THE EXPERIMENTALIST

Encyclopedia of Science and Technology for Young People

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Conteúdo:

"Earthrise". A photograph taken, 24 December 1968, by an astronaut during the Apollo 8 mission to the Moon.

Editorial

A defect of many of our schools is that they have no equipment to teach science. Many high schools do not have a thermometer or a voltmeter or even a lens. How to teach physics without physical apparatus? It is not possible - not real physics.
The few schools that have apparatus often do not have competent teachers to demonstrate practical experiments because they were trained in training centres that have no equipment, nor trainers trained in practical work. It is a vicious circle.

This problem has long been recognized but not yet solved; science apparatus is very expensive; there are many schools in the country, and the process of teaching teachers to teach science is long and expensive.
To help with this situation, our *Experimentalist* publishes articles to show how to use cheap and locally available materials to do many of the experiments.
Our articles have many illustrations, and so are almost a video film.
There are also real films on Spark Group's Web Site on the Internet: <experimentalista.org>.

Of course, few schools have Internet access. However, the Provincial Directorates of Education (which do have access) can print the articles to distribute to schools and schools can put them on the board for students to read.
An example of such articles is "Thermometers" in this edition.

Thermometers - Part 2

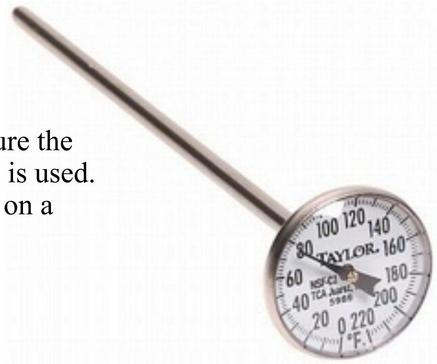
Other methods of measuring temperature

The examples that we have already explained in Part 1 (in a previous *Experimentalist*) use the change of a certain characteristic when the temperature changes. For example, the volume of a liquid expands when the temperature rises. A metal expands when it is hotter. Several substances change their characteristics according to their temperature changes. So there are many possibilities for measuring temperatures by measuring the characteristics of substances.

Here are other examples:

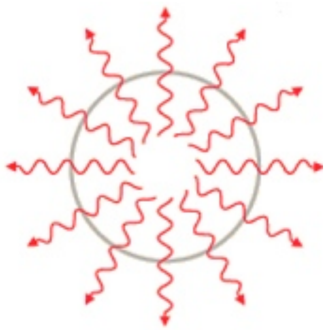
A pressure thermometer,

A glass thermometer or a complicated thermometer is not suitable to measure the temperature of the engine of a car or an oven. Instead, a tube filled with oil is used. When the temperature rises, the oil pressure increases and moves a pointer on a scale.



Radiation thermometers

The heat coming out in 'radiation' from a hot surface varies with its temperature.



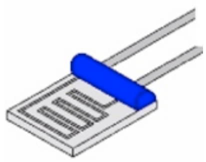
Devices using this effect are called "radiometers".
They measure temperature from a distance. For example, they are used to measure the temperature of the stars. The photo shows an astronomer focusing the image of a star in a radiometer through a telescope.

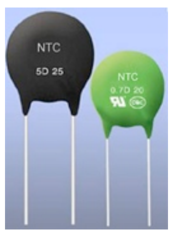
A radiometer is also used to measure the temperature inside your head - your core body temperature. The first photo shows a modern clinical thermometer. Inside is a radiation thermometer. The nurse puts it in your ear. It displays temperature in numbers on a digital display. The second photo shows a veterinarian measuring the temperature of a dog.

Resistance thermometer

The electrical resistance of a wire increases with temperature. For example the resistance of the filament of a light bulb of 220 Volts 100 Watts is about 50 ohms when it is cold. When it is switched on and has a temperature of about 3,000 C, its resistance rises to about 500 Ohms. Thus, by measuring the resistance of a wire with a multimeter, we can calculate the temperature of the wire.
Certain resistance thermometers, called "thermistors", use a piece of "semiconductor" in place of wire. They are much more sensitive than simple wire. They change their resistance considerably as their temperature changes.

The photos show the interior and exterior of thermistors.





Thermometers that melt

Substances melt at different temperatures. For example if you put a wire made of lead inside an oven and watch it through a hole in the wall of the oven and see that the lead begins to melt, you know that the temperature is about 330 degrees C. This is not an exact method but it gives some indication of the temperature. For example in kilns that are used to fire ceramics, the operator observes (through a 'spy hole') a ceramic rod which becomes soft when heated. When it starts to bend and lean (like a candle in the sun), you know that the kiln has reached the right temperature. The rods are specially made of various ceramics that melt at different temperatures. Some bend at 900 degrees C, some at 1000, some at 1300, and so on.

Temperature Units

Today, most people measure the temperature in degrees Celsius (Centigrade). But not in the US. The Americans use "degrees Fahrenheit" (°F). On this scale, ice melts at 32°F and water boils at 212 degrees. The human body temperature is 98.4 degrees F.

To convert between Celsius and Fahrenheit

Degrees Celsius = (Fahrenheit - 32) x 5 / 9. That is: note the temperature in Fahrenheit. Subtract 32. Then multiply by five and divide by 9. For example for the human body temperature, to convert from Fahrenheit to Celsius, (98.4 - 32) x 5 / 9 = 36.9.

To convert the other way:

Degrees Fahrenheit = Degrees Celsius x 9/5 + 32.

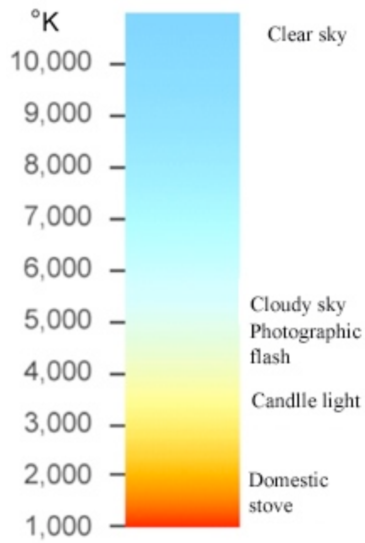
Temperature in degrees Kelvin

A temperature scale that is used often in science is 'Kelvin'. This starts from absolute zero - the coldest possible temperature (273 degrees below 0 degrees Celsius. On the Kelvin scale, ice melts at 273°K and water boils at 373°K. Oxygen gas becomes liquid at a temperature of -118°C, which is 155 degrees Kelvin).

The temperature of light

There is another indication of temperature, only used at high temperatures. The hot thing emits light. The color of the light indicates the temperature. In a domestic stove, red hot coal has a temperature of about 500 degrees C. When the fire has a bright red appearance, it has a temperature of about 700°C. Yellow is 900°C , and white is 1,200°C or above.

If a flame has a temperature over 2,000°C, it appears blue. Have you seen a welding torch with an electric or oxygen/acetylene flame? The flame is blue - probably about 2,500 degrees C.

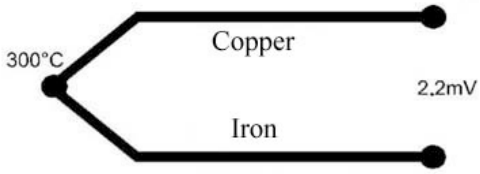


Thermo-cromismo

Thermo-cromismo is the ability of a substance to change color due to a change in temperature. There are thermometers that consist of a plastic strip coated with an ink that responds to temperature. A green check mark appears at the correct temperature.

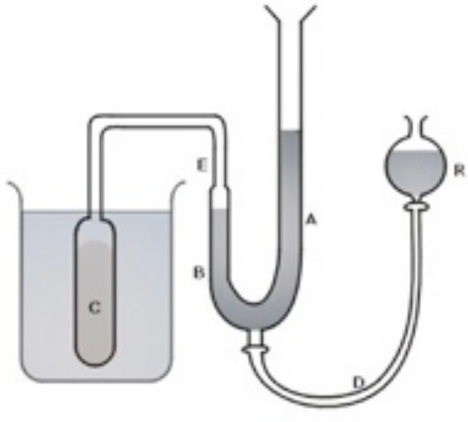
Thermocouples

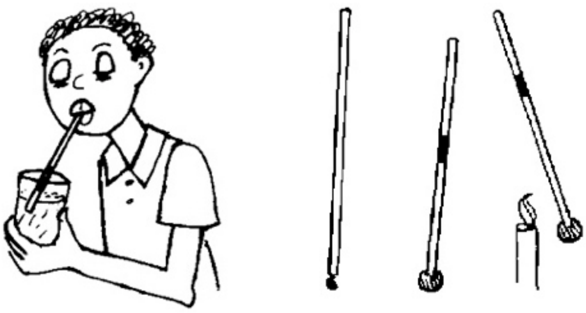
Another device for measuring the temperature is a "thermocouple". It consists of two wires of different metals or alloys (eg, iron and copper). These are twisted together at one end. The twisted part is the "joint". When the joint is heated, a voltage is created between the other ends of the wires. This voltage can be measured with a multimeter. Thus, measuring the voltage can measure the temperature.



Gas thermometer

The volume of a gas changes with temperature. The laboratory apparatus to show this effect is very complicated, as you can see in the picture.
But it is possible to show the effect in a simple way ▼





Suck a drop of water into a transparent straw.

Stop one end of the straw with chewing gum. Now you have a column of gas (air) between the gum and the water drop. Heat it near a candle. You can see that the gas expands.

Another method to demonstrate the expansion of air:

Put an empty glass bottle in a refrigerator to cool it. When the bottle is cold, remove it and put a coin on the mouth of the bottle as shown in the diagram. Then dip your finger in water and put a few drops around the coin to seal the gap between the coin and the bottle. Put your hands tightly around the bottle for some seconds to warm it.
The coin will begin to move up and down. This shows how air inside expands when heated. The cold air inside the bottle is heated by the warmth of your hands and escapes around the edge of the coin. This makes it go up and down to let the air out.
The bottle should be glass. If it is plastic, the mere pressure of the hands can produce the effect not the heat.

Expansion of a metal wire

Metals expand a little when they are heated. Here is an experiment you can do to see this expansion. The expansion is very small (for iron, it is a hundredth of 1% per degree C.) It is impossible to measure with a ruler, so it is necessary to enlarge the movement.

How to construct the thermometer wire

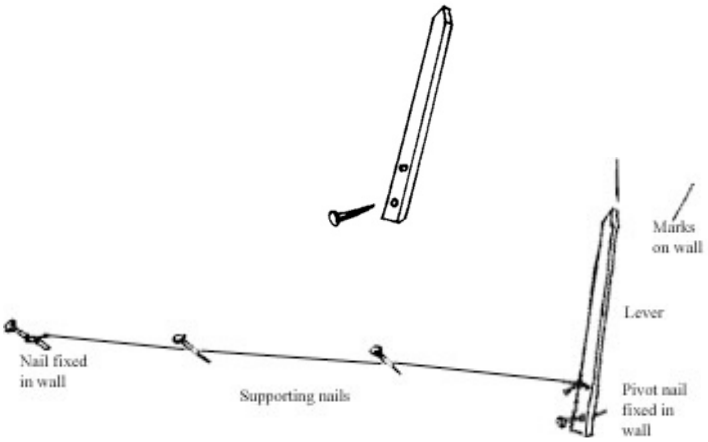
The drawings explain how to make the thermometer. Hammer a nail into a wall and fasten a wire to it as shown in the diagram. Any type of metal wire can be used.

It is a wire of about 3 meters, fixed at one end to a nail hammered into a wall. On the other end, it is fastened through a hole in a light wooden lever.

The lever is attached to the wall with a nail that passes through a hole large enough to let the lever move freely. Note that the wire is supported with nails so as not to fall.
You can experiment with a bundle grass on fire to heat the wire from one end to the other - that is, raising the temperature of the wire. Result: the wire expands and moves the lever down.

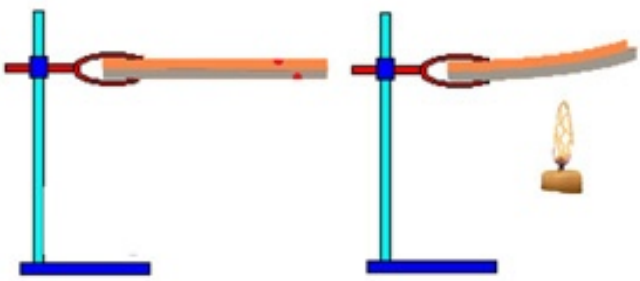
In the morning when the day is fresh, the pointer is in a higher position on the wall. At noon, when it's hot, the wire expands and the pointer goes up.

It is difficult to put numbers (degrees) on this thermometer, but the lowest mark in the morning is perhaps 18°C; and perhaps 28°C in the summer.

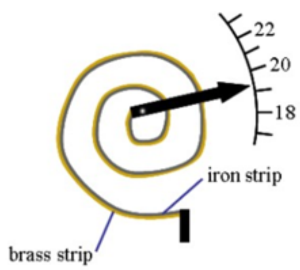


Bimetallic strip thermometers

A bimetallic strip thermometer relies on the fact that different metals expand differently when they are heated. This type of thermometer is often found in domestic ovens.



Two metals soldered together make up the bimetallic strip. In the diagram, when the temperature rises, the gray metal expands more than the orange-colored metal and the strip bends. The end of the strip can be connected to a lever that activates a pointer that indicates the temperature.



Playing with an air current

You will need a hairdryer, a ping pong ball and a straw.
Turn off the heater of the dryer and switch the air speed to "Max."
Direct it to the ceiling. Put a ping pong ball in air stream.

Result, the ball is supported by the air.

The boy is using the air to lift the ball ping-pong. How?
By controlling the air pressure.

This is an example of "Bernoulli's principle." Mr. Daniel Bernoulli was a Swiss scientist who discovered the effect more than 250 years ago.

Even if you can not see it, the air compresses and pushes things around us - including our own bodies. We rarely notice it, because we're used to it, and our bodies are made to push against the air. Things like tyres, airplanes and sailing boats work taking advantage of this effect, the force of air pressure.
When you put the ping pong ball in the air flow created by the hair dryer, air flows around the ball creating a low pressure area. The air around the flow of air has a higher pressure and pushes the ball to keep it in the air stream.
If you have strong lungs, you can do it with a flexible plastic straw. ▼

Pressure board

Get a board 50 x 50 cm of strong wood and a strong plastic bag with a long flexible tube fastened into (with an airtight join) so that it reaches your mouth. Put the wood on the bag on the floor and put your feet on the wood.

Blow into the tube. The bag fills up and lifts the board and you.

The pressure in your lungs is small but the area of the bag (and board) is large, so that the force (pressure times area) is great.

The Small Submarine

The submarine is a small device used to demonstrate the principle of Archimedes, and with its help you can study cases that present a body submerged in water.
A real submarine goes up and down, admitting or expelling water. Here, we present a small model of the operation.

Get the transparent cap of a ballpoint pen. If it has a little hole in the top, fill this with chewing gum or Blu-Tack.

Fastem a piece of chewing gum or Blu-Tack on the clip on the cap, enough to allow it to just float vertically in the water. (Try it in a basin of water and adjust it until it is vertical.) The cap should have no water inside, just air.)

Put it into a plastic bottle filled with water.
Check that the pen cap floats, full of air.

Check that the bottle is completely full of water. Then tighten the lid of the bottle and, with your hands, squeeze the bottle hard. This creates a pressure inside the bottle, forcing the water to rise a little in the cap of the pen, making it heavier, which makes it sink.

On relaxing your hands, the pressure inside the bottle decreases and the little water that entered the pen cap comes out so that the pen cap rises.

It is an amusing toy.

In a real submarine, cylinders of compressed air expel water from tanks in order to rise. To descend, a valve opens, allowing the sea to enter.

A very small submarine

You can do the same experiment with a piece of a match.
With your fingers, break off the head, leaving the wood fibres a bit frayed.

Put it in the water in the bottle, making sure that the bottle is absolutely full of water before tightening the lid very well.

Now, repeat the experiment with the piece of match in place of the pen cap. You will observe the same phenomenon. The match descends and ascends. But you must squeeze your hands with great force.

How does it work? Between the wood fibres, there are small balls of air. These are compressed and decompressed like the air in cap of the pen in the first experiment

Weigh cigarette smoke

Jorge sat smoking a cigarette. Beside him sat his friend John. They were not talking; they were watching the cigarette smoke rising into the air.

After some time, John asked George, "Do you imagine that you could weigh that smoke?"

George laughed. "Of course not! It's so light and scattered."

But John said, "You are wrong. It is easy to weigh the smoke."

"How?" Jorge said ...

Now, you, readers, can you think how to weigh the smoke?

How to weigh smoke - the solution ▼

First, weigh the cigarette. It weighs maybe 5 grams. Then you smoke the cigarette and saves the ash. Now, you weigh the ashes and the cigarette end. These weigh maybe 4 grams. So, the weight of the smoke is: weight of the cigarette minus the weight of the ash and the cigarette end. That is, 5 - 4 = 1 gram.

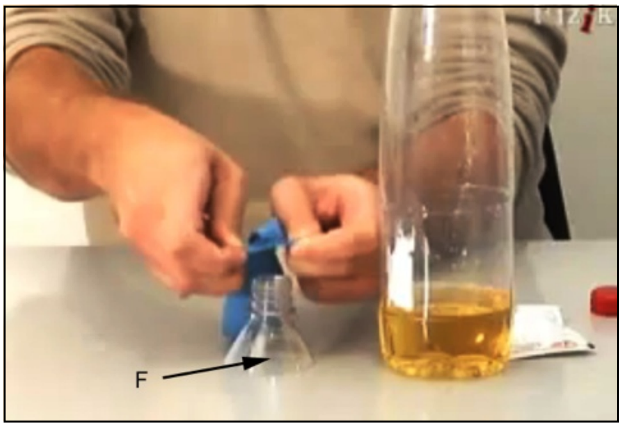
How to make Carbon Dioxide

You will need: A balloon, plastic bottle, 2-3 tablespoons of sodium bicarbonate (baking soda), 1/4 cup of vinegar and a small funnel (the top of a small plastic bottle)

Here's what you do:

V – Vinegar
F – Funnel (top of a small plastic bottle)
B – Balloon
Bic – Bicarbonate of soda

1. Pour the vinegar in the bottle.



2. Fix the mouth of the balloon on the funnel.

3. Put the bicarbonate of soda in the balloon using the funnel.

4. Put the mouth of the balloon on the bottle.

5. Lift the balloon so the baking soda falls into the bottle.

Shake the bottle to mix the contents a little.

See what happens.

Two Curiosities - The boy is from space or what?
And do you think the bicycle could work?

How Batteries Work.

The battery's energy and its uses

In any battery, the same electrochemical reaction happens so that the electrons move from one connector to the other. Metals and electrolytes determine the battery voltage; each different reaction has a characteristic voltage. This is, for example, what happens in a cell of a lead-acid car battery:

Each cell has one plate made of lead and another one made of lead dioxide. These are in an aqueous solution of sulphuric acid (the electrolyte). The battery in the photo has six cells.

Lead combines with SO_4 (sulfate ions) to create $PbSO_4$ (lead sulfate) plus an electron;

The lead dioxide, hydrogen ions and SO_4 ions plus electrons from the lead plate create $PbSO_4$ and water on the lead dioxide plate.

When the battery discharges, the two plates form $PbSO_4$ (lead sulphate) and water is formed in the acid. The characteristic voltage is about 2 volts per cell, so if you combine six cells you get a 12-volt battery;

A good feature of the lead-acid battery is that the chemical reaction is completely reversible. If you apply current to the battery at about 14 Volts, lead and lead dioxide form again on the plates so you can use the battery again. That is, it is recheargable.

In a zinc-carbon battery (the most common battery) you cannot reverse the reaction. That is, you cannot recharge it.

Modern batteries use a variety of chemical reactions to provide energy.
In the common zn-C battery, the electrodes are zinc and carbon with an acidic paste between them to serve as the electrolyte.

Alkaline batteries - used for common batteries Duracell and Energizer, the electrodes are zinc and manganese oxide with an alkaline electrolyte.

Nickel-cadmium battery - The electrodes are nickel-hydroxide and cadmium with a potassium hydroxide electrolyte (rechargeable)

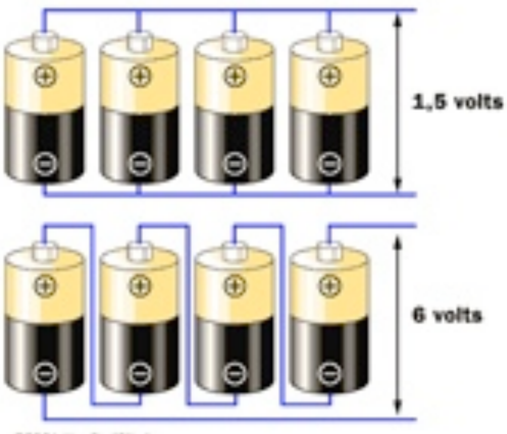
Nickel metal hydride - This battery is rapidly substituting the nickel/cadmium battery.

Rechargeable lithium-ion batteries - with a very good weight-power, it is usually found in laptop computers and cell phones (rechargeable);

Zinc air battery - This battery is lightweight and rechargeable;

Silver-zinc battery - used in aeronautical applications because of their high power to weight ratio;

Metal-chloride battery - used in electric vehicles.
Almost all devices that use batteries do not use only one cell at a time. They are sometimes grouped together serially to form higher voltages or in parallel to form higher currents. In a serial arrangement, the voltages add up. In a parallel arrangement, the currents add up.

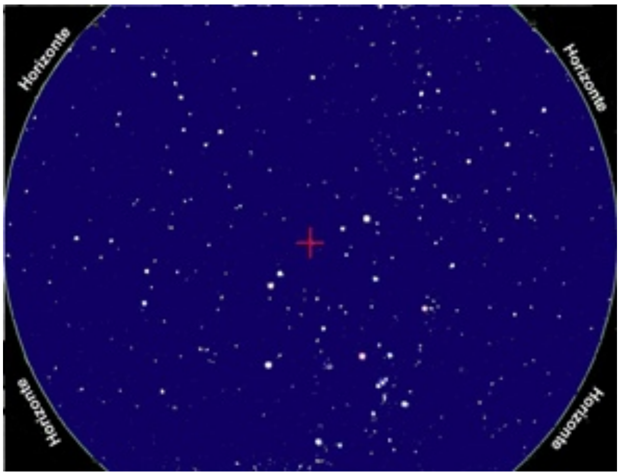


The diagram shows these two arrangements:
The first arrangement above is called parallel arrangement. Assuming that each cell produces 1.5 volts, then four batteries in parallel will also produce 1.5 volts, but the current supplied will be four times higher than that of a single cell. The arrangement below is called a serial arrangement. The four voltages add together to produce 6 volts.

Usually when you buy a battery pack, the package tells you the battery voltage. A typical digital camera for example, uses four nickel-cadmium batteries that are rated at 1.25 volts and 500 milliamp / hour for each cell.
A battery of 500 milliamp-hours could produce 5 milliamps for 100 hours, or 10 milliamps for 50 hours, or 25 milliamps for 20 hours, or - theoretically - 500 milliamps for 1 hour, or even one thousand milliamps for 30 minutes.

Have you ever looked inside a 9 volt battery? It contains 6 small batteries producing 1.5 volts each in a serial arrangement.

Astronomy



The Universe

When you look at the night sky you are looking at "The Universe". You see something like this. >>
These points of light (which we call stars) are not really points. They look so small because they are so far away. Indeed, many objects are extremely large - bigger than you can imagine. Moreover, they are so far from us on earth we can not imagine the distance.
There are many thousands of millions of them.

Galaxies

Here is a photo of several of these objects. The three objects are called spiral "galaxies." The largest of them in the picture is 6,500 Light Years* away from us and is about 10 LY wide. It contains thousands of smaller objects. Beside it in the photo are other objects and other galaxies. The galaxies have the form of spirals.

* Distance

Astronomers measure distances in "Light Years". A light year is the distance light travels in one year. The light has a speed of 300,000 kilometres per second. So in a year, it travels about 10 trillion km, which is 10,000,000,000,000 km.

Within galaxies, there are other smaller objects. Some of them are "solar" planets revolving around smaller stars.

The photo on the left shows our galaxy. An arrow points to our Solar System. As you can see, we are very insignificant in the vastness of the universe.

Solar systems are spheres of hot gas and molten metal and metal vapor, such as our sun. There are planets orbiting around many of them.

Our Solar System consists of our Sun and the planets Mercury, Venus, Pluto, Earth, Mars, Jupiter, Saturn, Uranus and Neptune, as shown in the diagram below. (The diagram is not to scale; the distance between them is enormous of course.)

Nebulas

Some of the other objects in a galaxy are clouds of the same materials in many different forms, called "nebulae".

This photo shows a nebula that is the result of an exploded star. These bursts are called "Supernova."

Space is very, very deep. Astronomers believe that it is expanding, and that it has no end. That is, it is expanding to infinity.

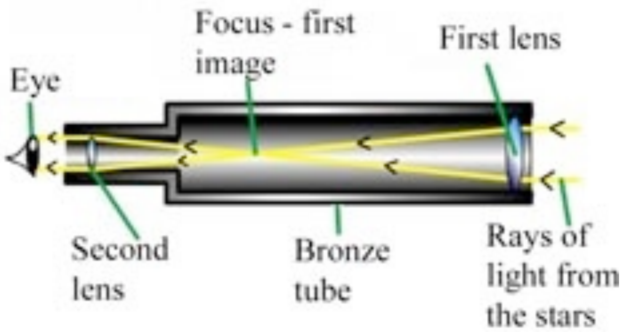
Many people do not understand what the stars are, nor the sun nor the moon. For thousands of years, only a few specialists (astronomers or priests) had any understanding of the night sky - Indians, Chinese, some South American cultures and some cultures in Africa. Knowledge of the stars, however, is still relatively significant among the hunting peoples in the Southern Hemisphere, especially among the African Bushmen.
People believed that the stars were fixed inside a huge inverted bowl high over their heads - a bowl of clear crystal. This bowl slowly rotated once a day, from East to West.

Some thought the sun was pulled by invisible horses driven by Apollo, the Sun God, and that the planets were gods or goddesses. ("Planet" in Greek means "wandering star") - Mercury, Mars, Venus, Saturn, etc. because they moved among the fixed stars.)
The picture shows an image of Apollo on an ancient Greek cup.

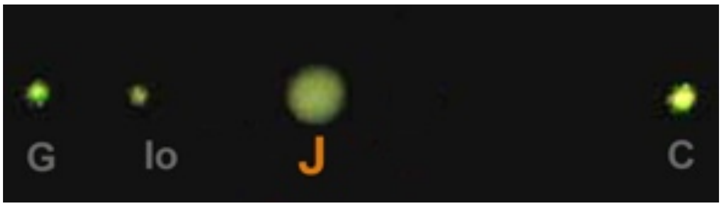
Telescopes

In Europe, about 500 years ago, several people invented "telescopes". These were sets of lenses (or curved mirrors) which were "the glass that can recognize a man several miles away." These lenses were placed in long tubes.

An ancient form of telescope ▼



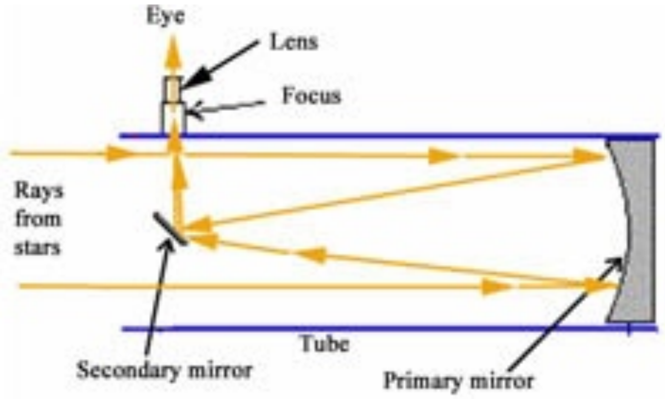
Using a telescope, astonomers saw that a planet was not just a blip, but a ball that had shadows and shapes in it.



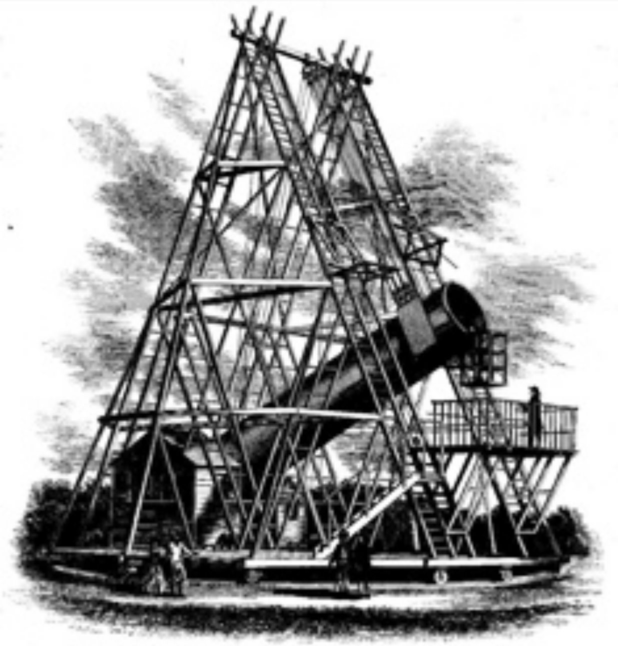
Early astronomers used telescopes saw that Jupiter was not a mere point of light but a planet with at least 3 or 4 satellites by its side (Ganymede, Io and Callisto.)

The planet Mars as they saw it >>

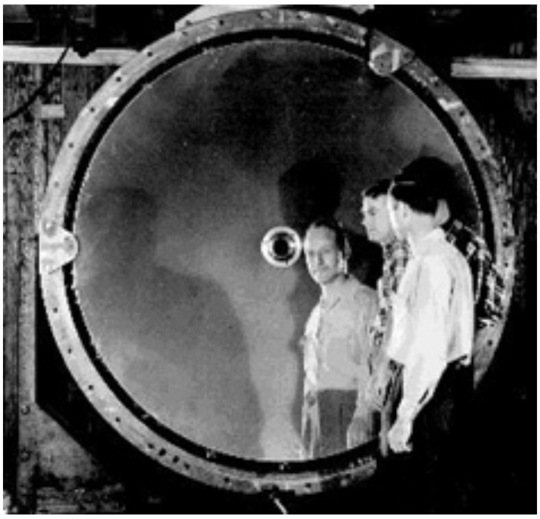
Some observers imagined that they saw "canals" on Mars and thought there might be people on the planet.



The diagram above shows a telescope that uses a curved mirror a normal (flat) mirror and a lens:
Astronomers gradually built larger telescopes that have larger images. About 200 years ago, William Herschel made a telescope nearly 20 feet long, which gave very large and detailed images.



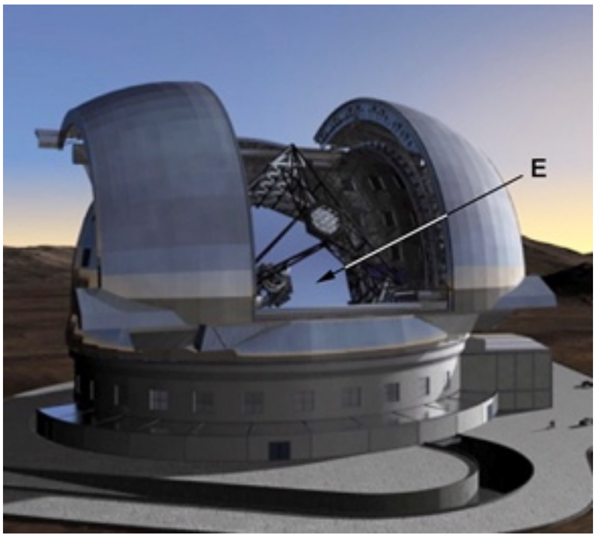
Little by little, Herschel came to understand that the stars were not in a bowl inverted in the sky, but that they were very at large distances from the Earth in what is now called "deep space".

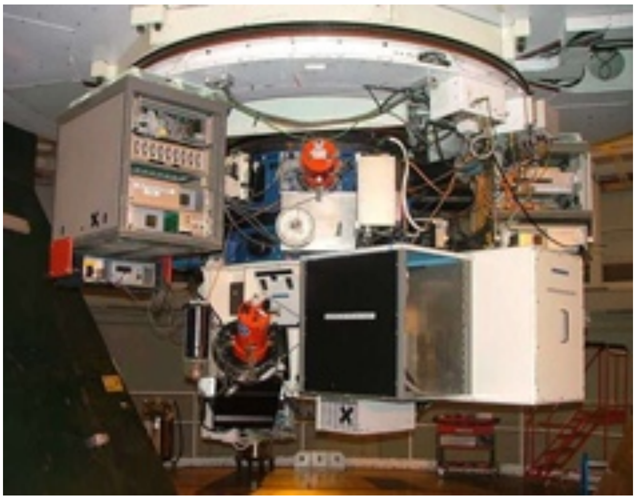


On the left, a picture of a curved mirror, used in a telescope.

In the twentieth century, large telescopes were built.
The photo above shows a building containing a large modern telescope.

The large telescope with the dome open. You can see the large mirror inside. (E)





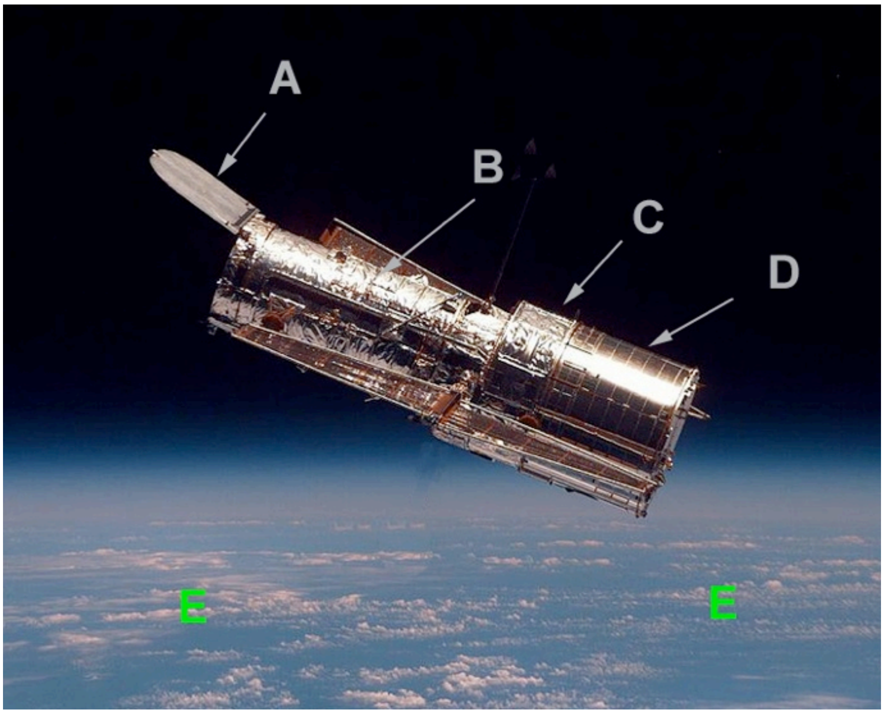
The control system of a large modern telescope to steer it towards the part of the sky you want to see.

In the mid 20th century, when rockets could launch satellites into space, engineers built telescopes to operate in space. The advantage is that there is no atmosphere in space. (Air distorts the images.)
The largest space telescope is the "Hubble".

The Hubble Space Telescope

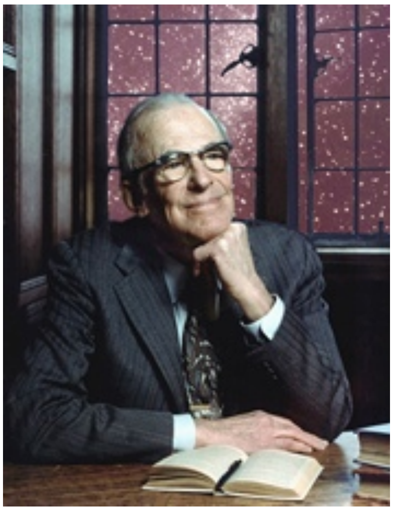
The Hubble Space Telescope is an astronomical, unmanned artificial satellite that is a large telescope. It was launched by NASA (the National Aeronautics and Space Agency) in 1990. This telescope has received several NASA space visits for equipment maintenance. It uses a very large curved mirror.
It is 550 miles (about 900 km) above the Earth.

A - The cover
B - Tube
C - The mirror position
D - Control Instruments and the transmitter for transmitting images to Earth.
E - The Earth with its clouds.



For the first time it was possible to see farther than the stars of our own galaxy and study the structures of the universe hitherto unknown or rarely observed.

Hubble, in general, has given the human civilization a new vision of the universe.



The story of the Hubble Space Telescope began in 1946 when astronomer Lyman Spitzer (pictured) wrote a paper entitled "Astronomical Advantages of an extraterrestrial observatory." There, he stated the two great advantages of observatory telescopes in space over those on the ground: first, the optical resolution (minimum distance separation between objects in which they remain clearly distinguished) would be limited only by diffraction, as opposed to the effects of atmospheric turbulence of that caused flickering of the stars.
The second major advantage is the possibility to observe the ultraviolet and infrared light, which is largely absorbed by the atmosphere.

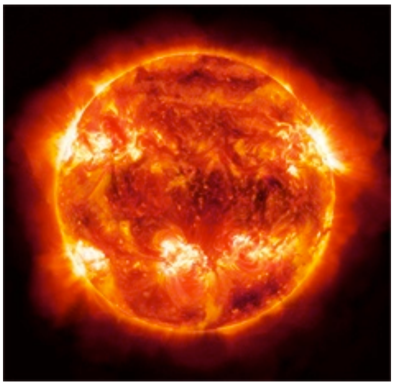
Some images taken by the Hubble Telescope

Many of the planets have satellites ("moons") revolving around them.

The photo shows four of the moons of Jupiter taken by the Hubble telescope.

From left to right in order of increasing distance from Jupiter: Io, Europa, Ganymede and Callisto.

Our Moon, seen by the Hubble telescope ▲



The Sun

Mars

The Southern African large telescope (SALT)
A reflector, located in the semi-desert region of the Karoo, South Africa, built in 2005. The diameter of the mirror is 11 meters. SALT is the largest optical telescope in the Southern Hemisphere.

Mozambique
The Department of Physics at the University Eduardo Mondlane has an astronomical telescope - a big refractor.