ASTROEDU

Peer-reviewed Astronomy Education Activities

How do telescopes work?

Let's discover telescopes and experiment simple optics

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KEYWORDS

reflection, optic, light, telescope, Newton, Galileo, mirror, lens, refraction

CATEGORY

<QuerySet [<SciCategory: Other>, <SciCategory: Physics>, <SciCategory: Scientific instrumentation>]>

LOCATION

Does not matter

AGE

10 - 12

LEVEL

<QuerySet [<Level: Primary>]>

TIME

1h

GROUP

Group

SUPERVISED

Yes

COST

Medium Cost

SKILLS

<QuerySet [<Skills: Asking questions>]>

TYPE OF LEARNING

<QuerySet [<Learning: Guided-discovery learning>, <Learning: Historical focussed activity>, <Learning: Observation based>]>

MATERIALS

- 10 – 15 lenses (magnifier lenses will work)
- 10 – 15 small mirrors
- 3 – 4 laser pointers
- glass of water
- teaspoon
- glasses of soap and/or juice.

Image: material

GOALS

Introducing different types of telescopes and the techniques used to get information about the observed objects.

LEARNING OBJECTIVES

- Get to know telescope history and the different types of telescopes.
- Get to know different types of lenses and how light behaves when passing through them.
- Get to know how light behaves when reflected on mirrors.
- Get to know the importance of using a telescope, how to use one, and how we observe the universe.

BACKGROUND

Reflection and refraction

Light rays change direction, following specific geometrical paths, when they reflect off a surface (reflection) or move from one transparent medium into another, as in the case of lenses (refraction).

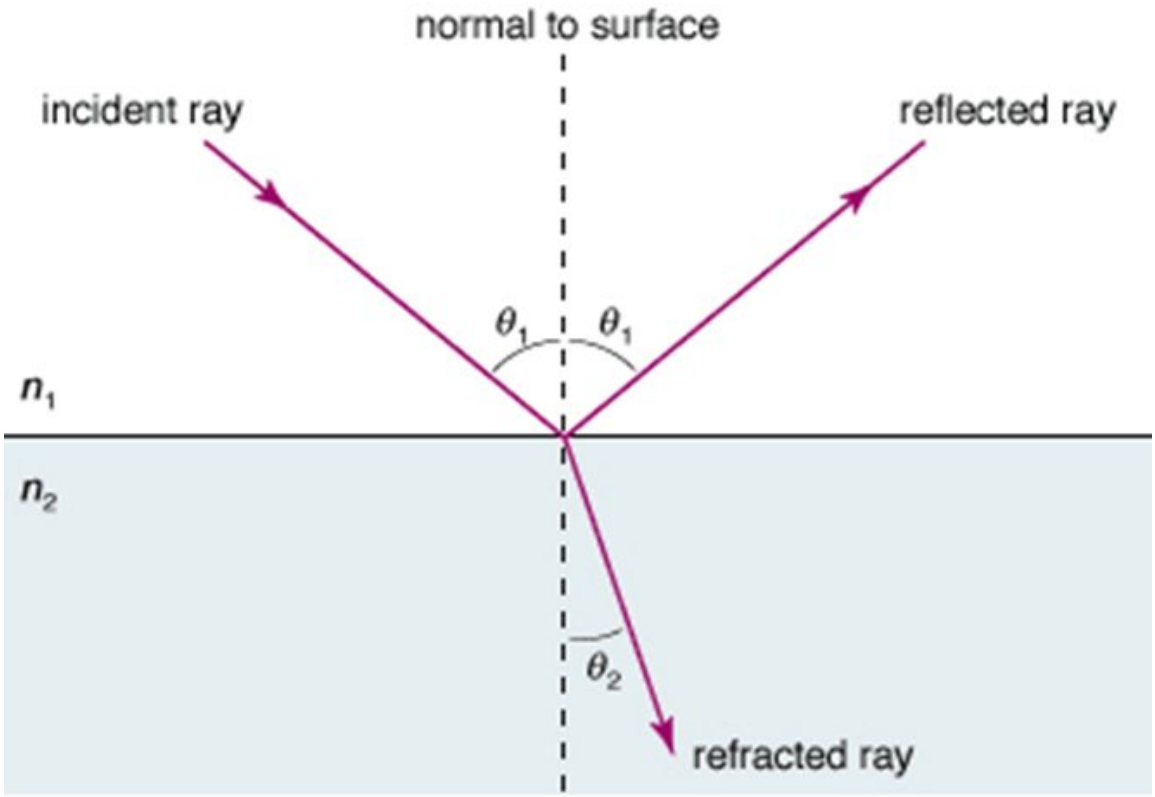

Image: law of reflection. Source: Encyclopedia Britannica

The law of reflection states that, on reflection from a smooth surface, the angle of the reflected ray is equal to the angle of the incident ray. The law of reflection can be used to understand the images produced by plane and curved mirrors. Curved mirrors like the ones in telescopes can focus the light, because each ray is reflected to a specific point, the focus of the curved mirror.

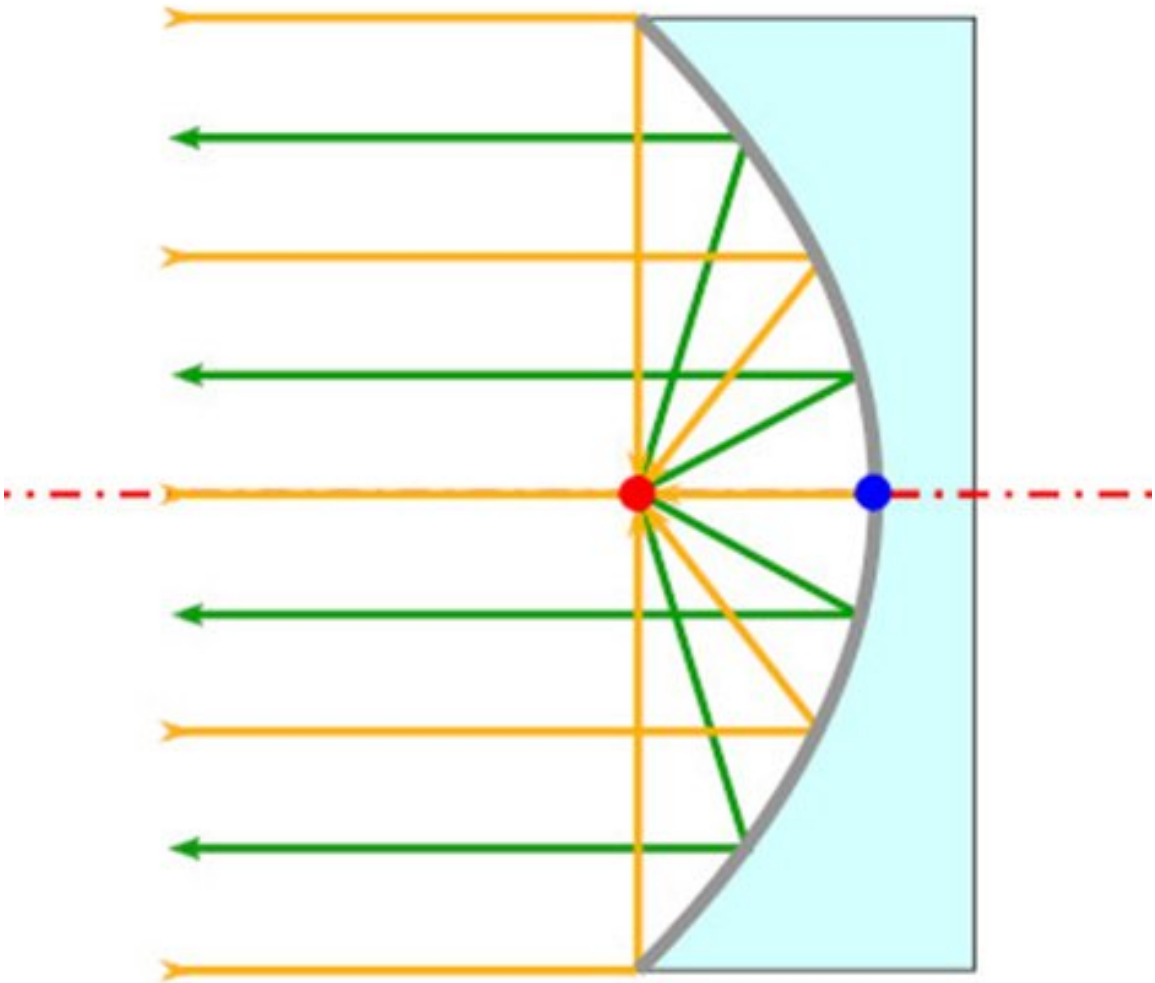

Image: light on a curved mirror. Source: Wikimedia commons

On the other side, when light traveling in one transparent medium encounters a boundary with a second transparent medium it changes its direction of travel; that is, it is refracted. This is due to the fact that different media have different "refraction index", i.e., light in them travels at lower speeds than in the vacuum, different for different media.

When light passes from a denser medium (water) to a less dense one (air) the direction of light rays is bent far away from the line perpendicular to the plane of separation (the "normal to the surface" in figure below). That's the reason why a straw in a glass of water looks bent to the bottom with respect to its normal shape.

Image: light through a glass full of water. Source: Wikimedia commons

Light rays passing through a lens are bent at both surfaces of the lens. With proper design of the curvatures of the surfaces, various focusing effects can be realized. For example, rays from a source of light, initially parallel, can be redirected by a lens to converge at a point in space, forming a focused image.

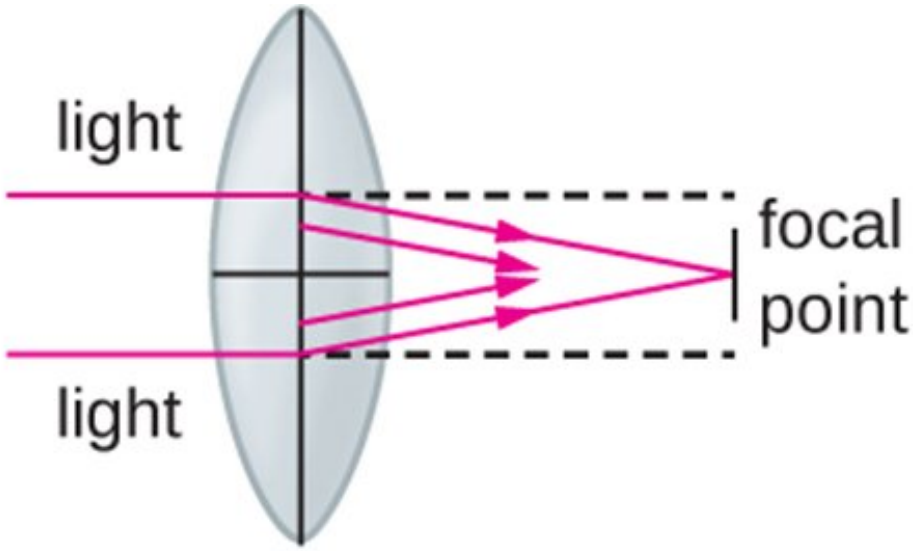

Image: how a lens works. Wikimedia commons.

Telescopes

Telescopes use this behaviour to collect the light received from very dim and really far away celestial objects. To do that, the mirrors or lenses have to be really big. The bigger the mirrors or lenses, the more light the telescope can gather and concentrate. That light is what we see when we look into the eyepiece of a telescope. The first telescopes focused light by using lenses. Modern telescopes use mirrors, because they are lighter and easier to make perfectly smooth. The mirrors or lenses in a telescope are called the “optics.” The optics of a telescope must be almost perfect. That means the mirrors and lenses have to be just the right shape to concentrate the light. The telescope that uses lenses must have one convex lens since it can magnify the objects by bending the path of light. The

concave lens is used to extend the focal length in some of the designs of the telescope. The mirrors in reflective telescopes are concave, they are made that way so they can reflect all points of light entering the Telescope tube and concentrate them into a single point, but since you are using a laser pointer you can explain the general idea with the use of normal mirrors. Both reflective and refractive Telescopes have their components painted with special material to make the refractivity or reflectivity of their optics more efficient.

To know more: https://www.britannica.com/science/light/Reflection-and-refraction

FULL DESCRIPTION

Introduction

The telescope is a great instrument that is shared all over the world, everybody knows about it and yet not all know how it works. This instrument has a great history of development and modifications by great scientists and amateur astronomers. We will start discussing the history behind this great tool, and we will go through stories about scientists using and developing it while we do the experiments.

We can introduce the activity with a little presentation about where do telescopes come from, telling the story of the Dutch inventor Hans Lippershey link . We can then tell about the great scientist Galileo Galilei and his implementation of the device in Astronomy and the impact it had on the way we look at the sky.2How Galileo turned the "looker" into a telescope: link

This activity is made of a series of smaller activities that can be done in different orders, so feel free to rearrange them as you like.

First activity: playing with lenses

Our first activity is to imagine ourselves disassembling an ordinary telescope like the one shown in Image below. Telescopes are composed of several lenses. By using several ordinary lenses (for example magnifiers) we can make our own Telescope just like Lippershey or Galileo.

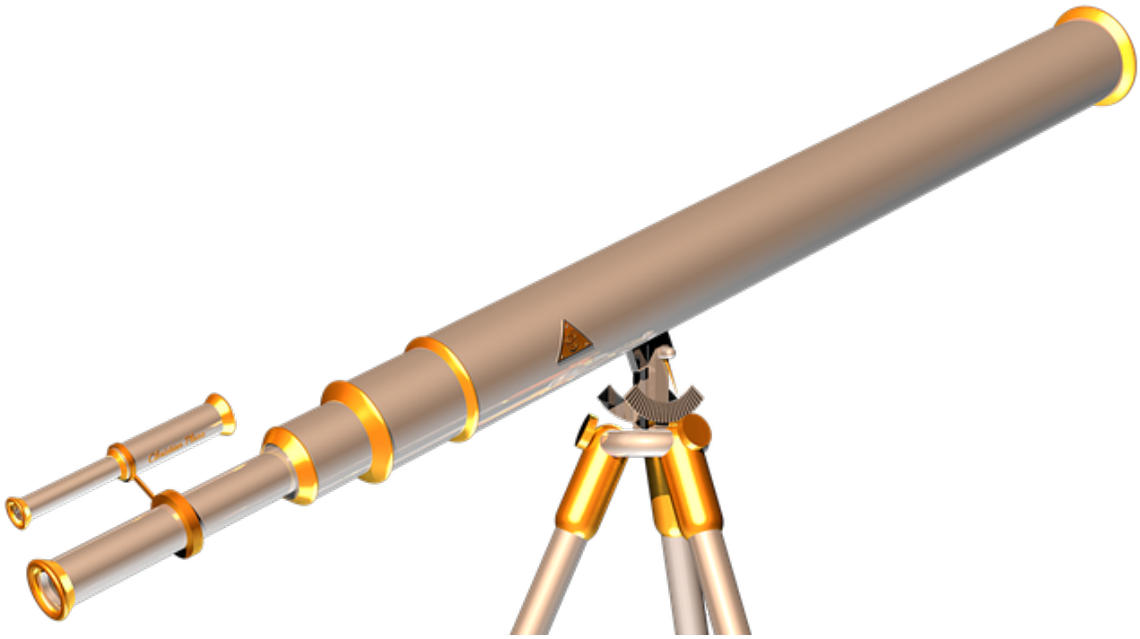

Image: a telescope.

Take a lens and start examining its behaviour. You could have students work together when using the lenses in an open space or by standing opposite to one another and moving towards each other to achieve focus. Try to ask the following questions and discuss ideas with kids:

- What happens to the image when I move the lens away from my eye? Or closer to my eye?

- Is the image upside down? How can I correct it? Will rotating the lens work?

- Is the lens that I am using flat? Or does it have a curve?

Image: Seeing through lenses

Using a laser pointer (careful when using laser pointers around kids) can be an effective way to better explain this idea by seeing how light refracts when passing through the lens.

You can use a white wall or screen to see the different positions of the laser beam, how it is changing according to the position of the lens, and then add another one and observe the light beam on the wall.

Image: Seeing through lenses using a laser.

You can also introduce the idea of refraction by simply showing a glass of water and a teaspoon in it. Possible questions to drive the discussion: What is happening to the spoon? Why does it look broken? Is it actually? Discuss the answers and introduce the concept of *refraction* of light.

So light is refracted when passing through water. You can now divide the children in groups and give them different kinds of liquids to add to the glass of water, (like soap or juice). Observe with them how light is refracted through these glasses, like in Image below.

Image: light through glasses

Second activity: reflection

In the next activity we have to ask the question: Are there other ways of changing the path of light? Yes, and the next scientist we talk about changed our perspective of the universe: Issac Newton' (more about Newton in the links below). He thought: "what if we used something other than lenses?". We can ask the same question to the kids and discuss what these "other" tools could be in Newton's idea. The answer would be mirrors: Newton wasn't thinking about refraction, but reflection! Newton used the idea of bouncing light off mirrors to make his own telescope. Now, let's build the telescope that Newton built by using 2 mirrors and a laser pointer (again please be careful!) as shown in Image below. You can put the mirror on one side of a table (if you like you can put it on carton paper like in the picture) and then put the other mirror in front of it but tilted 45 degrees. Then you can shine the laser pointer on the bigger mirror and watch the laser beam reflecting on the other one, and then reflecting to the side. You can adjust the mirrors as you like to make the laser beam clearer.

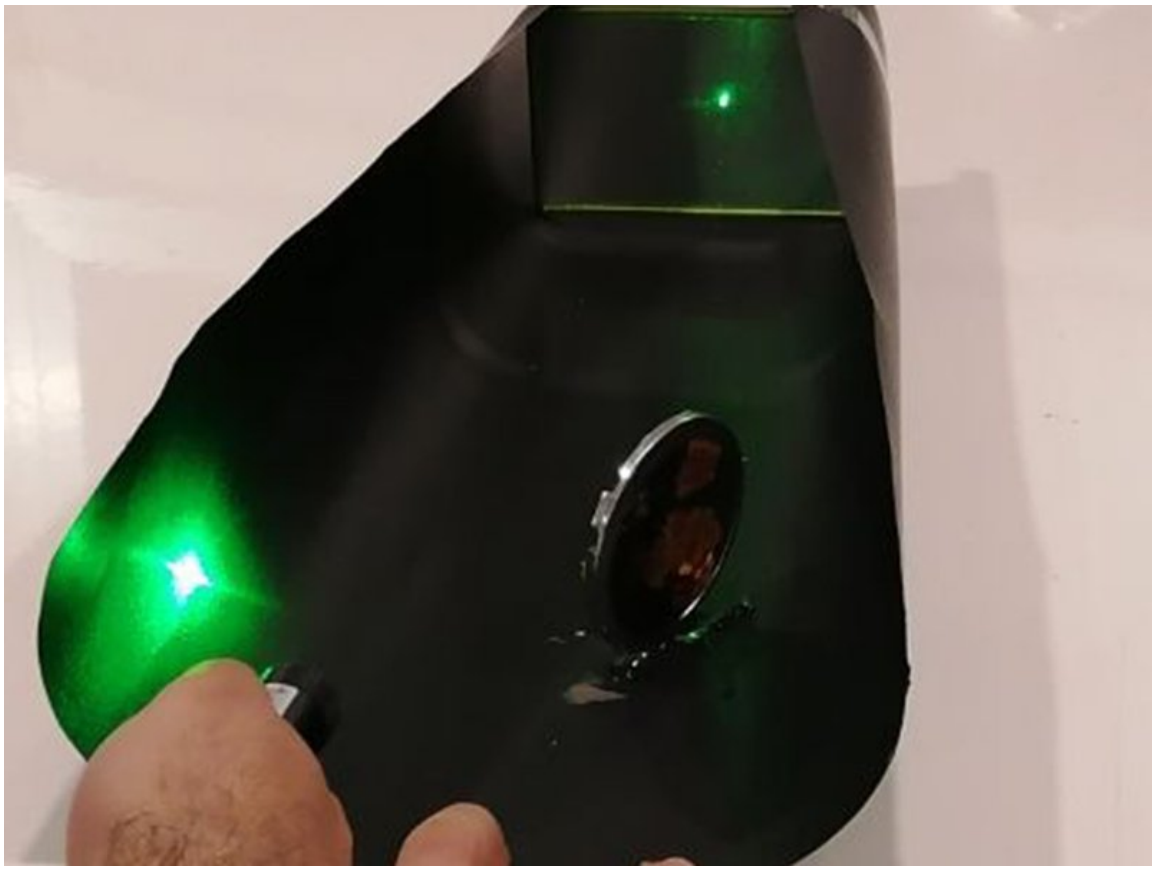

Image: Light reflecting on mirros

Facultative activities

Now that we know about the 2 main kinds of telescopes, let's see what happens if we combine mirrors and lenses in the same telescope. These are called a "catadioptric tele scopes" and in them light experiences both refraction and reflection. We could ask the participants to try and make a simple optical bench by using lenses or mirrors.

An interesting activity to do with older students is to have them search about the subject inside the class or as homework (if you are a classroom teacher). You can discuss with the kids how there are also telescopes sent to space, launched in big rockets to help study the universe better away from light pollution. You can also use pictures of telescopes, as the Hubble Space Telescope link or the CoRoT (Convection, Rotation and planetary Transits) space telescope: link to explain the idea furthermore.
Having a telescope in the classroom would be awesome, for the kids to see an actual one, or maybe planning after the activity is done a field trip to a nearby observatory.

One possible way of widening the activity is to also talk about eyepieces. You can't really see anything when looking into a telescope without an eyepiece, it is an important part of telescopes. You can hint out that we need an eyepiece with the use of a telescope to see the final image and sometimes we use cameras instead.

A storytelling approach to this activity and the stories of scientists is very helpful, like you can invent a character that travels through time and meets scientists and learns to use telescopes, it works great with little kids. The third activity is a way to leave the kids wondering about the universe and its mysteries and how we can unlock some of them, if we think and work hard enough. So, try focusing on explaining this idea to them. A final note is that if you avoid asking the questions

to the kids (according to our experience) they will end up asking at least one of them so make sure to read about them just a little bit more.

EVALUATION

Possible guiding questions for a class discussion:

- What is the use of a telescope tube?

(Answer: to hold the lens or mirrors in the correct place, and to focus on one region in the sky).

- Is having a bigger diameter in a telescope a good thing?

(Answer: when we have a bigger telescope, more light can enter, the clearer the image is going to be).

- Should we build a telescope near very tall buildings? or build one near a very bright light source?

(Answer: NO, we need to see the sky, and NO, the surrounding light will affect the way we observe).

- Why do we use Telescopes?

(More a prompt for discussion, to see how much this was achieved).

A quick small activity we like to call “explain it your own way” can be implemented, where a kid can stand in front of the classmates and explain a small idea: in this activity it can be “explaining how a certain type of telescope work”, for example.

CURRICULUM

This activity can be employed in many curricular subjects, such as: Science; Physics; Mathematics; History and Technology; History of instruments and stories of scientists.

ADDITIONAL INFORMATION

For more information about the STEAM-Med co-design project : Read this Link

This activity is available in other languages: Link (to be provided soon).

FURTHER READING

Some additional resources about space telescopes.

- Hubble Space Telescope images, info, videos and other interesting information: link link.
- Some interesting videos to look at about *Hubble's Servicing Mission*, designed and launched for fixing and updating the Hubble Telescope in space: link link.
- James Webb Telescope Gallery: link.
- James Webb Telescope Launch: link

CITATION

Muhammad Alassirry; Turkieh Jbour; Tareq Alkhateb, 2023, *How do telescopes work?*, astroEDU, 2307