosophy elements (geocentric and heliocentric system) to present a broad aspect of the work and thought of such phenomenal man as Nicolaus Copernicus was.

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

This case is a research proposal for young People studying in secondary school (13 - 15 years). Activities are conducted at school. There may be the optics lessons - especially when discussing the properties of light or law of light reflection. We present the observation by way of Nicolaus Copernicus (scenario of introductory lesson). May also be extra-curricular activities, or take the form of a research project.

Concepts and physical phenomena, which are used during the activities include: rectilinear propagation of light and the law of light reflection, mirror, gnomon, reflexive gnomon , geocentric and heliocentric system, ecliptic, celestial equator, the equinox, calendar, "white nights", rotation of the Earth, progressive motion (circulation) of the Earth, the apparent motion of the Sun .
There also well-known figures in the history of philosophy appear: Aristotle, Ptolemy, Aristarchus and Copernicus.

Some of these concepts are already known to pupils from first class of gymnasium. Within the content of teaching geography of the Earth as part of the Universe a young student learns issues of the ecliptic, the celestial equator, Earth's rotation, progressive motion *(circulation) of the Earth and the apparent motion of the Sun. While within the content of physics education with elements of astronomy - the youth meets the construction of the Solar System and take the description of the history of the Universe: geocentric system of Ptolemy and Copernicus heliocentric theory.*

During the course of this Case study depending on the suggestions of an appropriate curriculum, students learn or consolidate the above mentioned optics concepts.`

At the end of the project students understand the basic properties of light, in particular, rectilinear propagation of light, the law of light reflection and the apparent motion of the Sun. In addition, learn about the development of knowledge and physical and technical skills related to gnomon.

Within two months of work, they acquire the ability to communicate and collaborate with each other and adults (including parents, teachers, staff and Management Committee of School as well as the staff of the Institute of Physics, NCU). It is very important that students learn at the same time responsibility for an experiment carried out. It would be enough that one team did not make measurement and the work of other groups would be pointless. Of course, sometimes it was so, that the measurement was impossible to implement due to the bad weather, for example in the morning, but already at noon and afternoon we could determine the points. However, we knew that thanks to modern methods of mathematics and informatics we are able to find a missing point.

Because the teams were triple, the students watched each other and to the extent of their capabilities and skills they approached responsibly to carry out the experiment. It is also important that in this experiment all the students may attend, and therefore these very capable and less capable, but also sometimes the students, who create educative problems.

7. Activities, methods and tools of learning

Ongoing Case study shall be undertaken the following actions:
1) The introductory lesson - students learn the scientific gnomonic - reflection method used by Copernicus, and achieved the planned operational objectives through the experience of using a laser pointer, a mirror and a piece of paper. At the end of the session motivation discussion was initiated aimed at invitation of students to carry out the Copernicus experiment.

Fig. 1. Picture of ceiling, where the measurement poits were marked

2) During the more than two-month observations students marked at the ceiling many points in accordance with the prescribed rules (Fig. 1). By collaboration with teachers and other school employees experiment was carried out. Unfortunately, Copernicus was right in saying that "the sky in Poland is bad, much better is in Italy, because during the course of the experiment the sky was often overcast. In result we were able to carry out six full measurements, ie, mark the three points at different times in one day (Fig. 2).

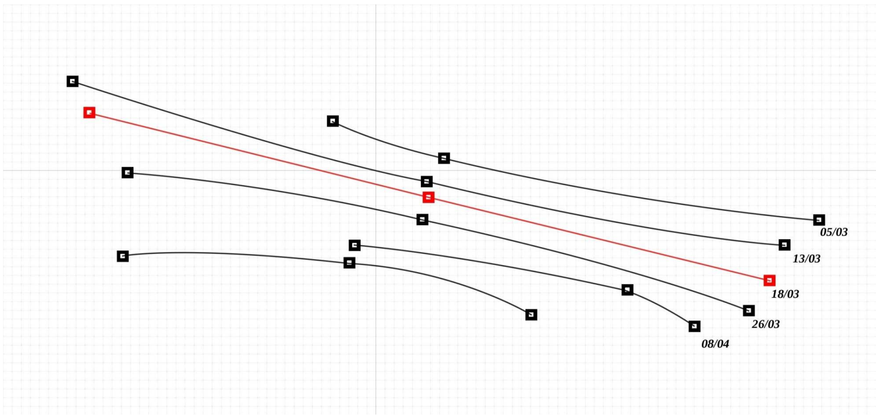


Fig.2. The results of student investigations

3) The main lesson is a summary of two months of student work and completion of operational objectives through the experience with a lamp and a globe to explain the progressive motion and circulation of the Earth, and the device called in short "gnomon with the lamp" to explain the apparent motion of the Sun and the formation of conical curves. At the end of activities, during the discussion students compare the results obtained by the Persons involved in the restoration of the Nicolaus Copernicus observations with the original charts received at the lesson. Together, we find the important differences:

- *line (approximately straight line) describing the spring equinox falls on March 18,*
- *hyperbolas are rather clear before equinox, however, subsequent graphs show the number of errors, which we made during measurements or when we moved the observation points to a coordinate system (particularly, the error is evident in the graph dated 8 April).*

Then, we reflect on the causes of the resulting errors:

- *difficulties in marking points: diameter of wheel ("rabbit"), is relatively large, rapid movement of the points - each group marked it in a slightly different way.*
- *transfer of points on the floor. Plumb made by the students was hanging on thin threads and despite the care was not always suspended in a vertical line.*
- *change of the time on the night of 28 to 29 March, which resulted that the marked points have shifted. This is particularly evident in charts when one compares the first measurement of 5.03 – approximately 10.30 hour, and the measurements: the first of 8.04 - about 12.00 and the second measurement of 22.04 - about 12.00.*

  In this way the point of curvature of the hyperbola was not read and for that reason, the curves do not have the expected shapes.
- *weather, overcast sky did not give the possibility to make more measurements, which would verify the other measurements.*

At the end we wonder together how to improve ***Case studies****. At the next lesson during the multimedia presentation the Nicolaus Copernicus Astronomical table was presented to the students (Fig.3.)*

Fig.3. Astronomical table of Nicolaus Copernicus placed at Olsztyn castle

The most imprtant part of this table is the line AEQUINOCTIUM, it means equinox. Three points survived until our time: first, looking like a T lingatura AE, with the upper bar has been drawn, the second – I and the third C.

8. Difficulties in teaching and learning

*During the introductory lesson, the question arises**: how the hyperbolas and straight line indicating the solar equinox appear?** This problem can be explained using a mathematical basis associated with conical curves and trigonometric functions. At the stage of higher secondary schools (engineering secondary schools) it is possible, but at the stage of lower secondary school students do not possess such knowledge.*
*The easiest way to resolve these difficulties is to **perform experiment with "gnomon and lamp"**, where young People in an accessible way can learn why the sun during the equinoxes in the Figure 2 is a straight line, and in other cases, the apparent movement of the sun appear hyperbolas (see scenario of the main lesson).*
*Also during this lesson we are making **the first stage of improvement of Case study**, hoping that further observations will better. Students immediately suggested that it should increase the frequency of measurements during the day - especially near the noon hours.*
***Another way** to improve the observation may be to find another idea for a selection of points, eg if the room is large, the points of the so-called "rabbits" will fall out on the ceiling and, if room is narrow - on the opposite wall. If could be possible to construct such plumb, which ensure that the projected points are perpendicular, it also reduced the errors of measurement.*
The next step to remove difficulties in the measurement is to compare the experimental results with those obtained theoretically, calculated and placed on website:
http://epsrv.astro.uni.torun.pl/cgi-bin/magda/sun/sun.cgi

9. Teacher's pedagogical competencies

Until now I and my students haven't known on Copernicus astronomical table. Through involvement in the project HIPST we learned a lot about this Case study. Participating in seminars on this subject and reviewing the relevant historical sources I have gained the skills necessary to carry out the experiment of Nicolaus Copernicus. In addition, besides knowledge
and skills the most important was the enthusiasm of students and others, similar, cooperating with us "hotheads".
I think that a lot of information needed to carry out the above activities you can find in the attached lesson scenarios and presentations.

10. Documentation (certificate) of studies

Within this Case study students were actively engaged in work relating to the restoration of the Nicolaus Copernicus experiment. They:
1) marked on the ceiling the points of light reflection at different times:
8.30 (Fig. 4):

Fig. 4. Points marked on the ceiling at 8.30

at 12.00 (Fig. 5):

Fig. 5. Points marked on the ceiling at 12.00

at 15.00 (Fig. 6):

Rys. 6. Points marked on the ceiling at 15.00

2) One student made the apparatus needed to carry out observation - the mirror stand. It was placed on the inner window in the selected point, marked by pencil. Also, the mirror was marked with a pencil point. System needed to make experiment was arranged properly, if these two points marked with pencil were tangential (Fig. 7)

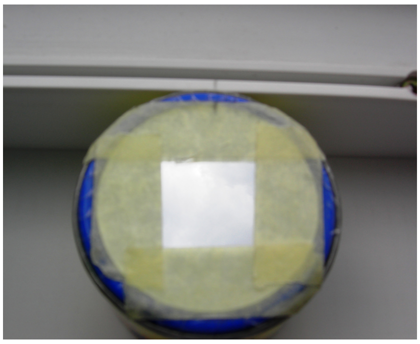


Fig. 7. Experimental setup: parapet - mirror

3) *Students in the following manner marked a point on the ceiling: in the middle, where a clear point (so-called "rabbit") with a diameter of about 5cm appeared they stuck tape and paper, wrote down a cross date and time of measurement (Fig. 8).*

Fig. 8. Point marked by students

4) *During transferring of points from the ceiling the students use the plumb constructed from threads and light bob.*
5) *One student, interested in computer science, developed and made a graph as a result of long, careful work (Fig. 2).*

Unfortunately I was not able to conduct the survey proposed by the project HIPST partners because the Case study began to pursue as early as of 9th February 2009.

11. Further professional development of users

Literature:

1. Tadeusz Przypkowski, *O Mikołaju Koperniku*, PWN, Warszawa, 1953.
2. Tadeusz Przypkowski, *Astronomiczne zabytki Olsztyna*, Muzeum Mazurskie w Olsztynie, Rocznik Olsztyński, vol. II, 1959, str. 135 – 172.
3. Jerzy Sikorski, *Z zagadnień organizacji pracy badawczej i warsztatu naukowego Mikołaja Kopernika,* „Komunikaty Mazursko – Warmińskie",1993, nr 2 (200), str. 131 – 166.
4. Grzegorz Derfel, *Wędrówki słoneczne,* „Wiedza i Życie", 1999, nr 9, str. 70 – 73
5. Agnieszka Witkowska, *Historia doświadczenia Mikołaja Kopernika,* prezentacja multimedialna
6. Zygmunt Turło, Agnieszka Witkowska, Józefina Turło, *O kalendarzu słonecznym Mikołaja Kopernika. Część I,* „Nauczanie przedmiotów przyrodniczych", biuletyn Polskiego Stowarzyszenia Nauczycieli Przedmiotów Przyrodniczych, 2009, nr 29 (1/2009), str. 9 – 17.
7. Agnieszka Witkowska *O kalendarzu słonecznym Mikołaja Kopernika. Część II,* „Nauczanie przedmiotów przyrodniczych", biuletyn Polskiego Stowarzyszenia Nauczycieli Przedmiotów Przyrodniczych, 2009, nr 30 (2/2009), str. 25 – 29.
8. Magdalena Czerwińska, *O kalendarzu słonecznym Mikołaja Kopernika. Część III,* „Nauczanie przedmiotów przyrodniczych", biuletyn Polskiego Stowarzyszenia Nauczycieli Przedmiotów Przyrodniczych, 2009, nr 30 (2/2009), str. 30 – 40.

9. Multimedia presentation at II National HIPST Meeting in Olsztyn 12.09.2009.
10. Honorata Korpikiewicz, *Jak brzmiał tytuł dzieła Kopernika?* „Urania", 1974, czerwiec.

There is possibility to check correctnes of measurements at the Web page:
http://epsrv.astro.uni.torun.pl/cgi-bin/magda/sun/sun.cgi

12. Written literature sources

Lesson scenarios (introductory and main), *Lectures about the sun calendar of Nicolaus Copernicus* and multimedia presentations can be found at **http://hipst.fizyka.umk.pl**
Other items - points 6-9, as above**.**

Enclosure 1
Scenario of introductory lesson

Theme: Astronomical table of Nicolaus Copernicus

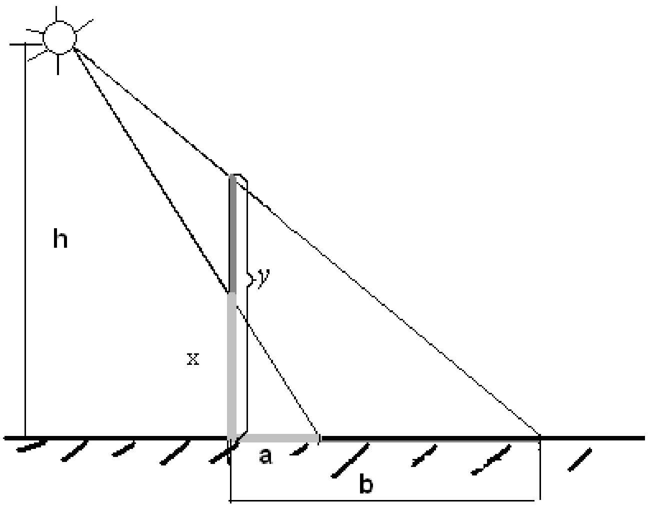
General aim: Get to know the scientific gnomon-reflection method employed by Nicolaus Copernicus.

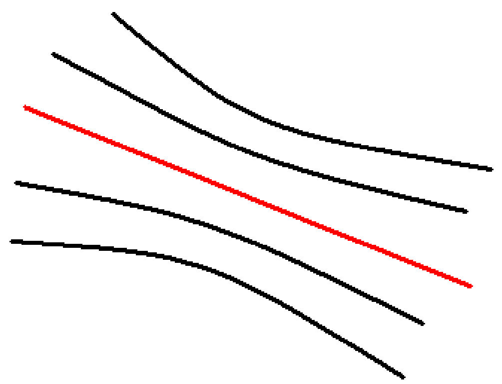
Operational aims: Student:

- knows the properties of light, particularly rectilinear transmission of light and law of light reflection,
- understand the action and the role of mirror,
- knows what it is and for what serve gnomon,
- knows how shadow emerges and what are the factors which have influence on its lenght,
- knows - how to take advantage of equinox phenomenon for real research of movement of Earth around Sun.

<u>Educational tools:</u>
Instruments for demonstration: a piece of paper, laser, mirror, board, sheet of paper to list of students willing to experiment.
Methods: experiments, a talk, discussion.
Forms: collective, individual

Teacher's activities	Student's activities
1. Introduction	
Organisation of lesson: welcome, checking of presence	
Communication of theme of the lesson	Writting the theme of the lesson: „Astronomical table of Nicolaus Copernicus".
Question 1: Who was Nicolaus Copernicus? **Question 2**: At the rurn of which centuries He lived?	**Answer:** Polish astronomer, physician, and a canon and lawyer, who, referring to some ideas from antiquity proposed and described the heliocentric system of the Universe. **Answer:** At the turn of the fifteenth and sixteenth century (1473 – 1543r.).
2. Explication of lesson	
I. History of astronomical table discovery	
Question 3.: Have you ever heard something about the astronomical table of Nicolaus Copernicus?	**Answer**: No.
It is located at the Castle in Olsztyn. In 1802, John Sniadecki in his work "On Copernicus" on the basis of the report of Tadeusz Czacki and Marcin Molski from the Warsaw Society describes the residence of Nicholas Copernicus University in Olsztyn, and also the memorial left at by him the castle –astronomical table. He specified that it was created by the use of gnomon-reflection method . It was a time when Poland was under foreign rule, and looked for signs of Polish in various locations throughout the Republic at that time.	
I. Astronomical gnomon	
Question 4: What is gnomon ?	**Answer:** It's vertical, in relation to the plane rod -bar, whose shadow indicates the height of the Sun above the horizon, often called the simplest sundial.
Gnomon utilizes the phenomenon of rectilinear propagation of light, so the shadow of the rod is a straight line, whose length depends on the height of the pillar and the height of the source	Students write a short note:. Eg. 1. Gnomon - in relation to the plane vertical rod -bar, whose shadow indicates the

of light. For example, if the at the sidewalk on a sunny day my dad comes with a small son - dad's shadow is longer than the shadow of the child because an adult is higher. It is illustrated by the rawing on the blackboard:  x – height of child,, y – height of dad,, h – height of Sun above horizon, a – height of child shadow, b – height of dad shadow.	height of the Sun above the horizon, often also called the simplest sundial. It uses rectilinear propagation of light. For example, father and child "cast" a shadow of different lengths. Students redraw the drawing from the blackboard.
Question 5: What happens to the shadow, if you change the location of light source, such as a light source will be lower?	**Answer:** Shadow will be longer.
Copernicus, however, to construct his astronomical table employed gnomon called reflective, and therefore one, that uses ... phenomenon of light reflection.	
Question 6: Who will remind the law of reflection of light?	**Answer:** The angle of incidence is equal to the angle of reflection. The radius of incident and reflected beams and perpendicular to the surface of reflection of light lie in one plane.
To reflect a light beam Copernicus used the mirror.	
Experiment with the laser, mirror and a piece of paper. Teacher reflects the laser beam from a flat, contemporary mirror to demonstrate changes in the angle of reflection depending on the angle of incidence. ***Note***: *The teacher remind the need for caution when using the laser experiment.*	One student holds the card.
Question 7:: How does the angle of reflection change?	**Answer**: If the angle of incidence is greater than the angle of reflection is greater, and if the angle of incidence decreases, then the angle of reflection decreases.
Question 8: Do the incident and reflected radiuses lie in different planes?	**Answer:** No, they lie in the same plane.

II. Mirror	
Question 9: What is mirror?	**Answer:** Mirror is the flat surface reflecting light.
Of course, at the time of Copernicus there were no such mirrors as they are today. At that time as a mirror, "our hero" could use: liquid mercury, red wine or honey mead. What was adopted by Astronomer as the reflecting surface is hard to say, the subject experts are not agreeable.. But apparently, it was not mercury because of the lack of availability and poisonous, although perfectly reflected light. Red wine, as well as honey mead reflect light less (darker color). Red wine by its sensitivity to wind blests and shocks can be considered less than the honey mead, which is more viscous, and thus one can expect a clearer reflection of sunlight and the "image of the Sun" could be more stable.	Students write a short note: Eg. 2. As the mirror a flat surface such as a light reflecting liquid - red wine, water, honey, etc. could be used for Copernicus experiment.
III. Astronomical table of Nicolaus Copernicus	
But back to Nicolaus Copernicus. From the read literature we know, that the mirror was very small and was located on the outer parapet of the porch, next to the resident of astronomer. But inside the porch, on the wall, the points that reflected the apparent motion of the Sun were marked. These points are obtained by gnomoni – reflection method - the ray of the sun reflected from the mirror in the so-called "light rabbit" fell on the opposite wall. Consequently, on the wall which astronomer smoothed out putting a layer of plaster, there are lines: a straight line and the hyperbolas , similar to those plotted in the chart below. The teacher draws a graph on the blackboard:  The straight line (red) meant the apparent motion of the Sun in the sky in the Spring equinox and hyperbolas above the straight line - the apparent motion of Sun before equinox (and therefore still in winter), and below the equinox line (and hence in the spring). Probably observations began 25 January and ended April 20, 1517 year, indicating points every five days. In his case, the spring equinox according to the Julian calendar (then obeyed) weas on March 11, 1517 year..	Students write a short note. Eg. 3. Nicolaus Copernicus Astronomical table: a) the place - the castle in Olsztyn, the wall of the porch, b) a diagram and description Students redraw chart from the table. Note to chart: **straight line** - the apparent motion of the Sun at Spring equinox, **hyperbolas** - the apparent movement of the sun in the winter (above the straight line) and spring (below the straight line), c) the experience is likely to be carried out from 25 January to 20 April 1517. c) the experiment is likely to be carried out f rom 25 January to 20 April 1517.
Question 10 And now when the Spring equinox falls? **Question 11**: Why is there this difference?	**Answer:** 21 March. **Answer:** there was another calendar obeyed, the calendar year other than it is today.

Just to answer this question tried Nicolaus Copernicus, who along with other prominent astronomers of those times took a part in the work to reform the calendar. During the time of Copernicus the Julian calendar obeyed, the calendar, which had an average year 365.25 days. At the Council of Nicaea in 325 year so.called "Movable feasts" were established. Particularly concerned with Easter, which are set to begin on the first Sunday after the spring first full moon, so after the spring equinox. Initially, the spring equinox was on March 21, but over the years this date began to shift. In the thirteenth century, talked about the need for change, but until the time of Copernicus could not enter them. Only in 1582, Pope Gregory XIII reformed the calendar and therefore it is called the Gregorian.	**Students ask**: What was the maln goal of Nicolaus Copernicus investigations?
Some People think that just astronomical table of Olsztyn is a continuation of the work of Copernicus on the reform of the calendar. But we have no direct evidence of this thesis. It is known that work on the calendar began in 1515 in Frombork, and sent a report on his work in the spring of 1516 year to the Pope Leo X..	
So, for what this table? Certain researchers believe that astronomical table in Olsztyn Copernicus drafted for the purpose of teaching descendants and also after 493 years we can watch it and also to chart aiming at the learning objectives.	
IV. Invitation	
I would like to invite you to do this experiment. There is a possibility of self-play experiment of Nicolaus Copernicus and verify if the Spring equinox day the has not moved? ... However, I must point out that for this experiment the responsible and persistent Persons are needed, because it will be last approximately two months. We will start during the winter break.	Students willing to perform the experiment are already part of a prepared list ..
3. Summary	
Nicolaus Copernicus in his work used various astronomical instruments, made by himself, one of them is astronomical table. To repeat the experiment leading to the cancellation of such a table we will use the method of Copernicus -gnomon reflection, using sunlight reflected from mirrors placed on the window sill. We have the ability to repeat this experiment. The first meeting will be held on Monday, 16 February at 10.00 in the physics laboratory room..	
4. Homework	
To find on the Internet or other source of knowledge, what were and for what purpose were used by Nicolaus Copernicus instruments: an astrolabe, quadrant, and triquetrum**.**	

Enclosure 2
Scenario of main lesson

Theme: The contribution of Nicholas Copernicus' observations to the reform of calendar .

General aim: Get to know Copernicus experiment observation results and their consequences

Operational aims: Student:

- understand the concepts: geocentric and heliocentric systems, ecliptic, celestial equator, the equinox, gnomon, calendar, „white nights”,
- understand what is the rotation of the Earth,
- understand what is the progressive movement (circulation) of the Earth,
- can explain the apparent movement of the Sun,
- knows who they were: Aristotle, Aristarchus, Ptolemy and Copernicus,
- knows how to exploit the Earth's motion around the Sun for investigation the phenomenon of actual equinox.

Educational tools:

- Instruments for demonstration:
  progressive and rotary motion (lamp, globe) and the apparent movement of the Sun (plasticine with a match - gnomon, a piece of paper, pencil an electrical circuit with the diode on a mobile stand - in short called "gnomon with a lamp),
- card (or foliogram) with chart presenting the experiment,
- blackboard.

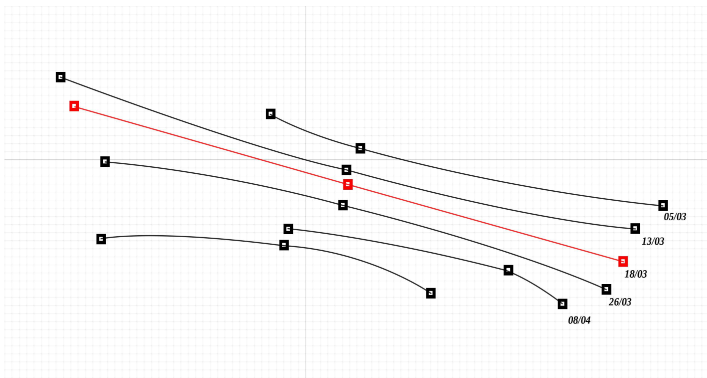
Methods: experiments, talks, discussion,.

Forms: collective, individual.

Teacher’s activities	Student’s activities
1. Introduction	
Organisation of lesson: welcome, checking of presence	
Communication of theme of the lesson	Writing the theme of the lesson: „The contribution of Nicholaus Copernicus to the reform of calendar.”.
Question 1: Could you remind: who was Nicolaus Copernicus? **Question 2:** Could you remind: what astronomical instruments were used by Nicolaus Copernicus for his observations?	**Answer:** Polish astronomer, physician, and a canon and lawyer, who, referring to some ideas from antiquity proposed and described the heliocentric system of the Universe. **Answer** Astrolabe, quadrant, triquetrum and astronomical table
2. Explication of lesson	
I. Elements of history	
- Geocentric system **Question3**: What was characterized geocentric system?	**Answer:** In the center of such a system is the Earth and other planets, Moon and Sun (on the third orbit) revolve around her.
• Aristotle (384 -322 BC on) placed the Earth in the center of the Universe; • Ptolemy (ca. 100 - 170 of n. e.) In 140, the n.e. described a system in which Earth was in the middle, and the planets circled	Students write a short note: Eg. : Geocentric system: a) Aristotle (384 -322 BC on) b) Ptolemy (c. 100 - 170 of n. e.)

around: Moon and Sun in third place. All these astronomical objects rotated in circular orbits.	
- heliocentric system **Question 4**: What was characterized heliocentric system?	**Answer:** In the center of this system is the Sun, and other planets, Earth and Moon (on the third orbit) revolve around him.
• Aristarchus (320 - 230 of BC.) Around 280 BC He and other thinkers have put the Sun in the middle of the world; • Nicolaus Copernicus (1473 - 1543) In his work, , "On the Revolutions of Heavenly Spheres ..." issued in 1543 He describes the motion of the Earth and other planets around the Sun in which the planets around the Sun and the Moon around the Earth rotate in circular orbits.	Students write a short note: Eg.2: Heliocentric system: a) Aristarchus (320 - 230 of BC), b) Copernicus (1473 - 1543).
- calendars **Question 5:** What according to you is meant by the calendar? The original name comes from the accounting books moneylender - the first day of the month - time to pay debts.	**Answer:** General calculations of days in a large time intervals.
Question 6: What kind od calendars do you know?	**Answer:** Gregorian and Julian calendars.
Roman Calendar The oldest known „the year of Romulus", repeatedly reformed. **Julian Calendar** A major reform of the Roman calendar was carried out in the time of Julius Caesar and in 46 BC the calendar as proposed by Sosigenesa – was introduced. Every four years was a leap year, ain this way year have been prelongated by one day - an average year of calendar was 365.25 days. **Gregorian Calendar** It turned out that the Julian calendar is not accurate (too long) and reformed back in 1582 year, as proposed by Luigi Lilio. To shorten the average year of the new calendar, leap years were introduced, but only those which are divisible by four, but if the year is divisible by one hundred is not a leap year (unless it is divisible by 400).	Students are writing the short note:. E.g. 3: Calendars: a) Julian – introduced in times of the Julius Caesar in 46 BC; the average year of the calendar counted 365.25 days, b) Gregorian – introduced in times of the Pope - Great Gregor in 1582 r.; leap years were implemented, but only the ones which are divisible by four, however, if the year is divisible by one hundred is not a leap year (unless it is divisible by 400).
Question 7: Where known, and as observed differences in time?	
II. Elements of geography	
- experiments with globe and a lamp	
• *rotational motion of the Earth - an explanation of days and nights;* **Question 8:** What are the lengths of day and night on the whole Planet?	Two students carry out the experiment, while others observe. All reflect on the question.
Overview of the length of day and night, when the Earth not revolves around the Sun , but rotates around an axis perpendicular to the line connecting it with the Sun;	**Answer**: In this case on whole Panet, day and night are equally long, as in any village the Sun each day is plotting on the sky exactly the same circle

Overview of the length of day and night, when the Earth not revolves around the Sun, but rotates around an axis inclined to the line connecting it to the sun at about 66.50 degrees.	**Answer:** In any place the Sun each day plots on the sky exactly the same circle, but for example, to the north of the tropic of Cancer lit areas occupy more than half the length of the given parallel and consequently on that parallel we can see the Sun for more than half a day. Days are longer than the nights farther to north, and even appear so.called „white nights" and vice versa, shorter, when we descend to the south. It is always so.
• *Circulation (progressive) motion of the Earth around the Sun* - an explanation of the seasons; **Question 9:** How do the light areas of the Earth changes?	Two students are carry out the experiment, while others observe. All reflect on the question.
Discussion of the emergence of the various lights of the Earth, when the Earth revolves around the Sun, but not ratate (spinning);	.**Answer:** Within one circulation of the Earth around the Sun, any place on Earth is illuminated once the market by 0.5 times. Lighting that changes smoothly.
Discussion of the emergence of the various lights of the Earth and, consequently, the seasons, when the Earth revolves around the Sun, and rotates about an axis inclined to the line connecting it to the sun at about 66.50 degrees.	**Answer:** Within one circulation of the Earth around the Sun, any place on Earth is lit, but lengths of day and night are changing and thus to cause the appearance of the seasons.
Please make a brief note on inversion and progressive movement (circulation).	Students draw up a note - record the effects of rotational and advancing (circulation motions of the Earth as: Eg 4: The effects of motion of the Earth and the inclination to the ecliptic plane: a) rotational - day and night, b) circulating (progressive) - the time of the year- seasons.
Question10: What differences in time referred to different calendars have been observed?	
At the Council of Nicaea in 325 day of Easter on the Sunday after the spring full moon was established, so after the spring equinox.. Equinox is a special time in which the ecliptic - the path of the Sun crosses the celestial equator - the plane of Earth's equator. During the year, this phenomenon occurs twice. When?	**Answer:** About 21st of March and 23rd of September.
From around the thirteenth century the differences between the actual seasons, and seasons resulting from the Julian calendar century were marked ,and therefore, intended to improve the current calendar - but there still was not a good idea how to do this. During the **Luteran Council** (1513 - 1517), in the time of Pope Leo X, work on calendar reform were intensified. It turns out that in this work Copernicus also participated. His work on the calendar began in 1515 and ended in mid-1516. We know that based on the letter of 4 June 1516 by Paul from the Middelburg (Bishop, who asked Copernicus in 1513 to work on the calendar) to Pope Leo X. The results of his observations, he has also placed at work "On the Revolutions of Heavenly Spheres ..."	

-experiments with gnomon and lamp	
It turns out that after submitting their results to Paul of Middelburg Copernicus continued his studies in Olsztyn. As the administrator of the castle in Olsztyn, he left the so-called astronomical table showing the apparent motion of the Sun on the sky.	
The apparent motion of the Sun Using "gnomon with a lamp the teacher draws on the card: 1) points left after shadow when the sun (light) is set at the equinox, defines directions of the world: east - west, north - south. Draw the line (should be straight line). 2) points left after the shadow when it is winter, so the Sun rises in the southeast, and set in the southwest. Draw the line (should be hyperbole). 3) points left after the shade when it is summer, so the sun rises in the northeast, and it is in the northwest. Draw the line (should be hyperbole bent the other way). **Important**: During experiment gnomon should be in the same place, but the card (or stand) can be moved.	Students in groups approach the table with a completed experiment. They are Watching the experiment.
III Experimental resulds	
Students are presenting the results of experiments that we conducted at the school (hrough the presentation of the obtained charts).	After wathing the results they drawn up a note, for example: *The apparent motion of the sun in the sky* a) straight line (red line) is representing a movement of the Sun, when the ecliptic equator coincides with the celestian equator - the equinox, the Sun "rises in the east" and "sets in the west" b) the hyperbolas (black lines) are representing a movement of the Sun, when the ecliptic crosses the celestial equator and: • Winter - the Sun "rises in the southeast" and "sets in the southwest, • Summer:- the Sun "rises in the northeast" and "sets s in the northwest" c) the complete graph is looking as follows:  Students should remember that the similar graph they already saw.

• Discussion **Question 11:** What similarities and what differences do you see in comparison with the original graph made by Copernicus?	**Answer:** The graph obtained as the result of experiment, which was carried out at school is very similar to the Copernicus graph. However, students will read a different date for Spring equinox - March 18 and inexact graph of the hyperbola from April 8. They communicate the cause of the errors (the diameter of the point is about 5cm, not precise method of „dropping points" in a coordinate system, measurements with the use of measuring tape, etc).
3. Summary	
Nicolaus Copernicus, knowing that within a year the Sun twice intersects the plane of the celestial equator (equinox) could calculate: 1) if the date of obeyed calendar is shifted to the date of the astronomical equinox - a discrepancy was about 10 days, 2) how long is the year of actual movement of the Earth around the Sun – and from these to conclude that the the difference is about 11 minutes/year at that time.	