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GEOMETRICAL OPTICS BENCH

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29 Experiments to perform

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1	Slide 50x50	4024
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1	Box	JT3
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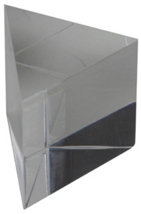
NOTICE

The small differences between the characteristics of the pieces making the collection and the relative drawings are justified by technological upgrade.

DESCRIPTION OF PROVIDED MATERIAL


1116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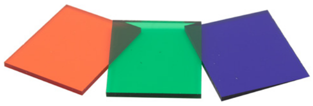
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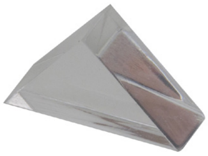
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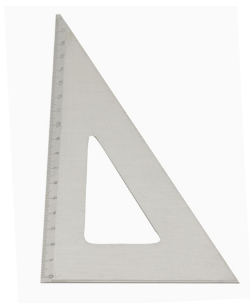
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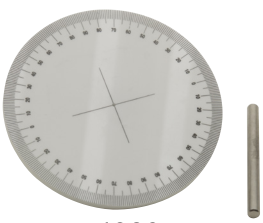
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1° THE OPTICAL PROJECTOR

The projector used for the optics experiments, which can be performed with this set, is shown in figure 1.
The light source is comprised of a white LED that works with a 6V tension.
The necessary power is provided by the transformer that has to be connected with the projector.
The condensing lens has a focus *f* = 6cm and the LED is positioned so as to create a parallel light path.
The projector is equipped with three diaphragms: one with a slot, one with four and one with an arrow-shaped slot.

figure 1

figure 2

In the projector's front side there is a slot whereby the diaphragms (figure 2) can be placed as shown in figure 3. The joint allows to modify the projector's inclination.

figure 3

2° THE RECTILINEAR PROPAGATION OF LIGHT

Considering light as a type of energy, we can divide the bodies into two wide categories:
- *light sources;*
- *the illuminated bodies.*

The light sources are defined as devices that emit light using another type of energy.
The second ones are bodies receiving light from a source and spreading it in all directions.
Some examples include Sun, stars, candles, light bulbs, etc.
The bodies which do not emit light, but diffuse the light they receive, are called nonself-luminous bodies. This category includes the Moon that diffuses the light received by the Sun.

Another distinction related to the light among bodies is the following:
1. *the transparent bodies;*
2. *the opaque bodies.*

The first ones allow the light to go through, while the others don't.
The opaque bodies, when hit by the beam, cast behind themselves a cone of shade. The study of the shadows allows you to verify that light travels in straight lines.

EXPERIMENT N. 1

Required material: 1 optical bench; 1 lamp; 1 power supply; 2 riders; 1 Earth-Moon system; 1 white screen; 1 linear ruler.

Using the measuring rod, measure the sphere's diameter D_1 then mount the device as shown in fig. 4. Then measure the diameter D_2 of the shadow projected by the sphere on the screen

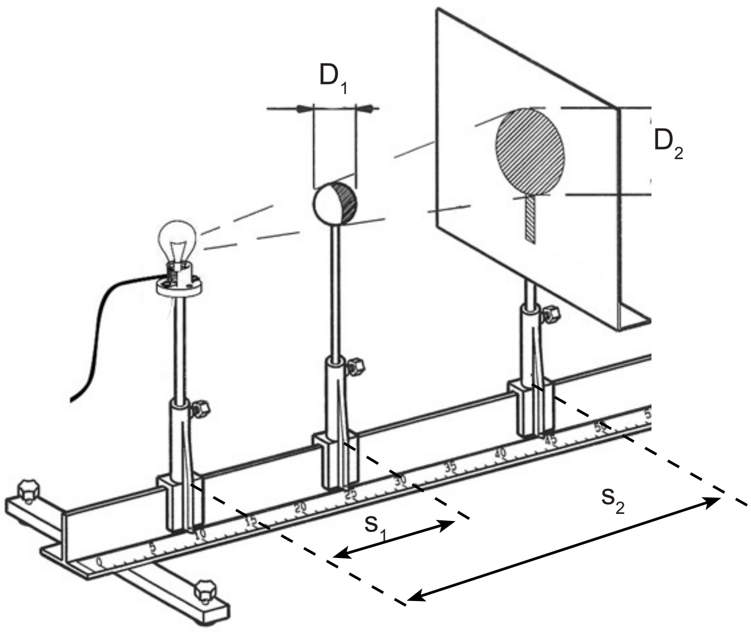


Fig. 4

Repeat the experiment changing the distances s_1 and s_2.
- Within the limits of errors, can you state that the following relation is verified:

$$s_2 : s_1 = D_2 : D_1$$

- Which conclusions can you take referring to a well-known property of the similar triangles?

3° MOON AND SOLAR ECLIPSES

The proof that light travels in straight lines is given by the previous experiment.
Solar and *lunar eclipses* are two well-known phenomena that can be considered as consequence of this property. To understand these two phenomena you must consider that Sun is a very big light source. Besides the cone of shade, where there is no light, there will be two cones of twilight, in which only a part of the light drawn by the Sun arrives (fig. 5).

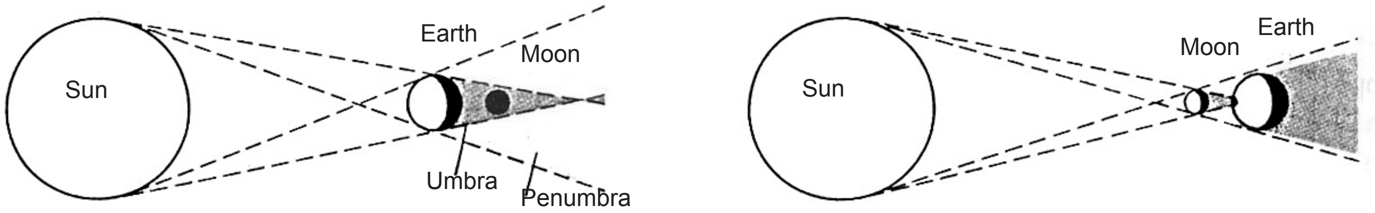


Fig. 5

EXPERIMENT N. 2

Materiale occorrente: 1 optical bench; 1 projector; 1 projector power supply; 2 riders; 1 Earth-Moon system; 1 white screen; 1 linear ruler.

Complete the device as shown in picture 6, where the projector simulates the Sun and the big sphere simulates the Earth. Making the small sphere rotate (the Moon) around the bigger one, you can easily understand that every time it comes in the cone of shade of the Earth, the Moon is darkened.

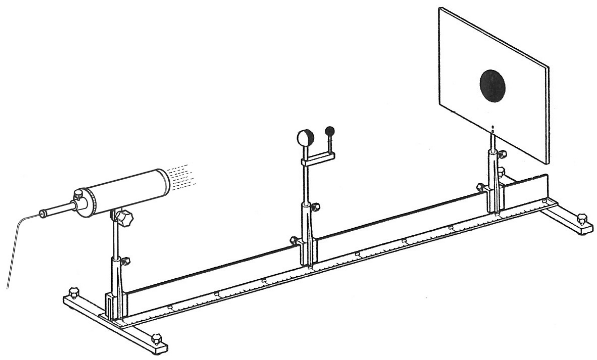


Fig. 6

While the Lunar eclipse happens when the Earth is between the Sun and the Moon, the Solar eclipse happens when the Moon is between the Sun and the Earth (fig. 7) In both cases, the eclipse can be partial or total. If then the eclipse is central but it doesn’t cover the whole solar disc, there will be the annular eclipse, because the part of the solar surface remaining uncovered is a circular corona.

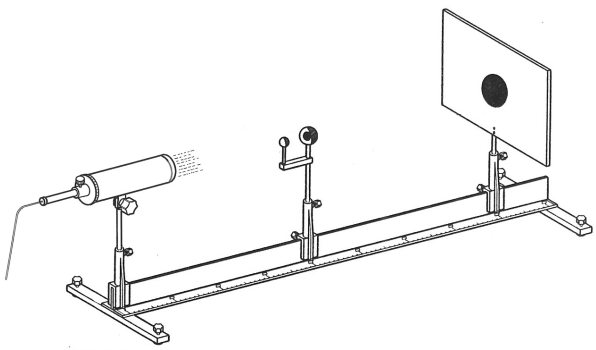


Fig. 7

4° THE LUNAR PHASES

The different positions of Moon towards Sun and Earth, during its revolution motion, are called lunar phases. They are represented in a seven-days cycle in figure 8, from a terrestrial observer.

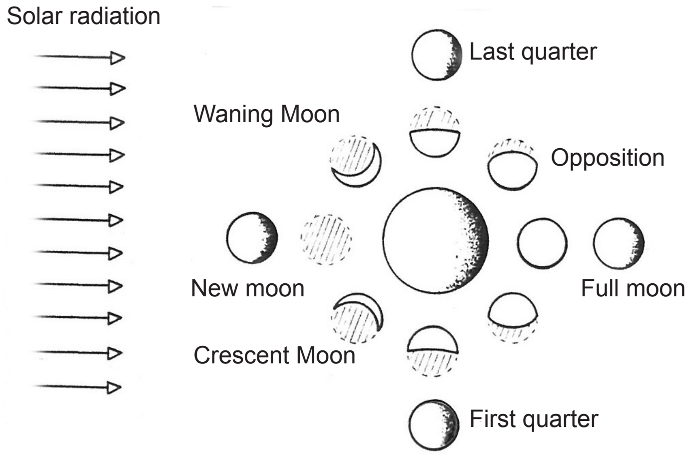


Fig. 8

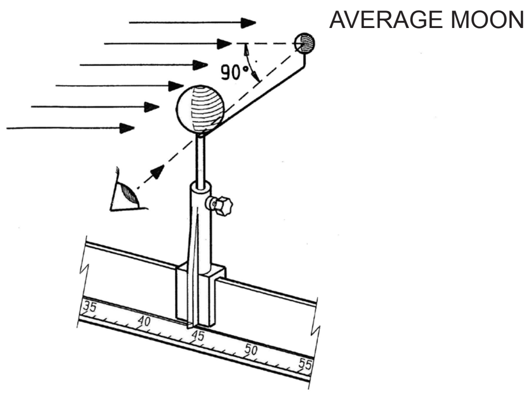


Fig. 9

1° ***New Moon***: it is the phase when the Moon is in conjunction with the Sun, that is when they rise and set at the same time. In this phase, the Moon is invisible for a terrestrial observer.

2° ***First quarter***: during this second phase, the direction Earth-Moon forms a right angle with the solar light rays. Only one quarter of the Moon surface is visible. During the following days the visible part keeps on increasing in order to become maximum between the fourteenth and the fifteenth day.

3° ***Full Moon***: during this phase, the Moon is in opposition to the Sun, so that the entire lunar hemisphere is visible.

4° ***(Second or) last quarter***: this is on 22nd day. During the following days, the illuminated part will be reduced more and more until it will disappear completely. When the cycle is completed, the Moon is still in conjunction with the Sun.

EXPERIMENT N. 3

Required material: 1 optical bench; 1 projector; 1 projector power supply; 2 riders; 1 Earth-Moon system; 1 white screen; 1 linear ruler.

With the arrangement shown in figure 9, you can simulate the different lunar phases.
Darken the room where you are and then put your eye in a tangent direction with the opaque surface of the bigger sphere representing the Earth. Revolving slowly round the smallest sphere, you can easily see its illuminated parts in correspondence with the different phases.

5° IRRADIATION LAW

If along the path of a beam of optics radiations emitted by a spotlight source, you put an opaque screen with a squared hole in the middle, only a small part of the energy emitted by the source will arrive at the screen. If you measure the dimensions of the hole and of the illuminated area on the screen and the distances from the source, the diaphragm and the screen, you have a further proof of the linear diffusion of light (along straight lines).

EXPERIMENT N. 4

Required material: 1 optical bench; 1 lamp; 1 projector power supply; 2 riders; 1 filters holder; 1 white screen; 1 screen with squared hole; 1 linear ruler.

Once you have set the device as shown in figure 10, you can carry out the following experiment:

1° measure the distance *d* between the filament and the diaphragm;
2° measure the distance *D* between the filament and the white screen;
3° measure the length *l* of the side of the squared slot in the diaphragm;
4° measure the length *L* of the side of the illuminated area of the screen;

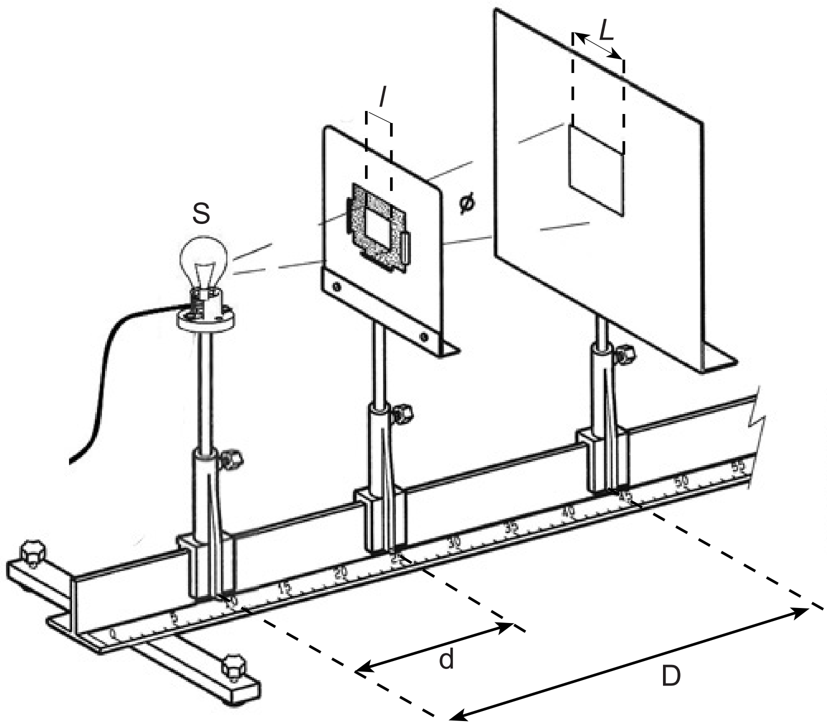


Fig. 10

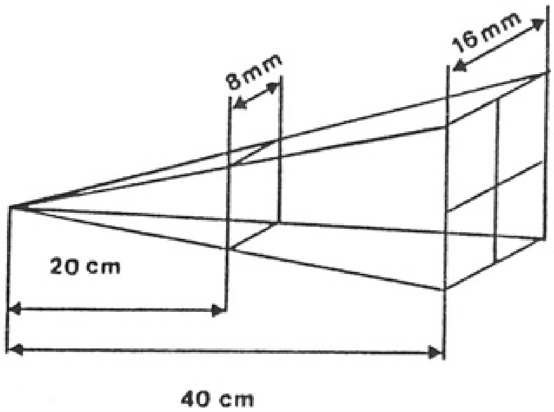


Fig. 11

- Within the limits of the experimental error, you can then verify the relation $d : D = l : L$?
- If this relation is verified, which consequences are there?

If we indicate with *E* all the solar energy passing through the slot and falling on the screen, the energy distributing on the surface unit, also defined as "*illumination*", results:

$$I = \frac{E}{L^2}$$

But, if the distance *D* between the screen and the source, is doubled, tripled, etc… the area of the irradiated surface will become 4 times bigger, 9 times bigger etc…
So at a double distance the flow of energy is distributed over a surface four times bigger, at a triple distance over a surface nine times bigger etc… we can conclude that:
The illumination is inversely proportional to the square of the distance of the source (fig. 11).

6° LIGHT SCATTERING

In a room with closed windows, without light sources, we can't see the objects around us.
If we want to see something there must be at least one optical source in the room, for instance a turned on light bulb.
This fact makes us realize that the objects can be seen only if they receive by a source the radiating energy that then is emitted in all directions. A typical example is the Moon that can be seen only at night because it receives radiations by the sun and then emits them in all directions. The air molecules, in fact, receive the solar light and they diffuse it inside the room in which we are (fig.12).
If there was not air around the Earth, looking upwards you would see the black sky with many stars. We wouldn't have that diffusing brightness that is produced by the diffusion of the solar light done by air molecules.
The following experiment explains this concept.

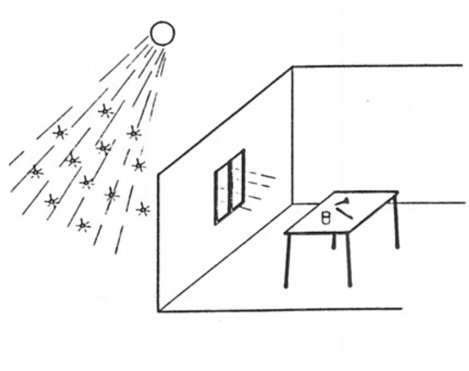


Fig. 12

EXPERIMENT N. 5

Required material: 1 optical bench; 1 projector; 1 projector power supply; 1 rider; 1 diaphragm with four slots; 1 protractor; 1 glass.

you put the diaphragm with four linear holes on the projector. Adjust the position in order to obtain four horizontal plans of light. Clean the beaker using a moistened cloth, removing any particle of dust. Finally complete the device as shown in figure 13 and darken the room where you are.

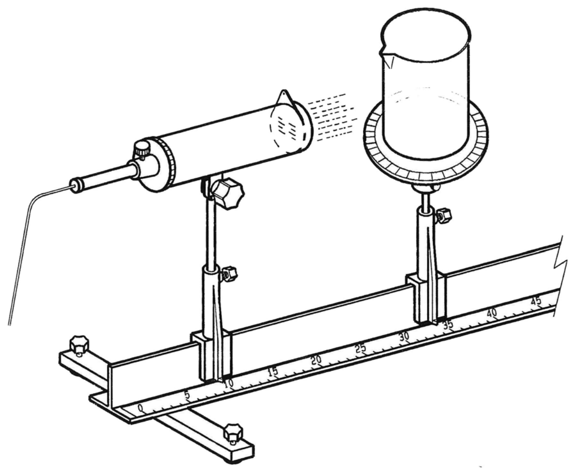


Fig. 13

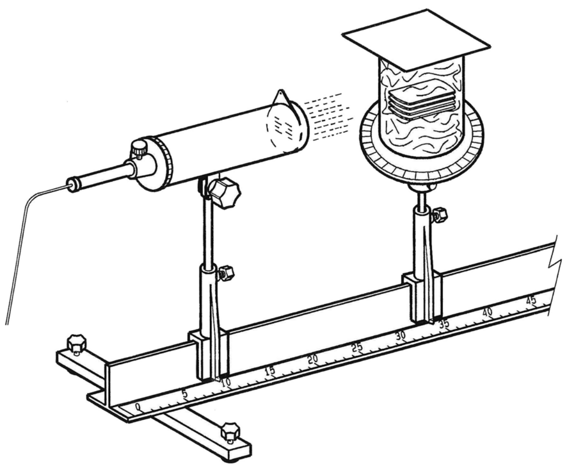


Fig. 14

Can you see the four luminous traces inside the beaker?
Put inside the beaker some smoke from a cigarette or shake a duster for cleaning the board on top of the beaker, and then cover it with a piece of cardboard (fig. 14)
What you now see inside the beaker, are they rays of light?
Then, the so-called rays of light don't exist physically: they are just the directions along which the light travels.

7° LIGHT REFLECTION

Each time a beam falls on a secular surface, you can see the reflection phenomenon, where the two following laws are verified:

1° ***The incident ray, the reflected one and the normal n to the surface of reflection in the point of incidence, lay on the same plane.***
2° ***The angle of incidence i corresponds to the reflection angle i.***

Note: with “rays of light” we mean the directions along which the incident and reflected beams propagate. You can check the previous laws with the following experiment.

EXPERIMENT N. 6

Required material: 1 optical bench; 1 projector; 1 projector power supply; 1 rider; 1 diaphragm with one slot; 1 protractor; 1 flat mirror.

After mounting the diaphragm on the projector, you can adjust its position in order to obtain a thin beam of vertical light. Then, put the goniometer and a flat mirror in a perpendicular position with the axis passing through the zero on the scale of the goniometer (fig. 15).

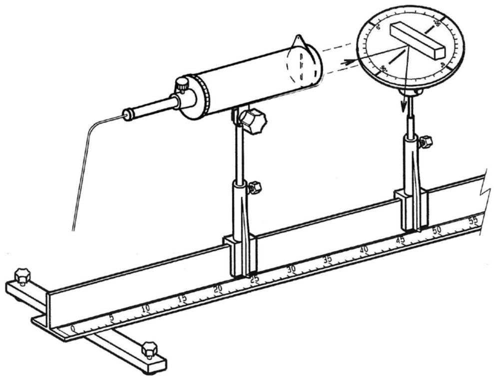


Fig. 15

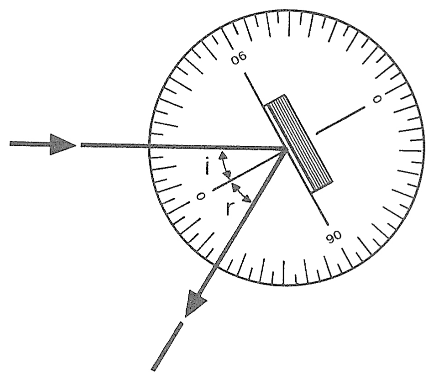


Fig. 16

Set up the device so that the beam coming out from the diaphragm can lap on the goniometer leaving a luminous trace and can strike the mirror on the central point of the goniometer. You could then verify that for each inclination of the mirror, the reflection angle r is always identical to the incident ***i*** (fig. 16).

8° REFLECTION IN SPHERICAL MIRRORS

Behind the light bulbs of the lights in the cars there is a concave mirror, that is a spherical mirror, o parabolic, whose reflecting surface is concave.
Instead in the rear mirrors the reflecting surface is convex.
The spherical mirrors have important properties that can be explained with the following experiment.

EXPERIMENT N. 7

Required material: 1 optical bench; 1 projector; 1 projector power supply; 1 diaphragm with three slots; 2 riders; 1 white screen; 1 double spherical mirror -10 +10 .

After mounting the diaphragm on the projector, you can adjust its position in order to obtain four thin beams of horizontal light. Adjust the position of the light bulb in order to have the beams parallel. Put the white screen so that the four luminous traces are clearly visible.

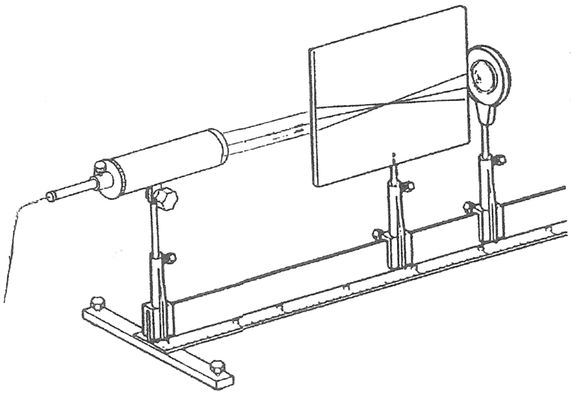


Fig. 17

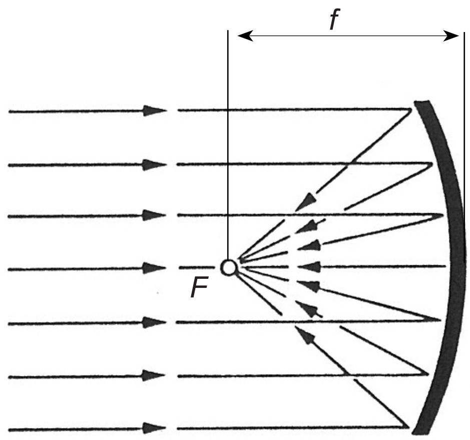


Fig. 18

Finally, put the concave mirror in the position indicated in figure 17. Adjusting the position, it's possible to verify that the reflected rays converge all in the same point ***F***, that is the focus of the concave mirror. The distance ***f*** between the focus and the mirror is defined focal length (fig. 18).
Replacing the concave with the convex mirror, as shown in figure 19, you can notice that the reflected rays diverge so that their prolongations will meet in the same point defined virtual focus of the convex mirror (fig. 20).

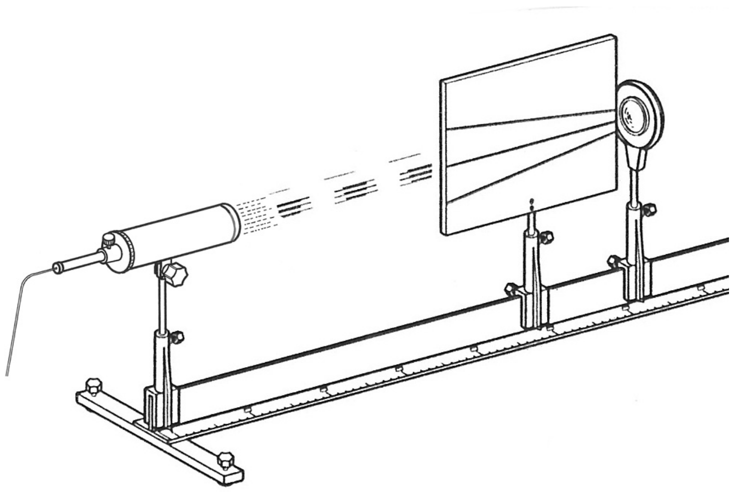


Fig. 19

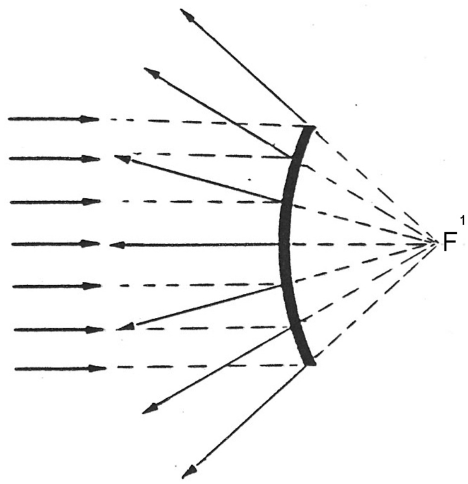


Fig. 20

9° THE REFRACTION OF LIGHT

The speed of light c is maximum (about 300.000 Km/s) when the light travels in a vacuum. In all other transparent bodies, its speed ***v*** is always slower. Every transparent body has a number ***n*** that is the ***absolute refractive index***. It allows you to know the speed with which the light travels across it.
Precisely, it results:

$$v = \frac{c}{n}$$

When a beam travels from a vacuum (or from the air) in a transparent material medium where its speed is slower, it will undergo a deviation and this phenomenon is called the ***refraction of light***.
You can easily measure the refractive index of Plexiglass with the following experiment.

EXPERIMENT N. 8

Required material: 1 optical bench; 1 projector; 1 projector power supply; 1 diaphragm with one slot; 1 rider; 1 protractor; 1 plexiglass semi-cylinder.

Adjust the position of the light bulb and the diaphragm in order to obtain a thin beam of vertical light. Put then on the goniometer the Plexiglass half-circle in a perpendicular position to the axis passing through the zero of the scale. Complete the device as shown in figure 21 so that the incident ray of light will form an angle i with the perpendicular to the half-circle in the point of incidence.

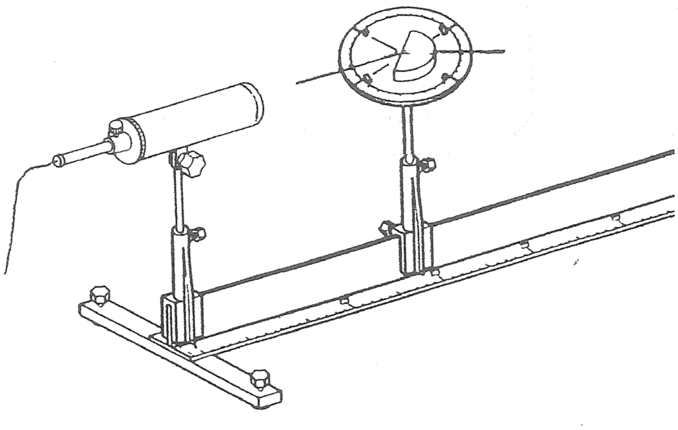


Fig. 21

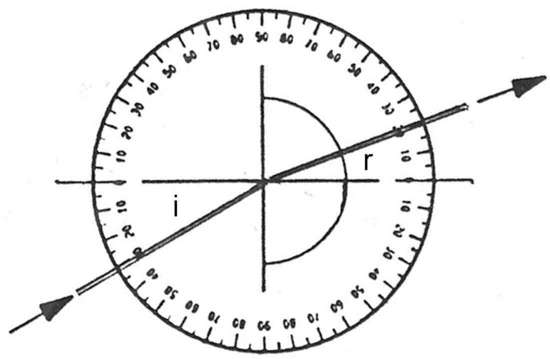


Fig. 22

You can then observe that the angle ***r*** formed between the refraction ray and the same perpendicular is always smaller than ***i*** (fig. 22). Draw on a paper the structure of the phenomenon, measuring the length of the two segments *AB* and *CD* shown in figure 23. It is demonstrated that:

$$n = \frac{AB}{CD} = \frac{sen\, i}{sen\, r}$$

- What is the speed of light in Plexiglass?

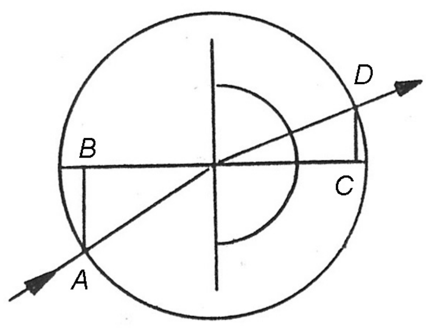


Fig. 23

10° THE REFRACTIVE INDEX AND THE COLOURS OF LIGHT

You have found that the speed of light in the transparent material medium is always slower than its speed in a vacuum with the previous experiment.
Light is a phenomenon produced by our eyes as a consequence of the reception of electromagnetic waves, whose wavelength is between 380 and 750 nanometres.
Each wavelength corresponds to a different colour. Precisely higher wavelengths correspond to red colour, and as the wavelengths become slower, there are different colours like orange, yellow, green, blue and purple (fig. 24).

Fig. 24

Question: Does the speed of light in transparent material medium change depending on the wavelength and consequently on the colour?
The following experiment allows you to answer the question.

EXPERIMENT N. 9

Required material: 1 optical bench; 1 projector; 1 projector power supply; 1 diaphragms with one slot; 2 riders; 1 filters holder; 3 coloured filters; 1 protractor; 1 Plexiglass semi cylinder.

Prepare the bench as shown in figure 25. In the filter holder you need to insert the red filter. Put it in a way so that the incident angle is = 50°. Take a note of the refraction angle ***r***.

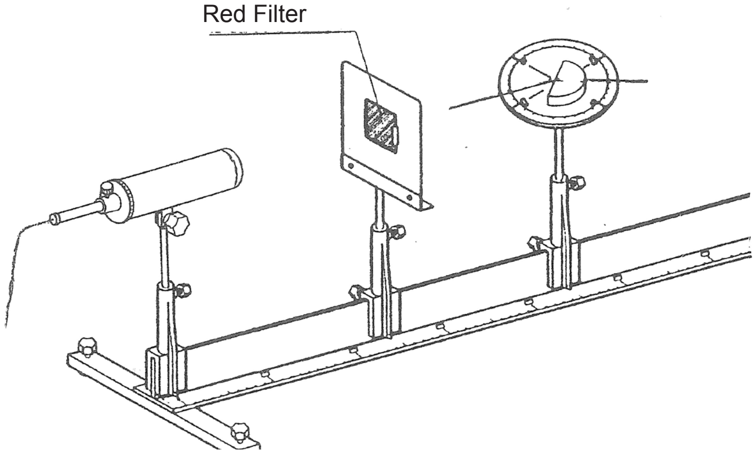


Fig. 25

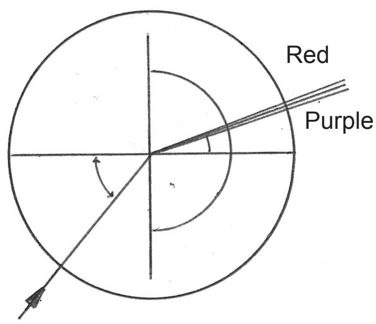


Fig. 26

Keeping the incident angle constant, replace the red filter, first with the green one and then with the purple one and take note of each and every refraction angle. Keep in mind that the changes are on the order of half degree (fig. 26).

- How does the refraction angle change depending on the colour of light?
- How does the refractive index change depending on the colour of light?
- How does the speed of light change in the transparent material media depending on the colour of light?

11° TOTAL REFLECTION

You could verify that the refracted beam gets close to the perpendicular when it passes from the air into a transparent medium with the previous experiments. You can observe in the next experiment that in the reverse transformation the refracted beam gets away from the perpendicular and that, in particular conditions, the incident ray will be reflected.

EXPERIMENT N. 10

Required material: 1 optical bench; 1 projector; 1 projector power supply; 1 diaphragm with one slot; 2 rider; 1 protractor; 1 Plexiglass semi cylinder; 1 isosceles prism.

Repeat the arrangement of experiment n. 8. Put the Plexiglass semi-cylinder on the goniometer in a perpendicular position to the axis passing through zero on the scale, so that the spherical face is oriented to the incident ray (fig. 27).

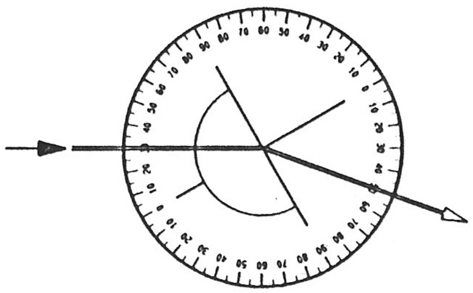


Fig. 27

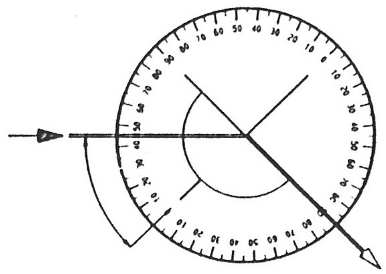


Fig. 28

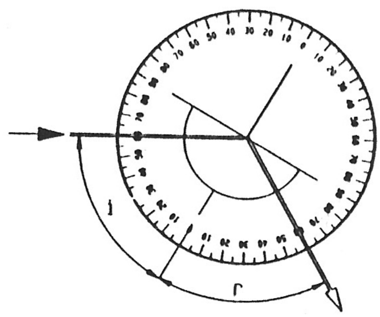


Fig. 29

You could then verify that the refraction angle r is always bigger than the incident angle *i*. Keeping the same arrangement, if you turn slowly the goniometer together with the semi-cylinder, you will increase the angle of incidence *i*. You will notice then that corresponding to a certain angle *l*, the refraction angle is 90° and that the refracted ray is tangent to the plane surface, as shown in figure 28.
The angle *l* is defined as limit angle, because if you increase further the angle of incidence, the ray will be reflected on the plane surface of the semi-cylinder as if it was a mirror (fig. 29).

EXPERIMENT N. 11

Required material: the same as the previous experiment, plus 1 rectangular optical prism.

The phenomenon of total reflection is mainly used in the *total reflection prisms*. They are isosceles with triangular and rectangular base prisms and made of transparent material (glass or) and whose limit angle is smaller than 45°. The angle of incidence is always bigger than this value, and so the outgoing ray will be totally reflected, as it is shown in figures 30 and 31.

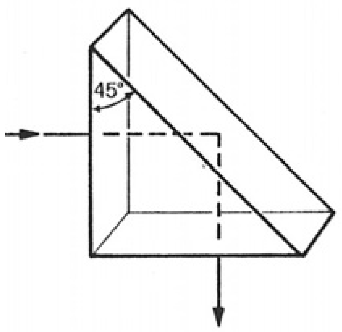


Fig. 30

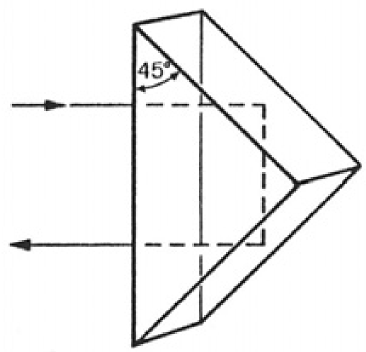


Fig. 31

12° THE REFRACTION OF LIGHT THROUGH A PRISM

If you make a beam fall on a transparent prism, you will observe two refraction phenomena, one at the incidence and the other at the emergency.
As a consequence, the outgoing beam of an angle ***d*** results deviated compared with the incident one, called total deviation angle. It is possible to demonstrate that:

$$\delta = i + e - \alpha$$

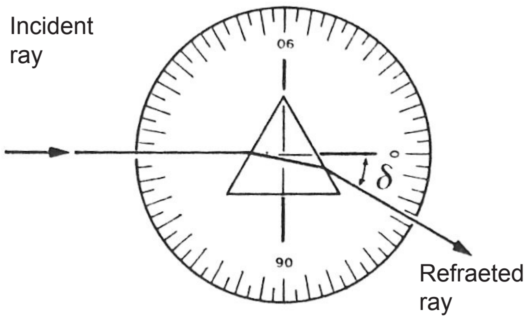


Fig. 32

where ***i*** is the angle of incidence, ***e*** is the angle of emergency and α is the angle to open the prism (fig. 32).

If you introduce a coloured filter between the projector and the prism, you can observe that the deviation angle δ depends on the colour and so on the wavelength of light.

EXPERIMENT N. 12

Required material: 1 optical bench; 1 projector; 1 projector power supply; 1 diaphragm with one slot; 2 riders; 1 filters holder; 3 coloured filters; 1 protractor; 1 equilateral prism.

Prepare the bench as shown in figure 33. Adjust the components in order to have a visible luminous trace of the incident and emergent beam on the plan of the goniometer. The fenditure of the diafram must be vertical.

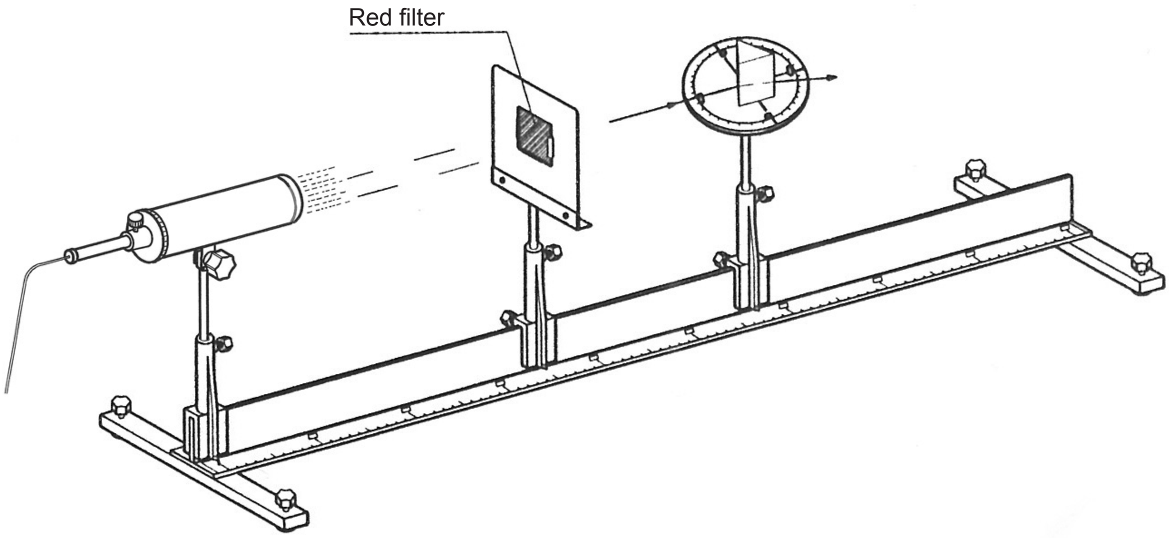


Fig. 33

Start the experiment inserting the red filter in the filter holder so that the incident angle *i* = 50°.
You can then observe that the total deviation angle will become bigger while the wavelength will become smaller. This means that green will be deviated more than the red and purple even more than green. Even though they are very small changes, they are quite visible (fig. 34).

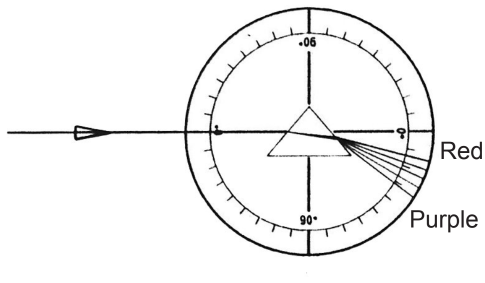


Fig. 34

13° THE DIFFUSION OF WHITE LIGHT

Some times after a storm, it is possible to see the rainbow and you may wonder the origin of those wonderful colours in the sky.
To understand the origin of this phenomenon, you just need to know the properties of optical prisms.

EXPERIMENT N. 13

Required material: 1 optical bench; 1 projector; 1 projector power supply; 1 diaphragm with linear slot; 1 rider; 1 holder for the screen; 1 white screen; 1 protractor; 1 equilateral prism.

After you have mounted the diaphragm with the linear slot on the projector, you can complete the device as shown in figure 35. You need to have a very clear trace of the beam on the goniometer. The beam has to emerge from the diaphragm and the angle of incidence on the optical prism has to be 50°.

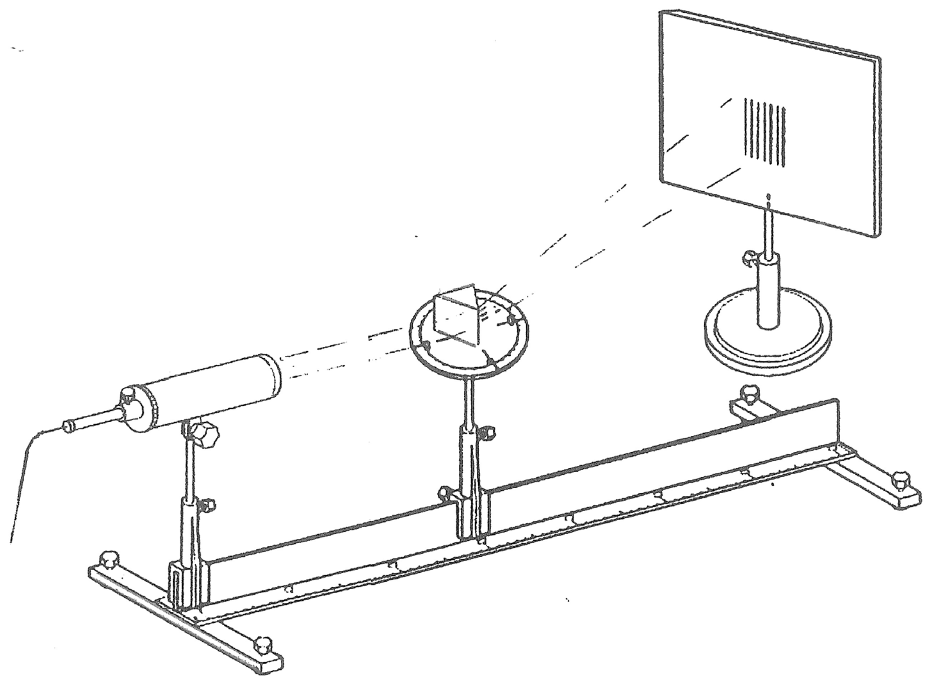


Fig. 35

If you put the white screen in the correct position you can see the light, coming out from the prism, composed of many colours.
The reason is that the light produced by the projector, called white light, is composed of many colours. All these colours, passing through the optical prism, undergo different deviations. The same phenomenon happens with the solar e light. During the storms the water drops are like prisms, producing the rainbow phenomenon, as shown in figure 36.

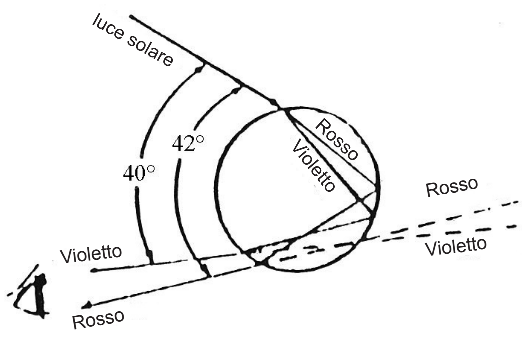
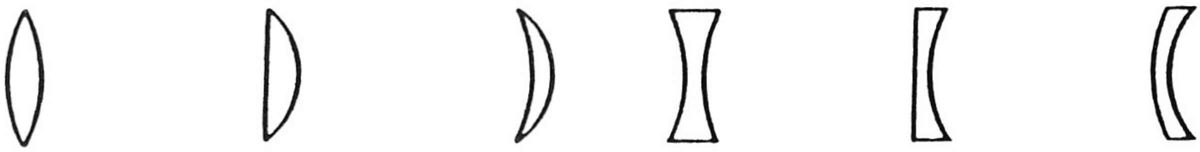


Fig. 36

14° THE LENS

Cameras, microscopes, binocular and all the other optical devices base their working on the lens properties. Also the sight faults can be corrected with the use of proper lenses. We recommend you to read about their properties. The lenses can de divided into two wide categories: the ***converging*** and the ***diverging lenses***. The first ones are thicker in the middle and thinner on the sides; the second ones are thinner in the centre and thicker on the sides.

CONVERGING LENSES DIVERGING LENSES



EXPERIMENT N. 14

Required material: 1 optical bench; 1 projector; 1 projector power supply; 1 diaphragm with three slots; 2 riders; 1 screen; 1 converging lens +10; 1 diverging lens –10.

Adjust the position of the diaphragm in order to obtain three parallel and horizontal beams. Complete then the device as shown in figure 37, where a converging lens is used. You can observe that the refracted rays converge all in the same point *F*, that is defined the focus *of the lens*. The distance *f* between the focus and the lens is defined focal length (fig. 38).

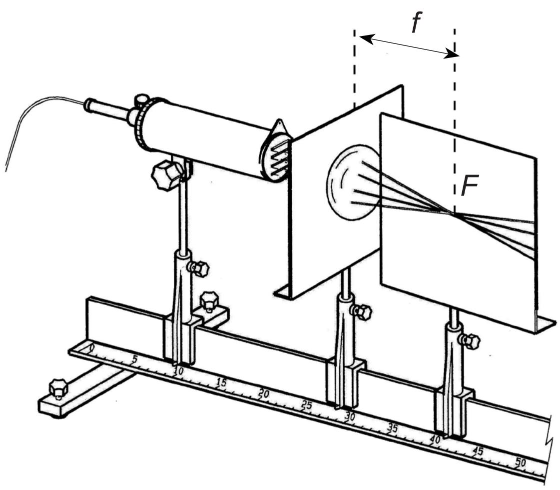


Fig. 37

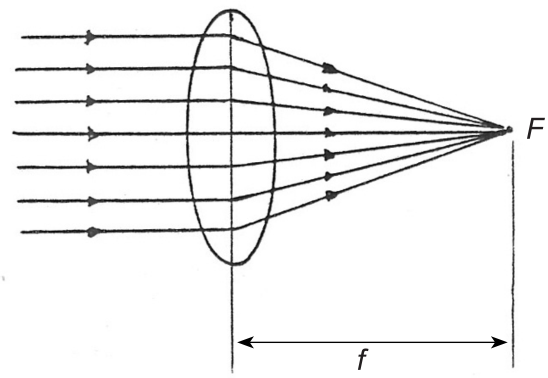


Fig. 38

If you replace the converging lens with the diverging lens and you keep constant the position of the other components, you can observe that the refracted rays diverge, as it is shown in figure 39. Their prolongations converge all in the same point *F’*, that is defined virtual focus of the diverging lens (fig. 40).

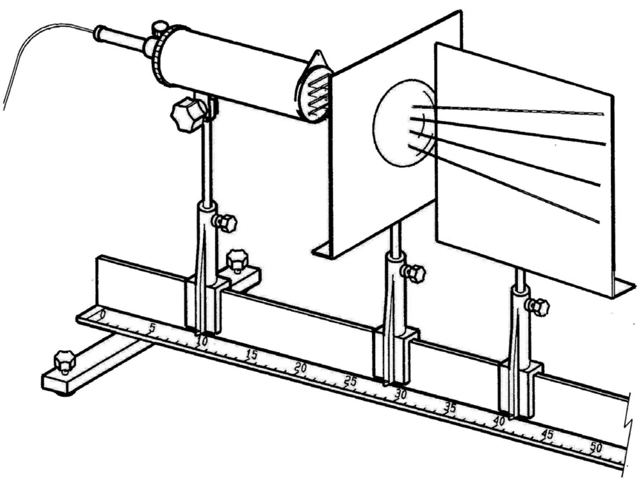


Fig. 39

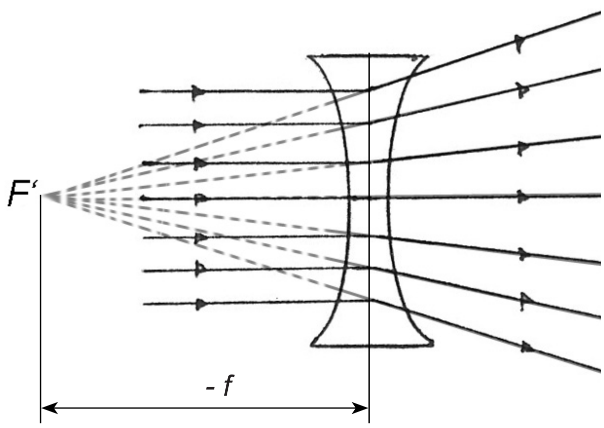


Fig. 40

15° IMAGES IN PLANE MIRRORS

If you put an object in front of a plane mirror, you will see the image behind him (fig. 41). This is the reason why we define *virtual* the images produced by this kind of mirror.
The images in the flat mirrors have also another feature. If you stand in front of a mirror and you lift up your right arm, your image will appear at the same distance from the mirror, but with the left arm raised. It seems like *the right side has been inverted with the left side* (fig. 42).

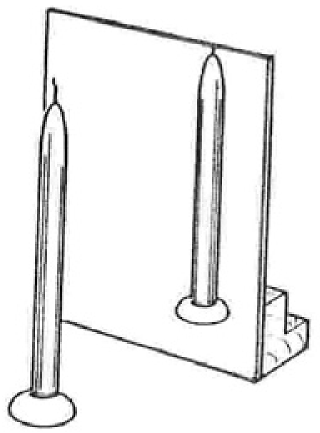


Fig. 41

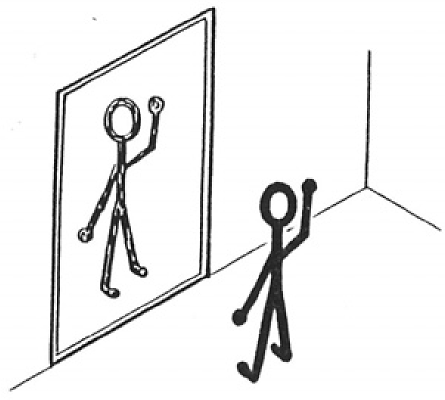


Fig. 42

These features of the images in the plane mirrors are a consequence of the reflection law for light that you have learnt with the section 7. You can verify it by carrying out the following experiment.

EXPERIMENT N. 15

Required material: 1 flat mirror; 1 checked sheet of paper.

Draw on the sheet a clearly visible line and then put the mirror on the paper so that its reflecting plan coincides with this line. Then, draw a point *A* at 10 small squares from it, as it is shown in figure 43.

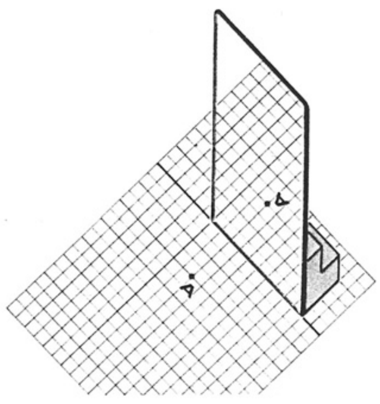


Fig. 43

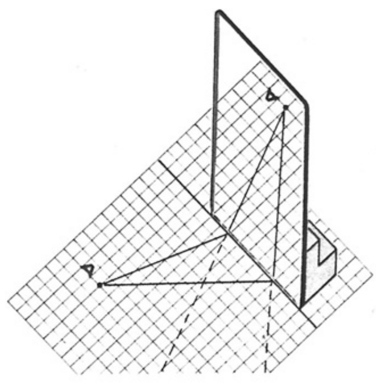


Fig. 44

- How many small squares are there between the image A’ and A?
  You can draw two outgoing rays from point A towards the mirror and you can build the relative reflected rays (fig. 44).
- Where do the prolongations of the two reflected rays meet?
  Complete the following sentence: The image of an object like a dot is at .... from the mirror. The object is situated in the point where the .... of reflected rays of all the rays coming out from the object meet.

16° IMAGES IN SPHERICAL MIRRORS

The spherical concave mirror supplied in this collection has a focal length of $f \cong$ 10 cm.
This data is important for the spherical mirrors because the type of image provided by a spherical mirror depends on the distance between the object and the mirror.

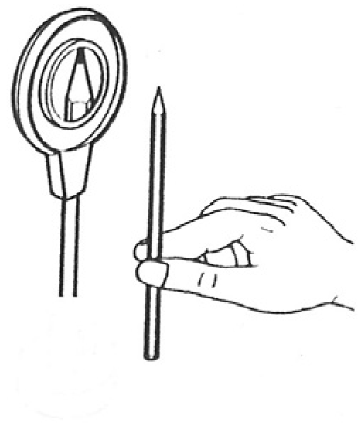


Fig. 45

EXPERIMENT N. 16 **Object between the mirror and its focus**

Required material: 1 spherical concave mirror.

As it is shown in figure 1, if the object is between the mirror and the focus the image is always virtual and enlarged.

EXPERIMENT N. 17 **Object between the focal length and the double focal length**

Required material: 1 optical bench; 1 projector; 1 projector power supply;
1 arrow-shaped diaphragm;
1 holder for the screen; 1 white screen; 1 rider;
1 concave mirror +10; 1 linear ruler.

Therefore, you need to complete the device shown in figure 46, so that the distance p from the arrow and the mirror is included between the focal length and the double focal length, between 10 and 20 cm. If you adjust the position of the screen until the image of the arrow is really visible, you can verify that the distance q from the mirror and the image is always bigger of the double focal length. Besides, the image results enlarged and inverted.
The position of the arrow-shape fenditure can be determinated by a square ruler as showed in picture 47.

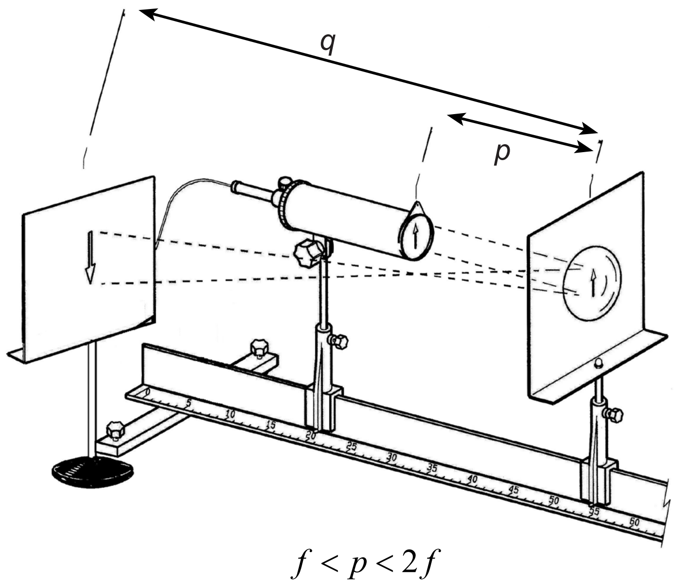


Fig. 46

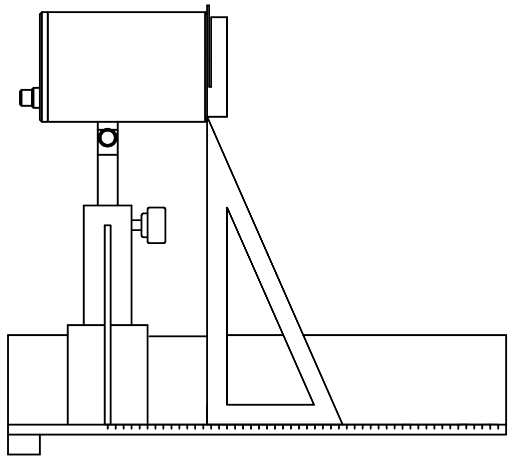
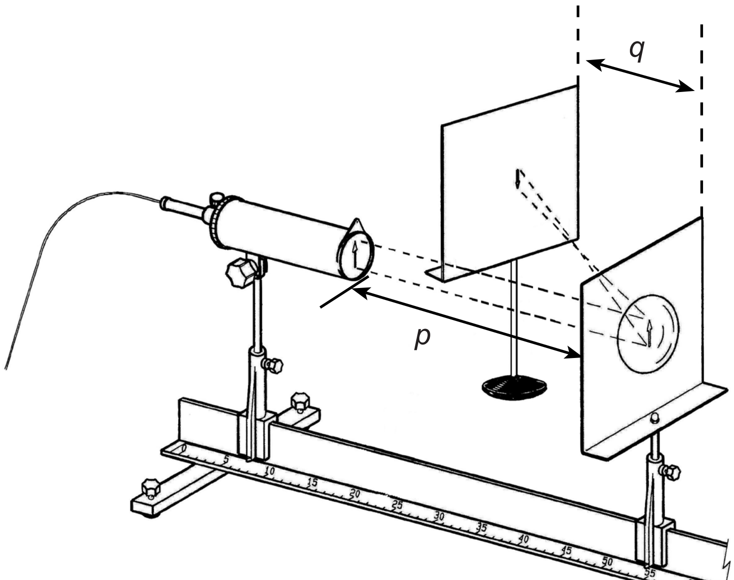


Fig. 47

EXPERIMENT N. 18 **Object between the double focal length and the infinity**

You can then prepare the device as shown in figure 48 in order to have the distance between the arrow and the mirror bigger than the double focal length. The sharp image is between the focus and the end of the double focal length and becomes smaller and inverted.



$$p > 2f$$

Fig. 48

The previous experiments have shown that the image in a concave spherical mirror can be virtual or real, enlarged or shrank, depending on the position of the object.
In a spherical convex mirror, instead, the image is always virtual and diminished. You can understand this concept by carrying out the following experiment.

EXPERIMENT N. 19

Required material: 1 convex mirror.

Verify the properties of a convex spherical mirror placing a common object in front of it (fig. 49).

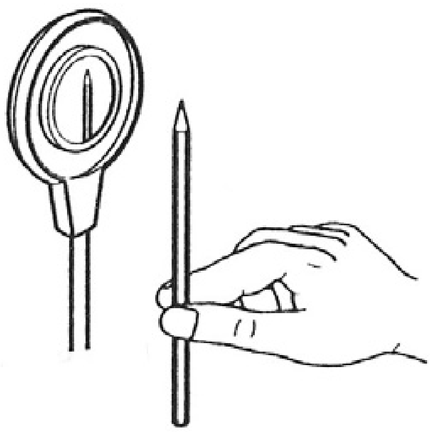


Fig. 49

17° THE CONJUGATED POINTS IN SPHERICAL MIRRORS

In the previous guide, you have carried out experiments on the images produced on the concave spherical mirrors. In this way, you have verified that when the object is at a higher distance from the mirror than its focal length, the image is always real.
It is possible to demonstrate that the following relation is verified among the three entities *p*, *q* and *f*:

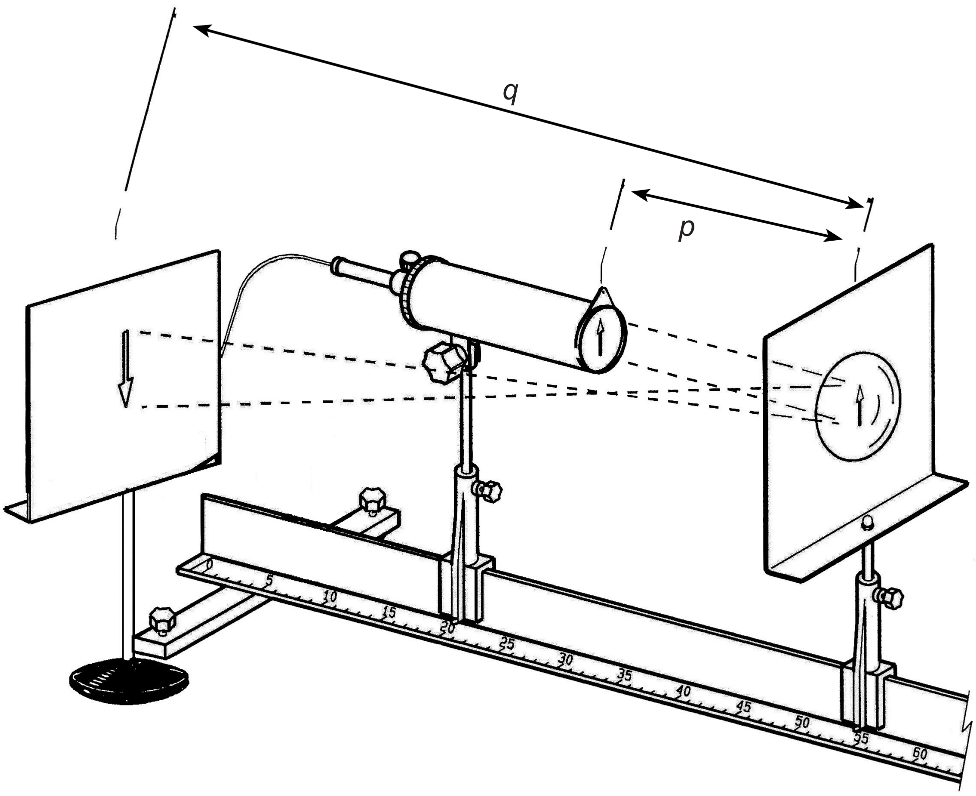
$$\frac{1}{p}+\frac{1}{q}=\frac{1}{f} \quad \text{from which you obtain:} \quad f=\frac{pq}{p+q}$$

The points where there are an object and its corresponding image are called *conjugate points*.

EXPERIMENT N. 20

Required material: 1 optical bench;1 projector; 1 projector power supply; 1 arrow-shaped diaphragm; 1 holder for the screen; 1 white screen; 1 concave mirror +10; 1 linear ruler.

Carry out the experiment 17 again and adjust the positions of the single components so that the image will be in focus (fig. 50).
Using the linear ruler you have to measure the distances *p* and *q*. Using the previous relation it is possible to determine the measure of the focal length of the mirror. The test has to be repeated more than once, changing the distances and calculating an average value of the results obtained.



$$f < p < 2f$$

Fig. 50

18° IMAGES WITH LENSES

In the converging lenses the images can be virtual or real depending on the position of the object.

EXPERIMENT N. 21 **Object between the lens and its focus**

Required material: 1 converging lens + 10.

The image is enlarged, right side and virtual because it is on the same side as the object compared with the lens (fig. 51)

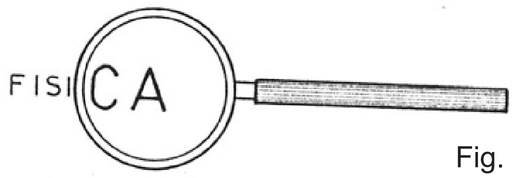
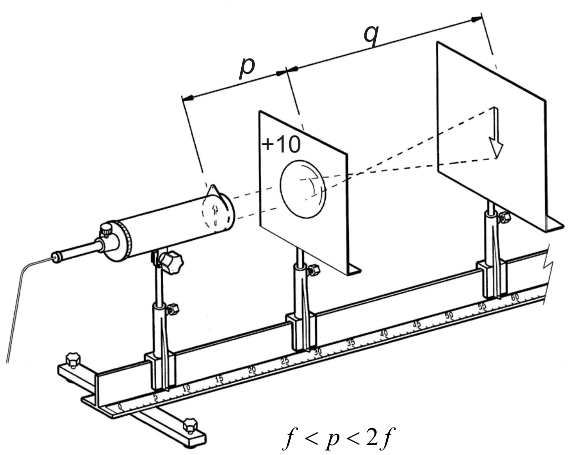


Fig. 51

EXPERIMENT N. 22 **Object between the focus and the end of the double focal length**

Required material: 1 optical bench; 1 projector; 1 projector power supply; 1 arrow-shaped diaphragm; 1 white screen; 2 riders; 1 riders; 1 linear ruler.

After you have adjusted the diaphragm with the arrow-shaped slot, complete the device as shown in figure 2 so that the filament of the light bulb is vertical. The length has to be at a distance between 10 and 20 cm far away from the arrow. The image of the arrow on the screen is real, enlarged, inverted and placed further on the double focal length.

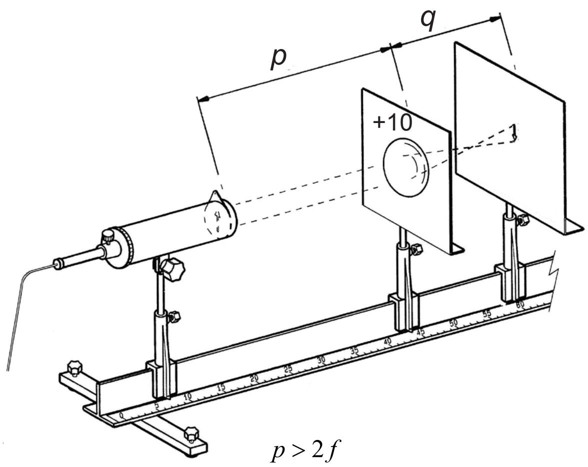


$f < p < 2f$

Fig. 52

EXPERIMENT N. 23 **Object between the double focal length and the infinity**

Prepare the device as shown for the previous experiment and put the lens at a distance from the arrow longer than 20 cm, as it is shown in figure 53. The image of the arrow on the screen is real, shrank, inverted and placed between the focus and the end of the double focal length.



$p > 2f$

Fig. 53

As you could observe with the previous experiments, the images in the converging lenses can be virtual or real, enlarged or shrank depending on the position of the object.
In diverging lenses, instead, the image is always virtual and shrank.

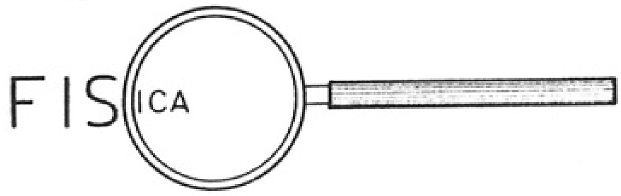


Fig. 54

EXPERIMENT N. 24

Required material: 1 diverging lens -10.

The image is always on the right side, shrank and virtual (fig. 54).

19° CONJUGATED POINTS IN CONVERGING LENSES

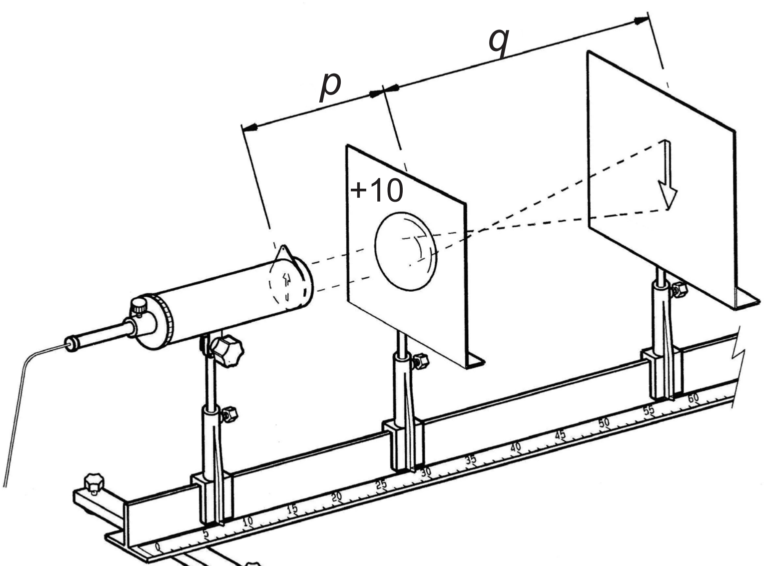
In the previous guide, you have carried out experiments on the images produced by converging lenses. In this way, you have verified that when the object is at a longer distance from the mirror than its focal length, the image is always real. If we indicate:
with *p* the distance between the object and the lens; with *q* the distance between the image and the lens; with *f* the focal length of the lens, it is possible to demonstrate that the following relation among them is valid:

$$\frac{1}{p}+\frac{1}{q}=\frac{1}{f} \qquad \text{from this you obtain:} \qquad f=\frac{p\,q}{p+q}$$

EXPERIMENT N. 25

Required material: 1 optical bench;1 projector; 1 projector power supply; 1 arrow-shaped diaphragm; 1 white screen; 2 riders; 1 converging lens +10; 1 linear ruler.

You can carry out the experiment N. 23 adjusting the positions of the single components so that the image will be in focus (fig. 55). You have to measure the distances *p* and *q*. The position of the arrow-shape fenditure can be determinated by a square ruler as showed in picture 47. Using the previous relation it is possible to determine the measure of the focal length of the mirror. The test has to be repeated many times, changing the distances and calculating an average value of the results obtained.



$f < p < 2f$

Fig. 55

20° THE EYE AND ITS DISEASES

The vision of the objects in the world around us is linked to the working of the visual apparatus, whose organ is the eye.
From a physical point of view, the eye is an optical system whose main component is the crystalline lens, acting like a converging lens. The ***crystalline lens*** projects shrank and inverted images of the objects on the internal part of the eyeball, that is the ***retina*** (fig. 56).
The crystalline lens changes automatically its thickness because the objects we watch are at different distances and so its focal length changes as well to allow a correct focusing on the retina.

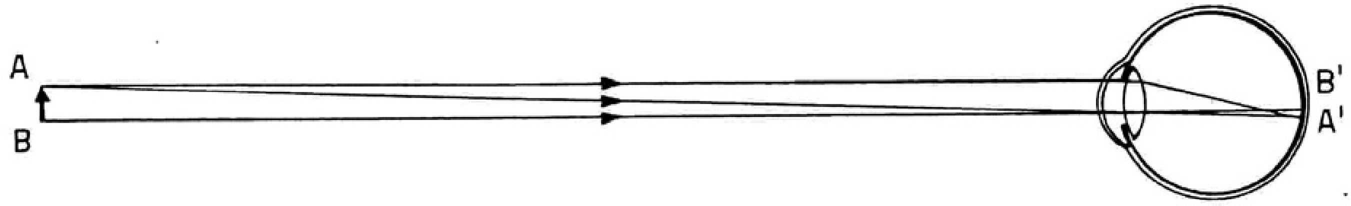


Fig. 56

For the defects of the cornea or of the length of the eyeball it may happen that the eye won't be able to focus the images of objects at different distances, so on the retina they result not focused and the vision is not clear.
In the first case, in the ***myopic eye***, the image of distant objects is in focus before the retina.
In the second case, in the **hypermetrope eye**, the image of close objects is in focus after the retina.
Those two defects are diseases that can be related to young people as well.
There is also a disease, called **presbyopia**, related to old people where the crystalline lens, loosing its elasticity, can't focus close objects, because their image focuses after the retina, like in hypermetropia.
Using correct lenses all these defects of the sight can be corrected, as it is shown in figure 57 for myopia and in figure 58 for presbyopia and hypermetropia.

MYOPIC EYE

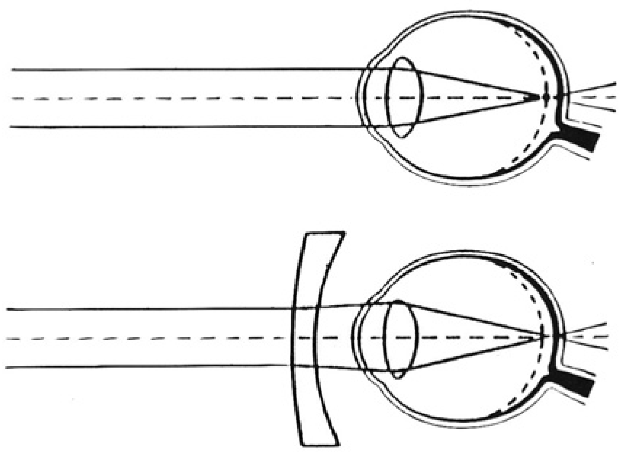


Fig. 57

PRESBYOPIA

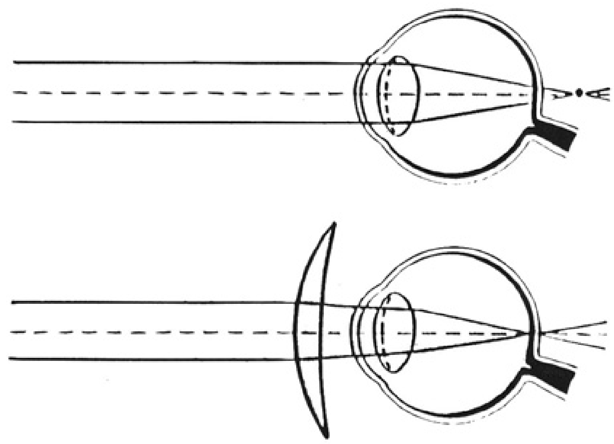


Fig. 58

21° CORRECTION OF THE EYE DISEASES

EXPERIMENT N. 26 **Correction of myopia**

Required material: 1 optical bench;1 projector;1 projector power supply; 1 white screen; 1 arrow-shaped diaphragm; 3 riders; 1 lens +10; 1 lens -10; 1 linear ruler.

Use the diaphragm with the arrow-shaped slot, which represents the object observed by the eye.
The filament of the light bulb must be vertical. To simulate the eye and its motions, put the converging lens +10 at about 20 cm from the arrow and then the white screen in order to have a real image shrank and inverted. The converging lens simulates the crystalline lens and the screen simulates the retina. In a myopic eye the image focuses before the retina, therefore the image is out of focus. To simulate this defect, you just need to put the screen at some cm of distance. To have the image in focus, you will just need to put the diverging lens - 10 in front of the crystalline lens, adjusting the position (fig. 59).

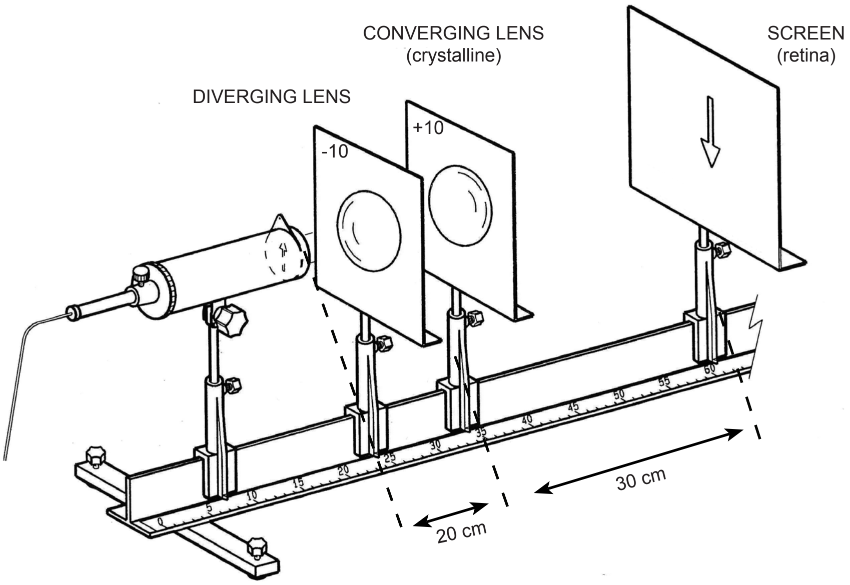


Fig. 59

EXPERIMENT N. 27 **Correction of presbyopia and hypermetropia**

Required material: the same as the previous experiment, plus a converging lens +6 instead of the diverging lens.

Create the simulation of the eye. Then, keeping in mind that in the hypermetrope and presbyopic eye the image focuses further on the retina, bring the screen at some cm closer to the converging lens. The image becomes out of focus. To have the image back in focus, you will just need to put a converging lens +20 in front of the crystalline lens, adjusting appropriately the position (fig. 60).

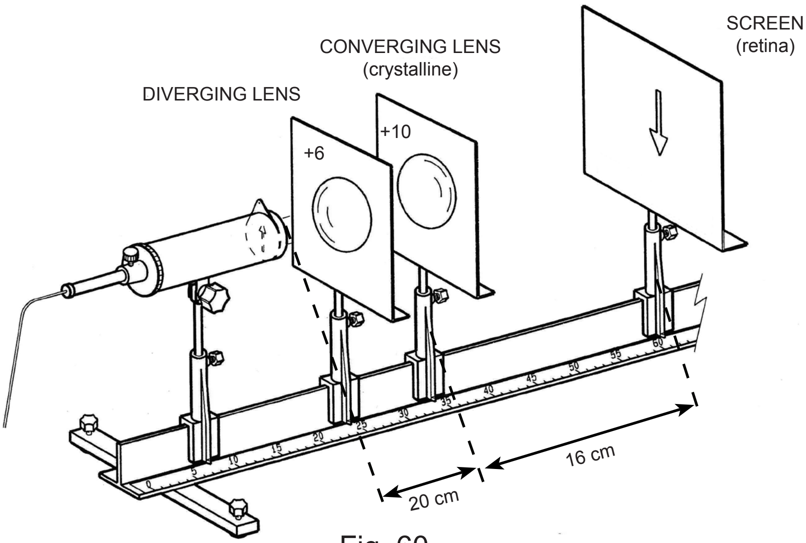


Fig. 60

22° THE COMPOUND MICROSCOPE

The optical instruments are devices that use mirrors, lenses, optical prisms and so on as components. They help the eyes in the vision of distant objects (spyglasses or telescopes), or very small (microscopes). They can also be used to project images and measure certain physical entities.

The compound microscope is an optical device that allows us to see very small objects magnified. It is composed essentially by two ***converging lenses***:
- ***the objective,*** close to the object to magnify;
- ***the eyepiece,*** close to the eye;

Its function is described in the following experiment.

EXPERIMENT N. 28

Required material: 1 optical bench; 1 projector; 1 projector power supply; 3 riders; 1 lens +10; 1 lens +6; 1 filters holder; 1 slide for microscope; 1 semi-transparent screen; 1 linear ruler.

After to have unmounted the diaphragm holder, mount the microscope slide with its holder on the projector (cod 4393). In front of the projector put now the converging lens +6 (objective).
Through the converging lens +10 (eyepiece) observe this image that is at less than 10 cm from the ground glass. It will appear even more enlarged.

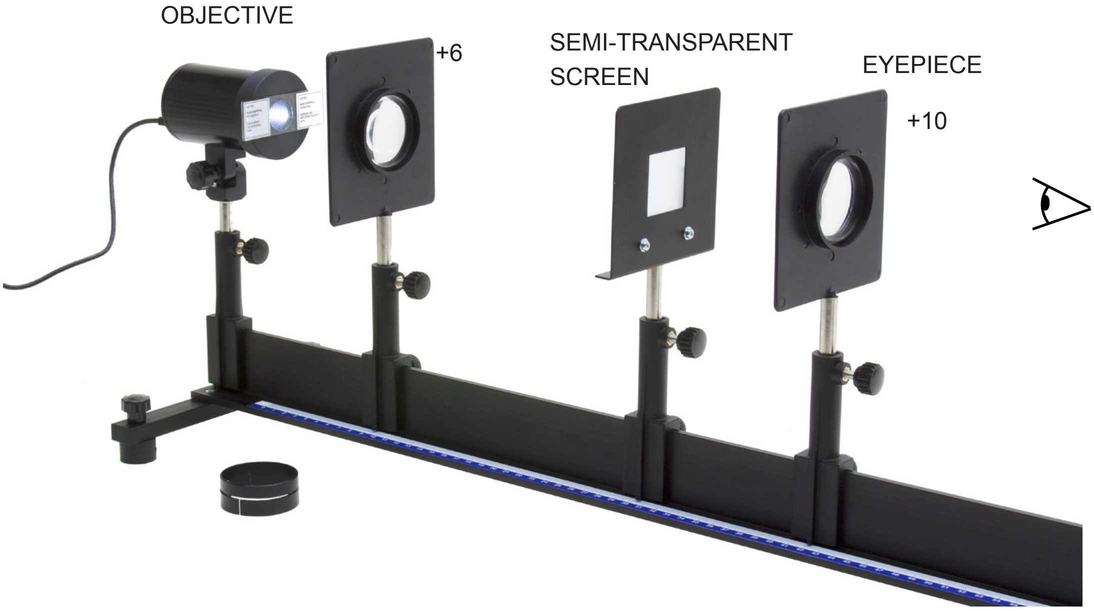


Fig. 61

Through the eyepiece you will see a larger object of the slide.

23° THE SLIDE PROJECTOR

The slide projector, also called diascope, is an optical instrument that allows to project the enlarged images of the slides on a screen.
In the following experiment we can discover how it works.

EXPERIMENT N. 29

Required material: 1 optical bench; 1 projector; 1 projector power supply; 3 riders; 1 lens +10; 1 filters holder; 1 white screen; 1 linear ruler; 1 slide.

After you have adjusted the position of the lamp in the projector in order to have a beam of parallel rays, prepare the device shown in figure 62 following the indicated distances.

Fig. 62

With little shifts, you can adjust the position of the length in order to obtain an image in focus on the screen.

- How far from the lens has the slide to be to have an enlarged image?
- In which position has the slide to be put so that the image is straight?