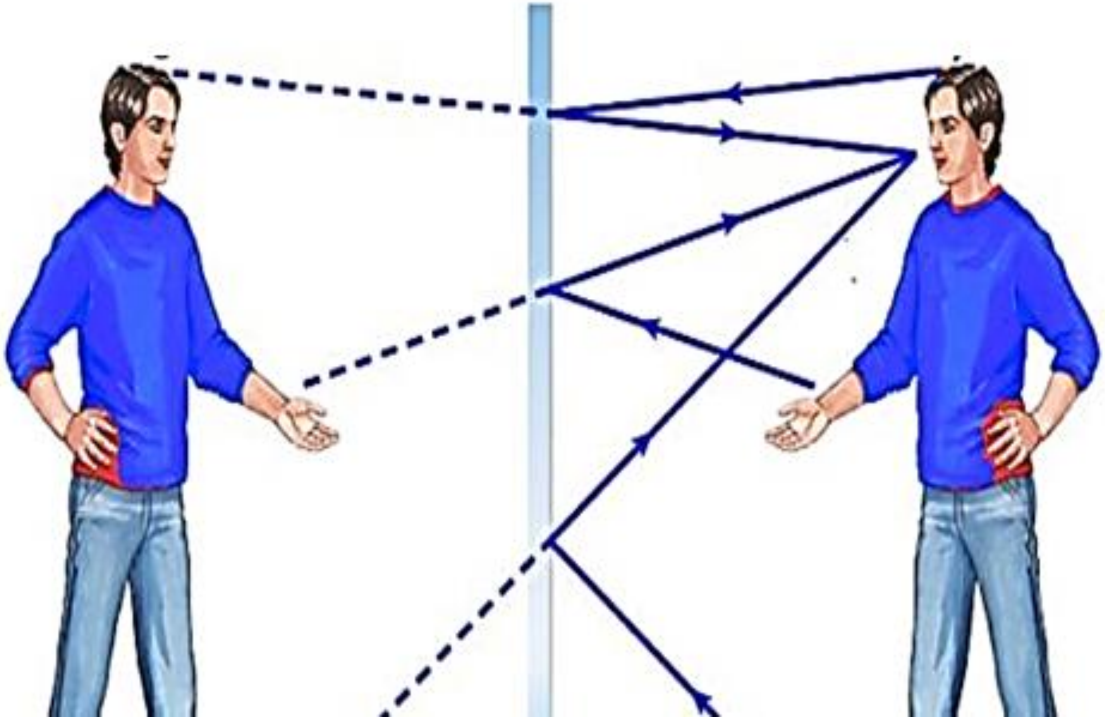



MIRRORS

MIRRORS

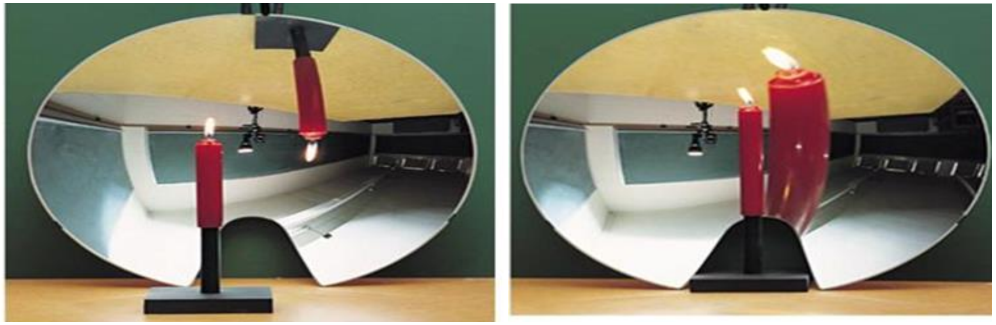
A mirror is a reflective surface that does not allow the passage of light and instead bounces it off, thus producing an image.

Depending on the shape of the reflecting surface mirrors can be

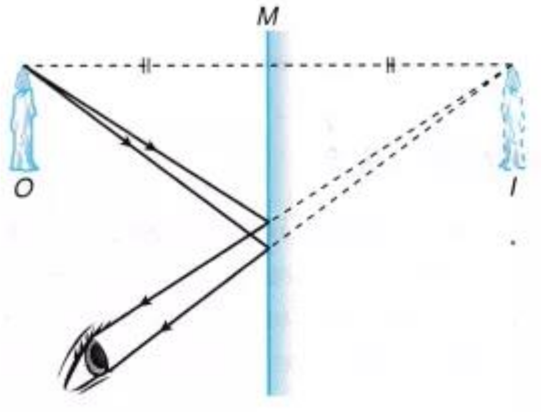
flat mirrors

spheric mirrors

A spherical mirror is a polished surface of a spherical segment reflecting light rays. A concave mirror is a spherical segment with the inner mirror surface, while a convex mirror has the outer mirror surface (picture 1).



Picture 1

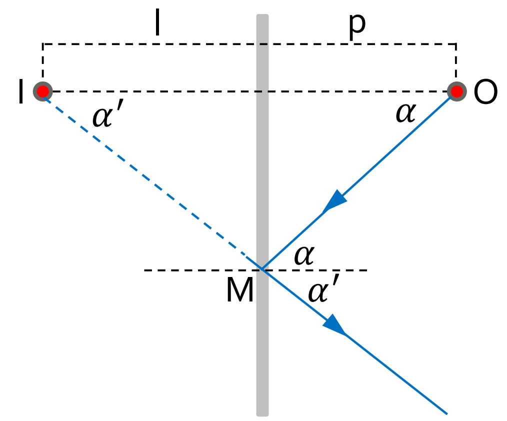


Picture 2

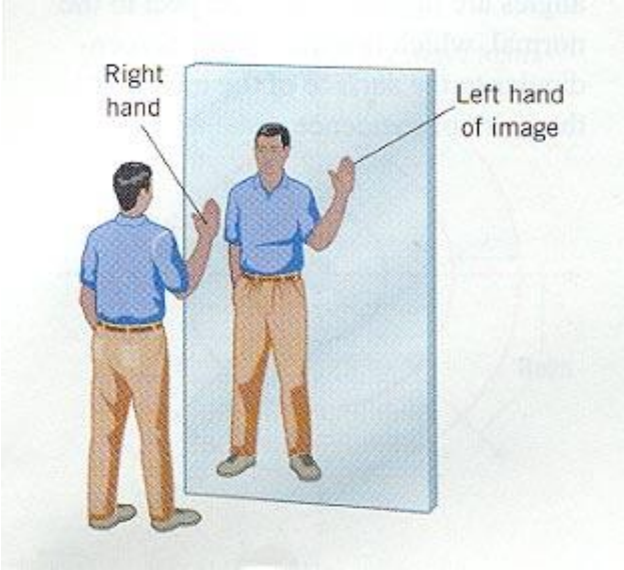
Images are classified as real or virtual. In the formation of a real image, light actually passes through the image point. For a virtual image, light doesn't pass through the image point, but appears to come (diverge) from there. The image formed by the flat mirror in picture 2 is a virtual image. In fact, the images seen in flat mirrors are always virtual (for real objects). Real images can be displayed on a screen (as at a movie), but virtual images cannot.

FLAT MIRRORS

Consider a point source of light placed at O in picture 3, a distance p in front of a flat mirror. The distance p is called the object distance. Light ray leave the source and are reflected from the mirror (at piont M).
After reflection, the ray diverge (spread apart), but they appear to the viewer to come from a point I behind the mirror. Point I is called the image of the object. Regardless of the system under study, images are formed at the point where rays of light actually intersect or where they appear to originate. Because the ray in the picture appear to originate at I, which is a distance behind the mirror, that is the location of the image. The distance l is called the image distance.



Picture 3



Picture 4

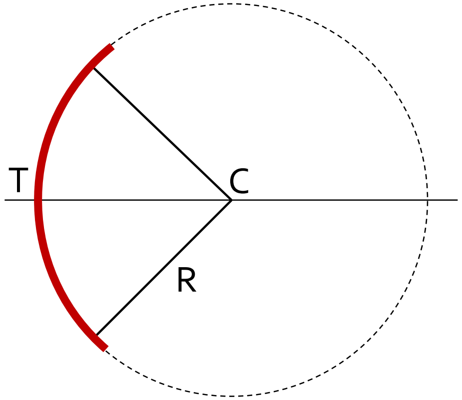
The image formed by a flat mirror has the following properties:
1. The image is as far behind the mirror as the object is in front.
2. The image is virtual, and upright. (By upright, we mean that if the object arrow points upward, so does the image arrow. The opposite of an upright image is an inverted image.)

Finally, note that a flat mirror produces an image having an apparent left–right reversal. You can see this reversal standing in front of a mirror and raising your right hand (picture 4). Your image in the mirror raises the left hand.

SPHERICAL MIRRORS

A spherical mirror, as its name implies, has the shape of a segment of a sphere.

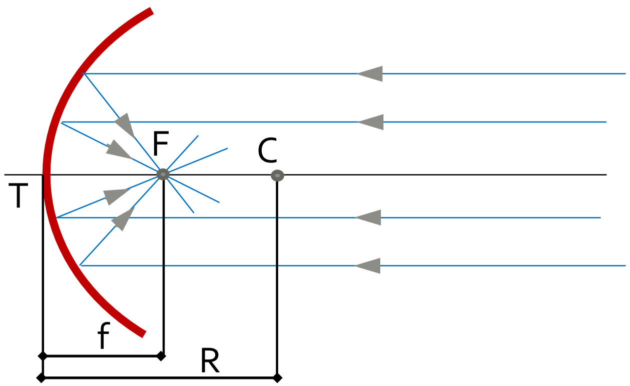
►CONCAVE MIRROR◄



Picture 5

Picture 5 shows a spherical mirror with a silvered inner, concave surface; this type of mirror is called a **concave mirror**. The mirror has radius of curvature *R*, and its center of curvature is at point *C*. The point *T* at the middle of the mirror is called its **pole.** and a line drawn from *C* to *T* is called the **principal axis** of the mirror.

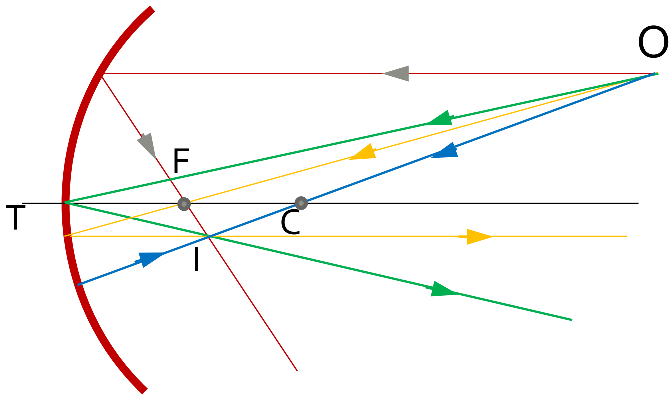
The rays passing in parallel to the principal optical axis are called **central rays** (picture 6). The point *F* at which rays parallel to the principal optical axis intersects it after having been reflected from the mirror is called the **focal point** (or **principal focus)** of the mirror. The focal point of a concave spherical mirror lies at the middle of the radius of the mirror, i.e. its focal length is $f = R/2$.



Picture 6

♦ Construction of image formed by a concave mirror ♦

The image of a point O formed by a spherical mirror is obtained graphically as the point of intersection of any two reflected rays or their continuations (picture 7).



Picture 7

Ray 1 (red) is an incident ray parallel to the principal optical axis. Having been reflected, it passes through the focal point.
Ray 2 *(yellow)* is an incident ray passing through the focal point. Having been reflected, the ray passes in parallel to the principal optical axis.
Ray 3 (blue) i s an incident ray passing through the centre of curvature of the mirror, i.e. along any auxiliary optical axis. Having been reflected, it returns along the same path since an optical axis is normal to the spherical surface of the mirror.

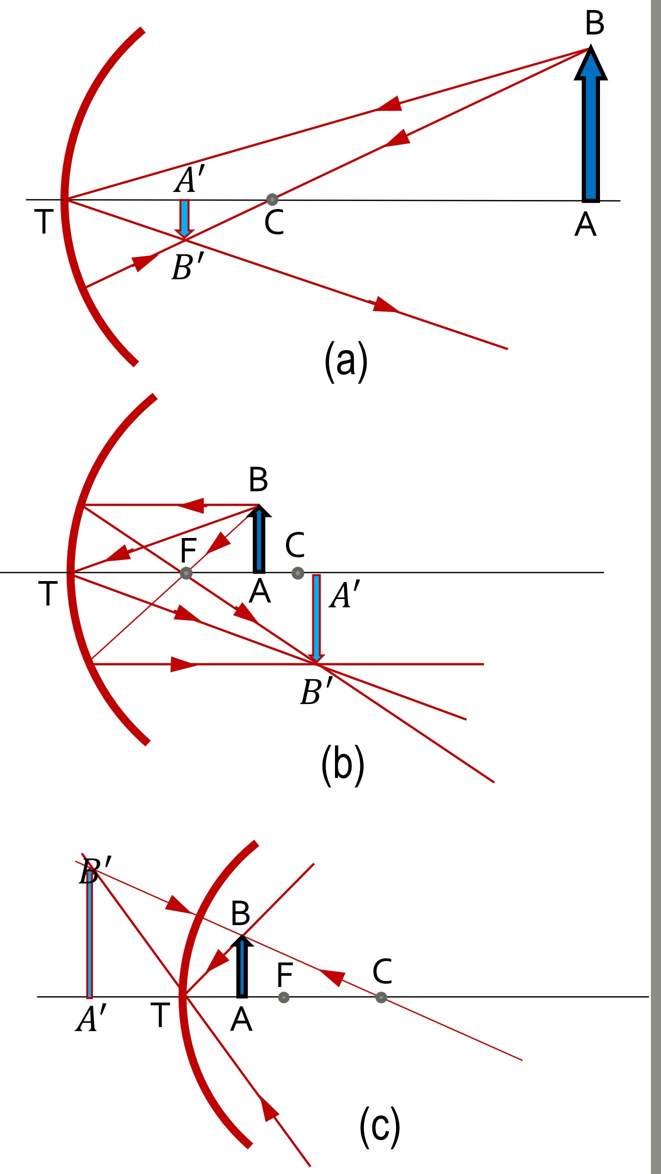
Ray *4 (green)* is an incident ray passing through the mirror pole. Having been reflected, it passes symmetrically about the principal optical axis. As has been mentioned above, it is sufficient to take any two of these rays to construct the image of a point formed by a spherical mirror.

The type and the position of the image of an object in a *concave spherical mirror* are mutually related:

1. An object *AB* is behind the centre of the mirror *(d* > 2f). The image $A'B'$ is real, reversed, and diminished, and lies between the mirror centre and pole of the mirror (picture 8-a).

2. An object *AB* is between the centre of the mirror and the focal point. The image $A'B'$ is real, reversed, and magnified, and lies behind the centre of the mirror (picture 8-b).

3. An object *A* is between the mirror and the focal point *(d* < *f).* The image $A'B'$ is virtual, erect, and magnified, and lies behind the mirror *(f* < 0) (picture 8-c).

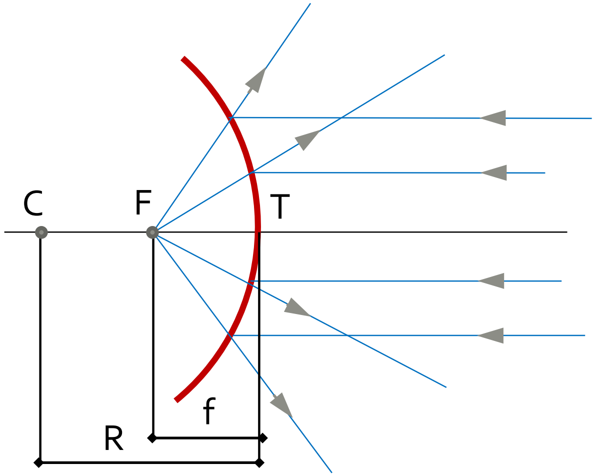


Picture 8

Problem: The picture shows a scene from a movie "Jurassic Park" in which T.rex is chasing after a jeep where we can see the reduced image of the dinosaur in the side-view mirror (picture 9). At the bottom of the mirror it is written: "Objects in mirror are closer than they appear".
The reason for the warning is that the images we see in the mirror are reduced in size so they seem to be farther away than they really are: a) plane; b) concave; c) convex?

Picture 9

►CONVEX MIRROR◄

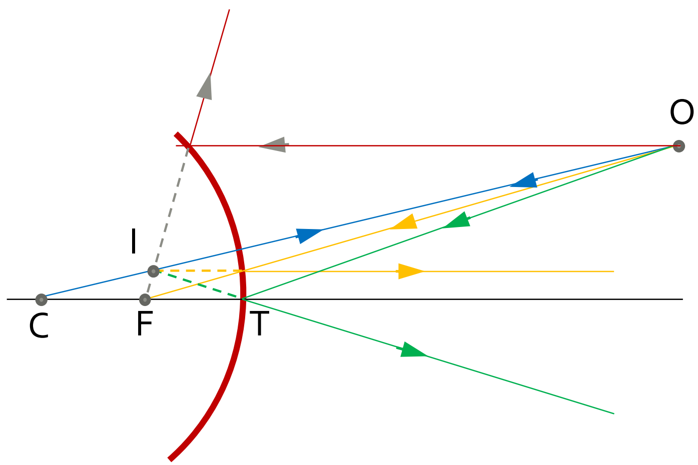


Picture 10

A **convex mirror** or **diverging mirror** is a curved mirror in which the reflective surface bulges toward the light source. Convex mirrors reflect light outwards, therefore they are not used to focus light. Such mirrors always form a virtual image, since the focal point (*F*) and the centre of curvature (*R*) are both imaginary points "inside" the mirror, that cannot be reached.
The focal point of a concave spherical mirror lies at the middle of the radius of the mirror, i.e. its focal length is negative and equal to $f = R/2$ (picture 10).

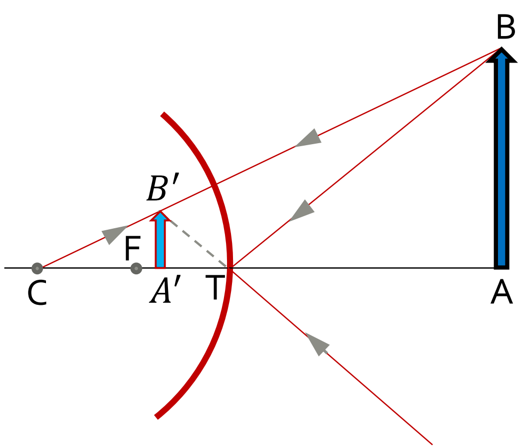
♦ Construction of image formed by a convex mirror ♦

The image of a point O formed by a convex mirror is obtained graphically as the point of intersection of any two continuations ray (picture 11)



Picture 11

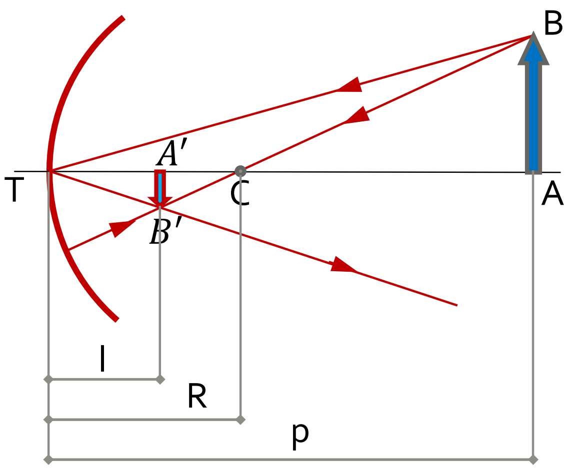
Ray 1 (red) An incident ray which is parallel to the principal axis is reflected as if it came from the virtual focus F of the mirror.
Ray 2 (yellow) An incident ray which is directed towards the virtual focus F of the mirror is reflected parallel to the principal axis.
Ray 3 (blue) An incident ray which is directed towards the centre of curvature C of the mirror is reflected back along its own path.
Ray 4 (green)) An incident ray passing through the mirror pole. Having been reflected, it passes symmetrically about the principal optical axis.



Picture 12

Picture 12 shows construction of image of object AB.
The image of an object formed by a convex spherical mirror Is always virtual, erect, and diminished.

THE MIRROR EQUATION



Picture 13

The mirror equation expresses the quantitative relationship between the object distance (p), the image distance (l), and the focal length (f).

Triangles ABT i $A'B'T$ are similar so it is valid: (picture 13):

$$\frac{AB}{A'B'} = \frac{AT}{A'T} \Rightarrow \frac{AB}{A'B'} = \frac{p}{l}$$

Triangles ABC i $A'B'C$ are again similar:

$$\frac{AB}{A'B'} = \frac{AC}{A'C} \Rightarrow \frac{AB}{A'B'} = \frac{p-R}{R-l}$$

$$\Rightarrow \frac{p}{l} = \frac{p-R}{R-l} \Rightarrow pR + Rl = 2pl$$

If the last equation is divided with plR, it is obtained:

$$\frac{1}{l} + \frac{1}{p} = \frac{2}{R}$$

This equation is the mirror equation for concave mirror:

$$\frac{1}{p} + \frac{1}{l} = \frac{1}{f}$$

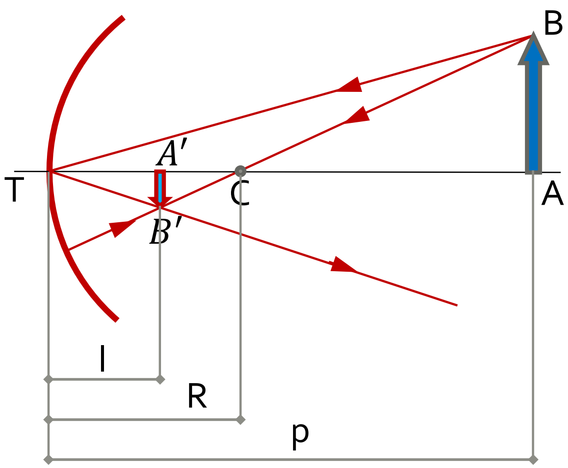
- If the object is between the mirror and focal point F then:

$$p < f \Rightarrow \frac{1}{p} > \frac{1}{f} \Rightarrow \frac{1}{l} = \frac{1}{f} - \frac{1}{p} < 0 \Rightarrow l < 0 \Rightarrow$$

A negative sign shows that the image is virtual.

For a convex mirror, only a virtual image can be formed, regardless of the object's location on the central axis, so the image distance(l) and focal length(f) should be take with sign -.

LATERAL MAGNIFICATION



Picture 14

The size of an object or image, as measured perpendicular to the mirror's central axis, is called the object or image *height.* Let *h* represent the height of the object, and h' the height of the image. Then the ratio h'/*h* is called the **lateral magnification** *m* produced by the mirror. However, by convention, the lateral magnification always includes a plus sign when the image orientation is that of the object and a minus sign when the image orientation is opposite that of the object.

For this reason, we write the formula for *m* as: $m = \frac{h'}{h}$

In picture 14 the object height is equal to AB, and the height of image is $A'B'$. Using similarity of triangles ABT and $A'B'T$ we can write:

$$\frac{AB}{A'B'} = \frac{p}{l}$$

Magnification produced by the mirror can be write:

$$\mathrm{m} = \frac{p}{l}$$

Magnification of the mirror can be larger, less or equal to 1.For a plane mirror, for which *p*=-*l*, we have *m*=*1*. The magnification of 1 means that the image is the same size as the object. The plus sign means that the image and the object have the same orientation. There is no unit of magnification as it is the ratio of two similar quantities.

PROBLEMS

1.An object 5cm high is placed at a distance of 60cm from the concave mirror. Find:
a) The position of the image if height of the image is 3cm?
b) The focal length of the mirror?

2.The virtual image of an object in a concave mirror is twice the size of the object. The distance between the object and the mirror is 15cm. Find the radius of curvature of the mirror?

3.A virtual image of half size is to be obtain in a convex mirror with a radius of curviture of 40cm. Where should the object be placed and where will the image be obtained?

4.A concave mirror forms 3 times enlarged real image of an object. Then the object is displaced 80cm (from initial position), and the new real image will be half size of an object. Find the focal length of the mirror?

5. A meterstick, 1m in length, lies along the optical axis of a convex mirror of focal length 40 cm, with its near end 60 cm from the mirror surface. Five-centimeter long toy figures stand erect on both the near and far ends of the meterstick.
a) How long is the virtual image of the meterstick?
b) How tall are the toy figures in the image, and are they erect or inverted?