HUMAN EYE AND COLORFUL WORLD

SCATTERING EFFECT

SCATTERING OF LIGHT

This is the phenomenon in which light is deflected from its path due to its interaction with the particles of the medium through which it passes . Basically, the scattering process involves the absorption of light by the molecules followed by its re-radiation in different directions.

Scattering represents basically change in the direction of light. As sunlight travels through the earth's atmosphere, it gets scattered by the large number of molecules and numerous small particles present in atmosphere.

If A = amplitude of incident light

l = wavelength of incident light

V = volume of the scattering particle

a = amplitude of scattered light at a distance r from the scattering particle

$$a = \frac{AV}{r\lambda^2}$$

As intensity of scattered light (I_S) varies directly as square of amplitude of scattered light (A^2) therefore

$$I_s \propto \frac{1}{\lambda^4}$$

intensity of scattered light varies as the fourth power of the wavelength of incident light.

Important factor in scattering is relative size of the wavelength of light (l) and the scatterer (of typical size, say x)

For x << l Rayleigh's scattering is valid i.e. when size of scatterer is much smaller than wavelength of light $I_s \propto \frac{1}{\lambda^4}$ this is called **elastic scattering**

For x >> l Rayleigh scattering is not valid and all wavelengths are scattered nearly equally.

This is called **inelastic scattering**

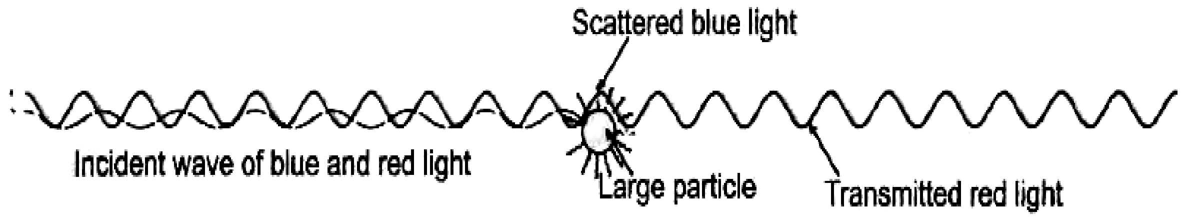
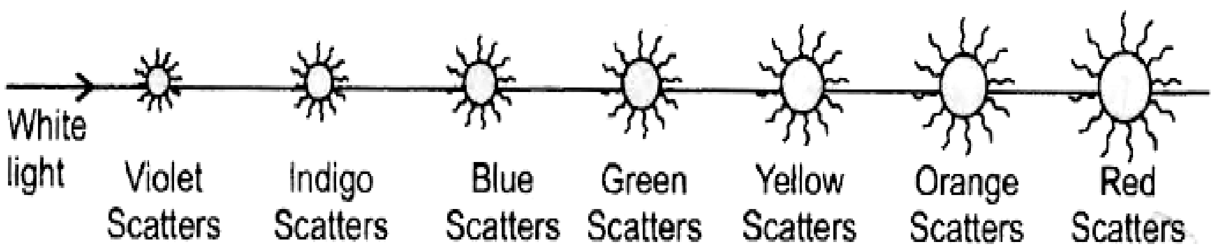


Figure shows a large particle whose diameter is greater than the wavelength of the blue light, but smaller than the wavelength of red light. Now, when a mixture of red and blue light is made incident on such a particle, then the blue light is absorbed by the particles and then transmitted in all possible directions, i.e., the blue light is scattered. The red light, however, continues moving straight as it is not absorbed or scattered.

Now, if your eyes receives scattered blue light, then the particle will appear blue in colour to you.

When the white sunlight enters the atmosphere of earth, the particle size is smallest. Thus, the violet light which has the smallest wavelength in white light scatters.



From the above statement it does not imply, that all the violet waves present in sunlight scatter. Instead it means that if **only a particular ray, which strikes a particle, whose diameter is greater than the wavelength of violet light gets scattered**. From this it follows that quite a large number of rays of white sunlight will reach us without scattering.

As the white light continues its journey through the atmosphere, the number and particle size present in the air increase. This results in the scattering of indigo and blue wavelengths. If the white light travels through longer distance through atmosphere, as during sunset or sunrise than even yellow, orange and red scatter. The red light has wavelength 1.8 times the wavelength of violet light, and hence, scatters last of all.

1 Tyndall effect

The earth's atmosphere is a heterogeneous mixture of minute particles. These particles include smoke, tiny water droplets, suspended particles of dust and molecules of air. When a beam of light strikes such fine particles, the path of the beam becomes visible. The light reaches us, after being reflected diffusely by these particles. **The phenomenon of scattering of light by the colloidal particles gives rise to Tyndall effect**. This phenomenon is seen when a fine beam of sunlight enters a smoke-filled room through a small hole. Thus, scattering of light makes the particles visible. Tyndall effect can also be observed when sunlight passes through a canopy of a dense forest. Here, tiny water droplets in the mist scatter light.

2 Some Common Phenomena of atmospheric scattering (Applications in Daily Life)

Some phenomena occurring in nature are explained on the basis of scattering of light.

(i) Sky would appear black in daytime if earth had no atmosphere:

If earth had no atmosphere, then there would be no gas present in the atmosphere. Since there is no scatterer in the atmosphere of the earth, so there will be no scattering of light. Hence, the sky would appear dark as there is not scattering of light.

When the earth had no atmosphere, sunlight would be visible only if we look directly at the sun. Even stars will be seen in day time in the absence of the earth atmosphere.

(ii) Why is the colour of clear sky blue?

Blue colour of sky is due to scattering of sunlight, light from the sun, while travelling through earth's atmosphere, gets scattered by large number of molecules in the earth's atmosphere.

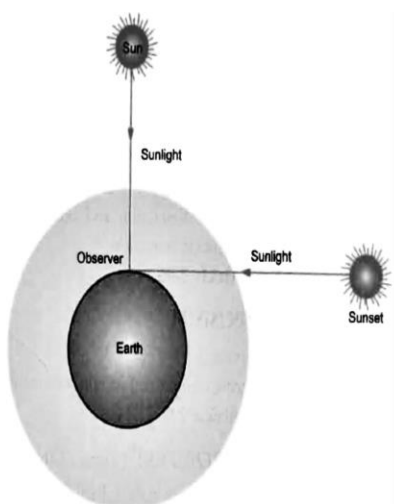
As x << l Rayleigh's scattering is valid.

The intensity of scattered light varies inversely as the fourth power of wavelength of light.

As blue color has a shorter wavelength than red. therefore blue color is scattered much more strongly. Hence the sky looks blue.

(iii) Why sunset and sunrise are Red?

At the time of sunrise or sunset, the position of the sun is very far away from us. The sunlight travels longer distance through the atmosphere of the earth before reaching our eyes. Scattering of blue light is more than the scattering of red light. As a result of this, more red light reaches our eyes than any other colour. Hence sunset and sunrise appear red.
During noon, the sun is overhead and sunlight travels less distance through the earth's atmosphere to reach our eyes. In this case, the scattering of almost all colours is very small. Hence the sun appears white.
However, as the sun rises up the horizon, the distance travelled by sunlight in the atmosphere decreases and hence, yellow, orange or red light are not scattered. Thus, sky appears blue & the sunlight yellowish.



(iv) Why clouds are white?

The clouds are at much lower height. They are seen due to scattering of light from lower parts of the atmosphere which contains large dust particles water droplets ice particles etc. In this case size of scatterer x >> l Therefore all wavelengths are scattered nearly equally All colours scattered equally merge to give us the sensation of white. Hence clouds generally appear white. **"This is termed as mie scattering".**

(v) Danger Signals are of red colour?

When light falls on the signal, all colours are scattered much more than that of red colour. So the red colour suffering least scattering remains confined around the signal, which in turn illuminates the signal significantly. Thus the danger signals can be seen from very far off distances. Moreover, among all colours, red light is scattered least by smoke or fog. Hence, red signals are visible even through the smoke or fog.

Note :

The red light has largest wavelength among the spectral colours, and hence, is least scattered. Thus, red light can easily pass through for mist or smoke without getting scattered, and hence, is visible from long distance. Thus it is used as universal danger signal.

Ex. Why does the sky appears dark instead of blue to an astronaut?

Sol. In space no particles are present. Thus, no scattering of light takes place. Hence, the sky appears dark as light by its own nature is invisible, but produces us the sensation of vision.

CONCEPT MAP