

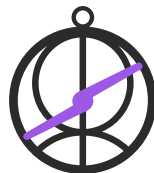


SPACE[☆] awareness

HOW BIG IS THAT THING?

Use the astrolabe to measure heights like a medieval civil engineer!

Grom D.Matthies, Nuclio



Téma podle vzdělávacího plánu

Constellations, stars

Velká vědecká myšlenka

Klíčová slova

Islamic Heritage

Věková skupina

12 - 16

Stupeň vzdělávání

Primary School, Middle School, Secondary School

Čas

1h30

Velikost skupiny

Group

Dohled z důvodu bezpečnosti

Unsupervised

Cena

Low (< ~5 EUR)

Místo

Outdoors

Základní dovednosti

Asking questions

Typ vzdělávací aktivity

Partial enquiry

STRUČNÝ POPIS

This activity uses the astrolabes' capability to determine the height or depth of objects in surrounding, both near and far. The method of measuring and calculating are perfectly suited for all pupils able to do basic arithmetic.

CÍLE

Since the principle of measuring heights with an astrolabe is based on the geometry of right angled triangles, the students will reinforce their previous knowledge and discover a useful application. They will also realise that quantities that seem to be very hard to measure can often be inferred by simple measurements and some mathematics. The activity fosters precision measuring skills.

VÝUKOVÉ CÍLE

After this activity, the students will be able to:

- explain how heights can be determined by measuring angles and distances.
- describe the principle behind Thales of Miletus' method to measure heights.

HODNOCENÍ

- Instead of explaining the method of measuring heights with the astrolabe to the entire group, the teacher/instructor may do so only to representatives of working groups, who then explain it to their peers. The teacher then acts as a supervisor.
- The teacher/instructor (or the students) may use a lamp (or flashlight) to cast a shadow over various objects like a stick or a pillar of different heights. By changing the incident angle, the students observe the changing length of the shadow. They should explain in which way the height of the object defines the length of the shadow. They discuss how the height can be inferred without measuring it directly.

POMŮCKY

- Astrolabe with shadow squares
- Tape measure, measuring stick or long ruler (1 meter)

INFORMACE O TÉMATU

Astrolabes were not only used for astronomical matters. They were also used, amongst many other things, in what we now consider to be civil engineering and topography. For measuring, a so-called shadow square is usually found on the backside of complex astrolabes. Often two shadow squares are mirrored and joint forming a wider rectangle. Each square divides an angle of 45° into 12 equal parts. The horizontal scales are called *umbra recta*, which is Latin for true shadow. The vertical scales are named *umbra versa*, from Latin meaning turned shadow. These names were not used initially. The first to refer to the term shadow and publish conversion tables (tangent) was Al-Battani (858 – 929 CE), an Arabic astronomer and mathematician born in Harran (today's Turkey).

Student directed Did you ever ask yourself how high something is, like a nearby mountain, or a tall building? Engineers do that all the time. But how can one measure the height of something, if it is not possible to reach the very top, like the pointed roof of a church tower. Or how to know the exact height of two hills, so that if a bridge is to be built between them, both sides meet halfway on the same level.

One clever solution for this is based on light. If there is light, then there is always a shadow. In ancient times, the only direct light source to cast shadows was the Sun, and occasionally, at night, the Moon.

A Greek mathematician, astronomer and philosopher named Thales of Miletus (624 – 546 BCE) recognised that if the Sun is exactly half way up in the sky (45° altitude) then the length of the shadow cast by an object is equal to the height of that object. With this idea in mind he determined the height of the Cheops pyramid by measuring its shadows length.

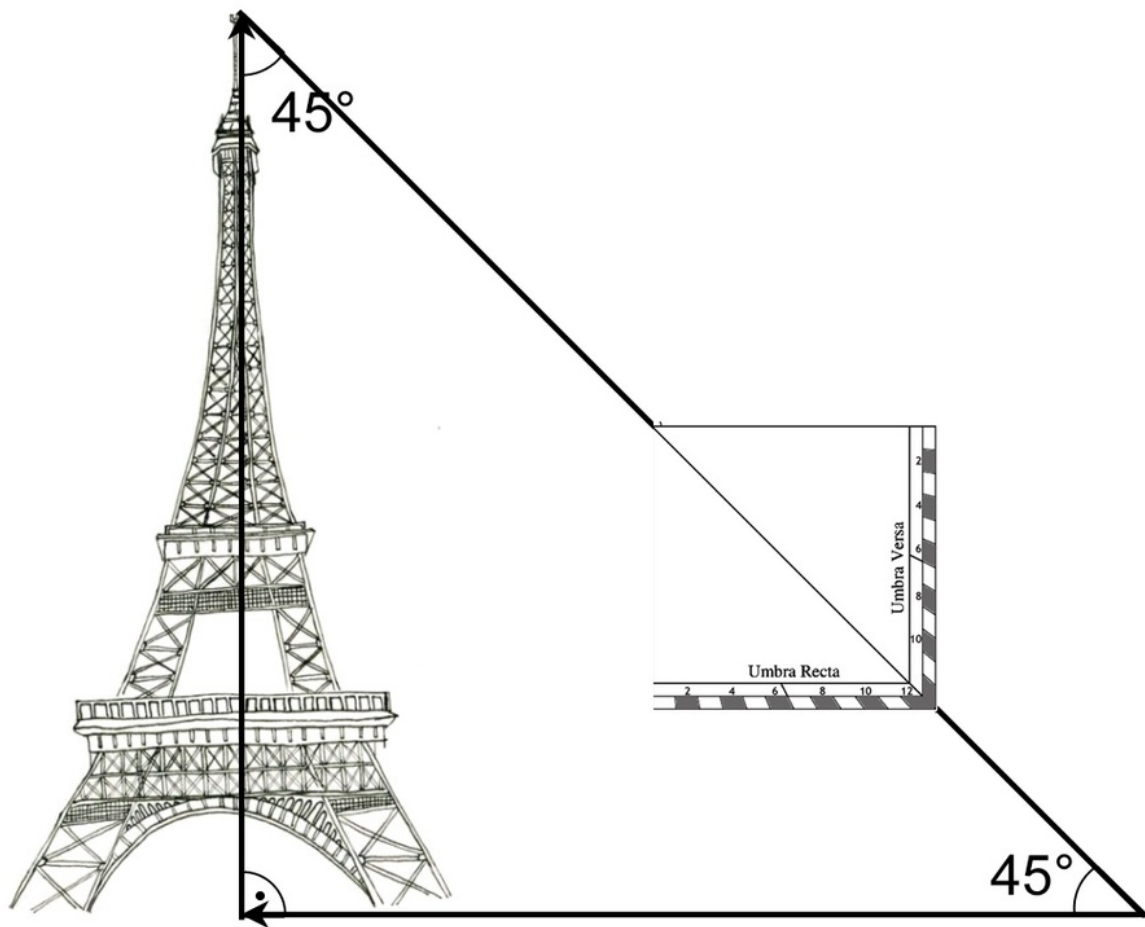


Fig. 30 A right triangle with one 45° angle (e.g. angle of incidence of the sun) will also have the third angle 45° and thus two sides of equal length. An isosceles right triangle (Credits: Grom Matthies)

Your astrolabe can do this measuring of heights, depths or even distances using the same basic principle but without the need to wait for the Sun to reach the necessary altitude in the sky.

PODROBNÝ POPIS AKTIVITY

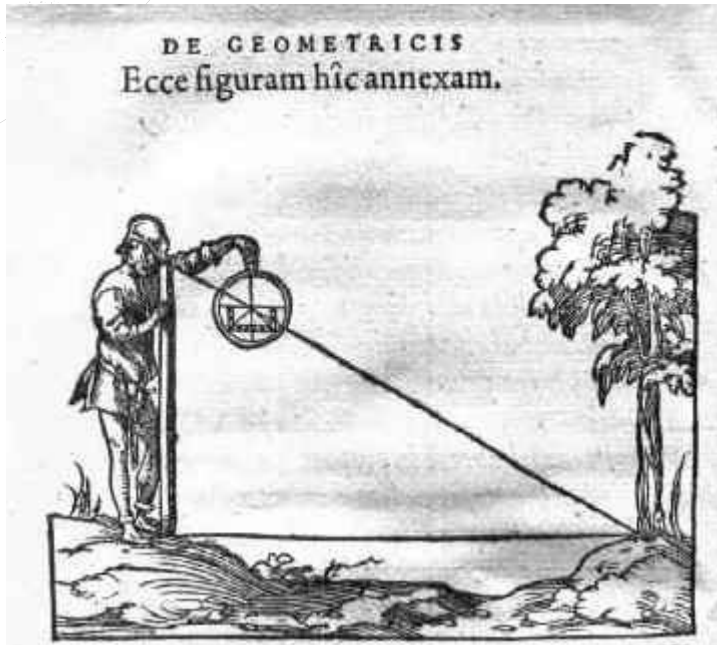


Fig. 31 Determining the height of

objects using the shadow squares (Credits: Grom Matthies)

You will determine the height of objects using the shadow squares from your astrolabe. You need to remember this rule: if you read from the **umbra recta** scale, then you calculate: **height of object = (12 / [reading]) * distance to object** If you have to read from the **umbra versa** line you calculate: **height of object = ([reading] / 12) * distance to object**

To measure distances to the object, you can use a tape measure, but you can also count the number of steps, or setting one foot in front of the other and count the number of feet. The results will be roughly the same. If you wish to convert into the units of meters, just measure the length of your step (or shoes) and multiply the number counted with that measure. For example, if one of your steps is 50 cm wide, then a distance of 10 steps is 500 cm, or 5 meters long.

Keep in mind, for objects that are nearby, the height of the object is what you measure plus your own height up to the eye level (figure 31).

Experiment 1 – My classroom is tiny

Let's measure your classroom.

Rotate the alidade so it points exactly to the number 12 in one of the shadow squares (the alidade is at a 45° angle).

Step toward one of the classroom walls until you are standing against it, and then take *one* step back and turn around.

Hold the astrolabe on its string, look along the alidade sight and look at the wall behind it.

With the alidade still in the position 12, retreat from the wall, step by step (count them) until the sight aligns perfectly with the point where the wall meets the ceiling.

How many steps did you make including the first? _ steps

Remember: At the shadow squares 12 position, the height of what you measure is exactly the same as its distance from you. The above value is thus the height of your classroom expressed in steps as unit of measure. A step is a very strange unit of measure.

It is probably better to use a more common unit of measure.

Measure the length of one of your backward steps: __ cm

The height of the wall in centimetres counted from your eye level is now:

__ number of steps * __ cm step size = __ cm

To finish, measure and add your own height to the walls height and you now have the height of your classroom:

Your height __ cm + wall height ___ cm = __ cm,

which makes the classroom __ meter high.

Compare the results with your classmates.

Experiment 2 – Is this a big school?

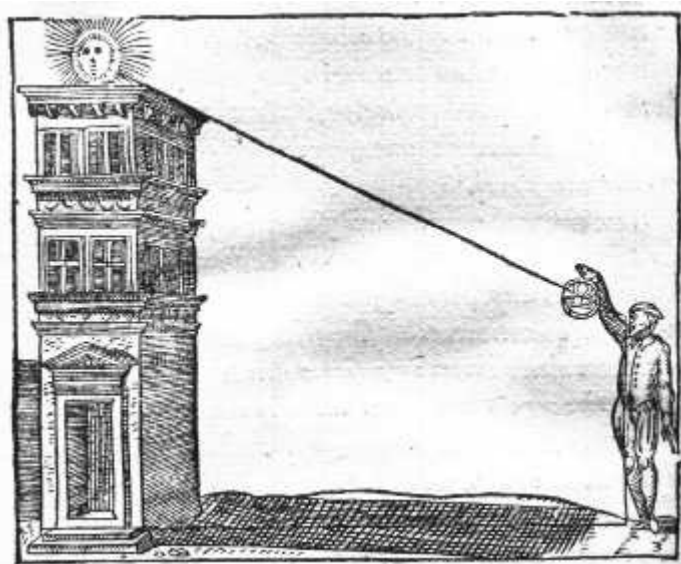


Fig. 31 Measuring the height of

buildings (Credits: Grom Matthies)

You will determine the height of your school building without climbing onto its roof. This can be done outdoors from within the schoolyard, or any place safe for you and your classmates.

Position yourself at some distance from your school building so you can see the edge of the roof.

Turn the alidade until the sight points exactly to the top of the buildings wall. Read the number from the shadow square which the alidade crosses and remember which umbra scale you read from.

Shadow number _ in umbra __

Walk towards the buildings wall, and count the number of steps until you reach the wall.
Distance is ___ steps

If the number you read was in **umbra recta**, calculate $12 / \text{factor is } _$

If the number you read was in **umbra versa**, calculate $/ 12 = \text{factor is } _$

Multiply the shadow square factor with the distance.

factor * **distance in steps** ___ = height of the building ___

The height of your building is expressed in steps.

Everybody has different step lengths, some longer, some shorter. To compare your results with the classmates, you need to convert to a more common unit, which should be meters. Measure the size of one of your steps in meters.

My school buildings height is Height of building in steps _ * step size in meter _ = ___ meters

Repeat this exercise with a tree or some other feature in your schoolyard. If you measure the distance directly in meters, then no conversion is needed.

To finish

You now have reproduced the way how in ancient times people measured heights of objects in their surrounding. Engineers today still use the same method to determine the heights of buildings, hills or any structures, albeit using more modern devices which do the math for them.

Try to measure the height of your room at home, or the height of the building you live in.

VZDĚLÁVACÍ PLÁN

Space Awareness curricula topics (EU and South Africa)

The journey of ideas, Constellations, stars

ZÁVĚR

The astrolabe that was built in the previous activity is used to estimate the height of various objects. As long as the distance to the object can be determined, the height is the result of a simple mathematical operation. This simplicity may motivate the children to measure heights of objects all around them.



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