Why the sky is blue

The way light scatters off molecules in the atmosphere explains why the sky is blue and why the sun looks red at sunrise and sunset. The molecules scatter light at the blue end of the visible spectrum much more than light at the red end of the visible spectrum. Scattering is a measure of the probability that light will interact with molecules when it passes through the atmosphere.

$$\text{Scattering} \propto \frac{1}{\lambda^4}$$

Violet light (λ = 400 nm) is almost 10 times as likely to be scattered than red light (λ = 700 nm).

1

Why the sky is blue

Why is the sky blue? When the Sun is high in the sky, some of the light that is not initially traveling towards us is scattered towards us by the molecules in the atmosphere. Most of this scattered light is from the blue end of the spectrum, so the sky appears blue.

So, why don't clouds appear blue?

2

Why clouds are not blue, but white

The water droplets in clouds are much larger than the molecules in the atmosphere, and they scatter light of all colors equally. This makes them look white.

Why does the sun look white in mid-day, but red at sunset?

3

Why the sun is red at sunset?

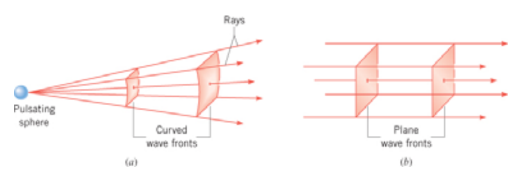
When the Sun is high in the sky, sunlight passes through a thin layer of atmosphere, so only a small fraction of the light is scattered. The Sun looks yellow-white because the colors are represented almost equally. At sunrise or sunset, sunlight has to pass through much more atmosphere to reach our eyes. Along the way, much of the light towards the blue end of the spectrum is scattered in other directions, but much less of the light towards the red end of the spectrum is scattered out of the beam, making the Sun appear orange or red.

4

Reflection

5

Waves from a Distant Source

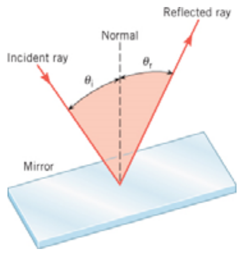


At large distances from the source, (i) the wave fronts become less and less curved and (ii) the directions of travel of the waves (as indicated by the direction of the "rays" above) become essentially parallel. <u>All our discussions about reflection assumes this large-distance limit of the waves.</u>

6

Law of Reflection

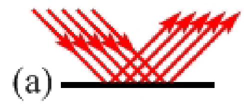
(i) The incident ray, the reflected ray, and the normal to the surface all lie in the same plane, and
(ii) the angle of incidence equals the angle of reflection.



7

Specular Reflection

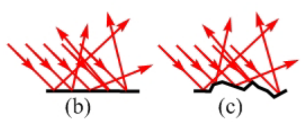
For reflective surface such as that of flat mirrors, which is so smooth that any hills or valleys on the surface are smaller than the wavelength of light, the law of reflection applies on a large scale (i.e., over a large area). All the light traveling in one direction and reflecting from a flat (or plane) mirror is reflected in one direction; reflection from such objects is known as specular reflection.



8

Diffuse Reflection

Most objects exhibit diffuse reflection, with light being reflected in all directions, as in (b) below. Reason: All objects obey the law of reflection on a microscopic level, but if the irregularities on the surface of an object are larger than the wavelength of light (as illustrated in (c)), which is usually the case, the light reflects off in all directions.



9

Image Formed by a Plane Mirror

Procedure to determine the position of the image by a **ray diagram**:
(1)Choose one point on the object (usually the point at the top of the object) and draw two rays emanating from it.
(2)Use law of reflection to determine the reflected rays.
(3)Extrapolate the reflected rays to the back of the mirror. The point where the extrapolated rays intercept is the location of the image.
(4)Notice how the reflected rays that reach the eye "appear" to emulate from the image but actual they are not. Such an image is a virtual image. Later we will see cases where the rays actually emulate from an image. Those images are real images.

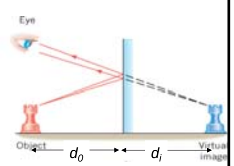


Image Formed by a Plane Mirror (cont'd)

The image formed by a plane mirror has four properties:

1. It is upright.
2. It is formed behind the plane mirror. That is, the image is virtual (or imaginary). One characteristic of a virtual image is that we cannot record it with a photographic plate or project it on a screen.
3. It has the same size as the object. That is, magnification, m = (image size)/(object size) = 1.
4. The image is as far behind the mirror as the object is in front of it. That is, image distance, d_i = object distance, d_o.

One can show that magnification = d_i/d_o. So properties 3 and 4 are equivalent.

11

Example I

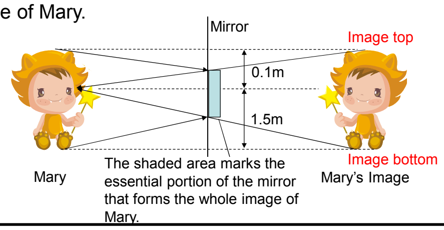
Mary has a mirror that is 1 m long and she is 1.6 m tall. She finds that if she hangs the mirror too high or too low on the wall, she can't see the whole image of herself. What is the maximum and minimum distance above ground she may position the lower edge of the mirror in order for her to see her whole image? Assume that her eyes are 0.1 m below the top of her head.

12

Hanging a mirror

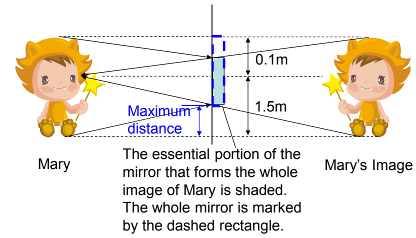
Solution

Draw Mary and the mirror. Then draw her image at the same distance behind the mirror as Mary is in front of the mirror. Next, trace the rays from her image's top and the image's bottom that will reach (the real) Mary's eyes. The points where these two rays intercepts the mirror (in the middle between Mary and her image) defines the essential portion of the mirror responsible for forming the whole image of Mary.



13

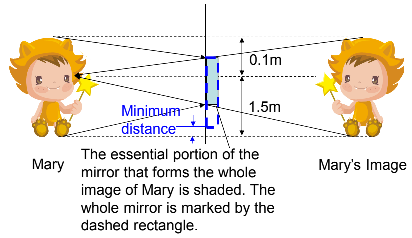
Highest point of the mirror's lower edge



From the drawing, one can see that the lower edge of the "essential portion" of the mirror is 0.75 m (= 1.5 m/2) above ground. This is the maximum distance the mirror's lower edge can have above ground.

14

Lowest point of the mirror's lower edge



Next, we recognize that the upper edge of the "essential portion" of the mirror is 1.55 m (= 1.5 m + 0.1 m/2) above ground. When the upper edge of the mirror is aligned with this point, the lower edge of the mirror has the minimum distance above ground and given by (1.55 m – length of the mirror) = 1.55 m – 1 m = 0.55 m.

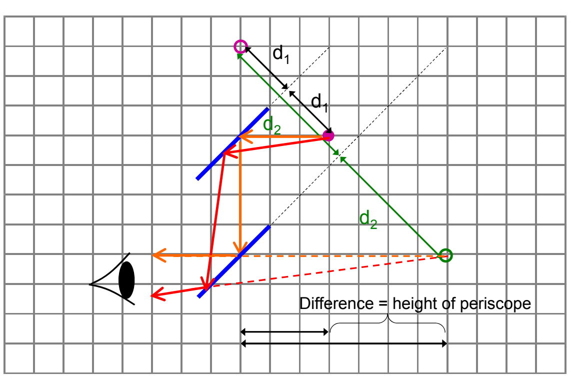
15

Periscope

A periscope is an optical device used in a submarine to enable surveying of what is at the surface of the water. It is consisted of two parallel plane mirrors making 45^o to the horizontal plane. Draw a ray diagram to show how an image is formed in a periscope.

16

Periscope

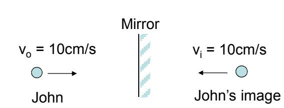


Walking towards a mirror

John is trying a new shirt. To see how the shirt fits him more clearly, he walks towards a mirror. If John's speed is 10 cm/s, what is the direction and speed by which his image moves relative to him?

Solution

Distance of John's image from him is the distance is two times his distance from the mirror, d_i. This is due to the law of reflection, $d_i = d_o$ (*). As John walks towards the mirror, his image moves towards the mirror, too. So the direction of his image's motion is opposite to John's. Equation (*) also means that $v_i = |\Delta d_i/\Delta t| = |\Delta d_o/\Delta t| = v_o$. That is, the speed of John's image relative to the mirror should be the same as John's. So the speed of John's image relative to John is 10cm/s – (-10cm/s) = 20 cm/s.



18