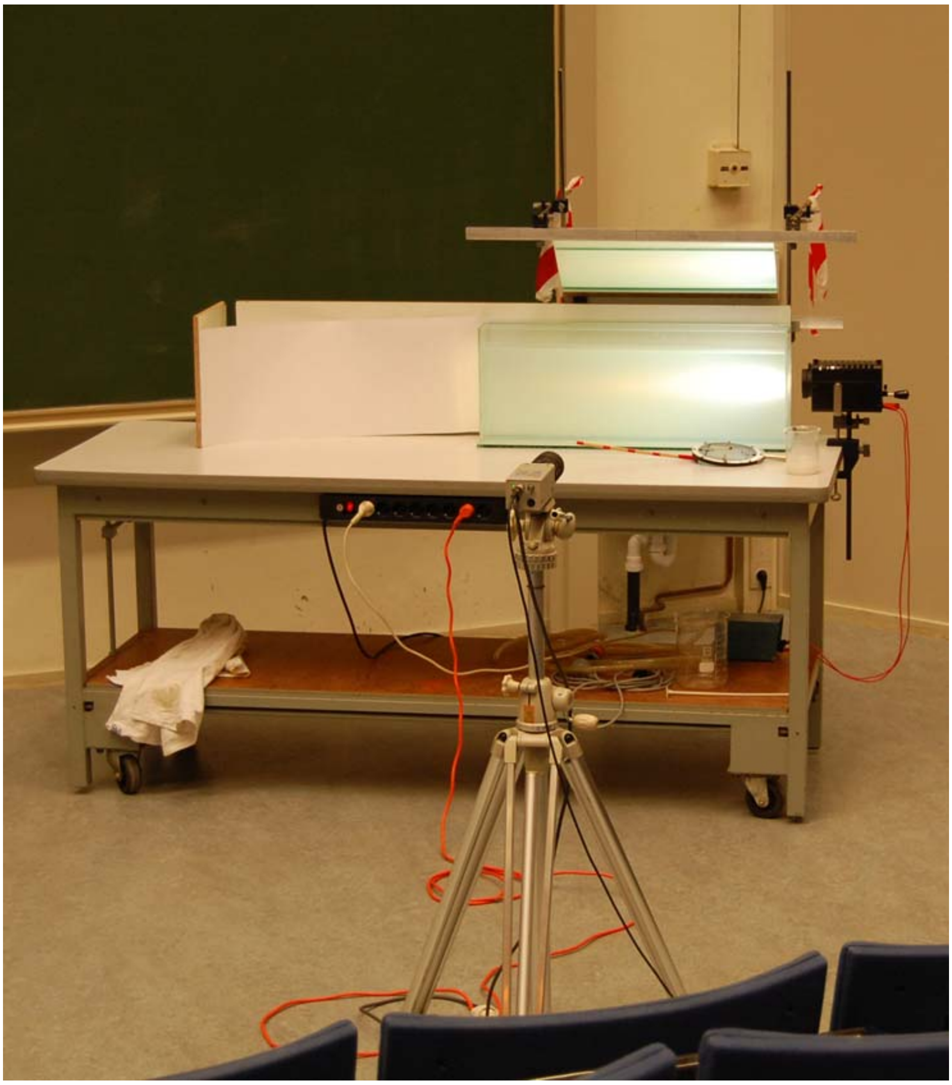
Scattering of light

Aim:

- To show Rayleigh scattering of light.
- To show frequency dependence and polarization in scattering.

Subjectcode: 6F40 (Scattering)

Diagram:



Equipment:

- Glass water tank ($80 \times 30 \times 10 cm^3$).
- Mirror (we use: $57 \times 39 cm^2$).
- Lamp, halogen 12V/90W, and transformer 220-12V.
- Polaroid sheet, a stick connected to it to show the direction of the E-vector.
- A little milk.
- Camera.

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Presentation: Build the set-up as shown in Diagram and in the side view of Figure 1.

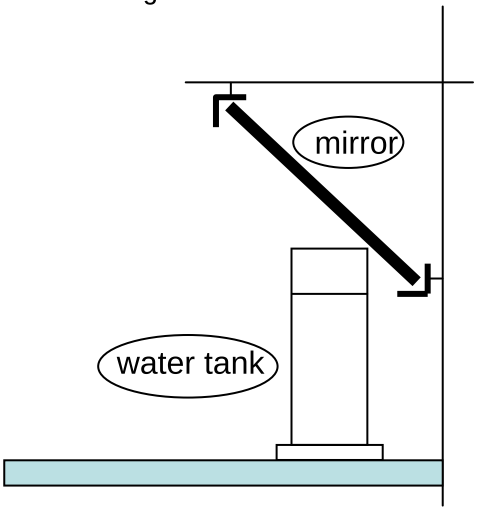

Figure 1

Part 1:

The lamp is switched on and a very bright light spot is observed on the paper behind the water tank (see Figure 2).

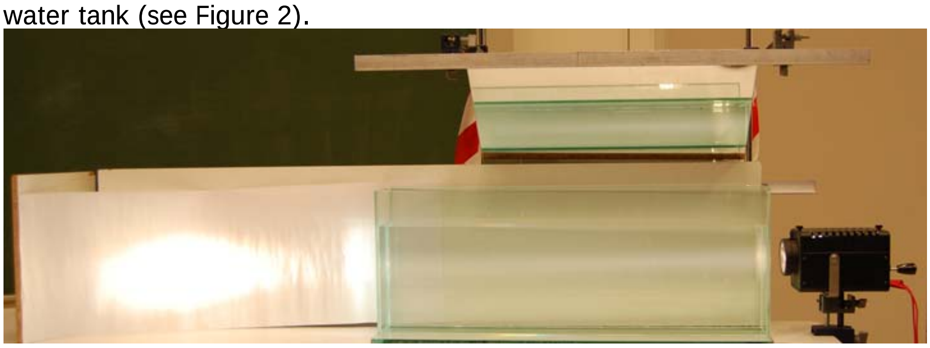

Figure 2

There is almost no reflection of light from the water, nor forward, towards the audience, nor upwards towards the mirror.

A little milk is poured into the water tank. Now a reflection form the water is clearly observed (Figure 3): there is a reflection in the forward and upward direction.

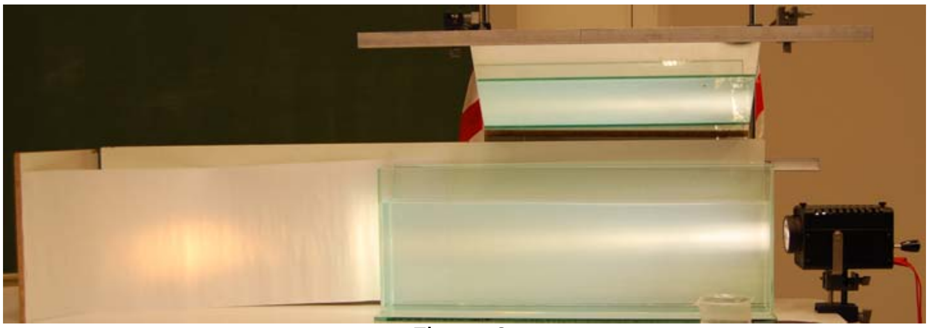

Figure 3

The transmitted light as seen on the paper has a lower intensity now and shows an orange-reddish colour. The scattered light towards us has a bluish haze (not really visible in our picture).

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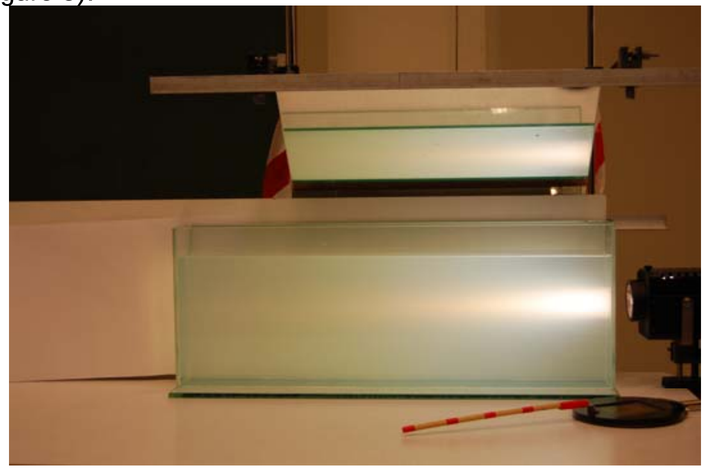
Pouring still more milk into the water tank intensifies the phenomenon (Figure 4).

Figure 4

The transmitted light is clearly red now.

Part 2:

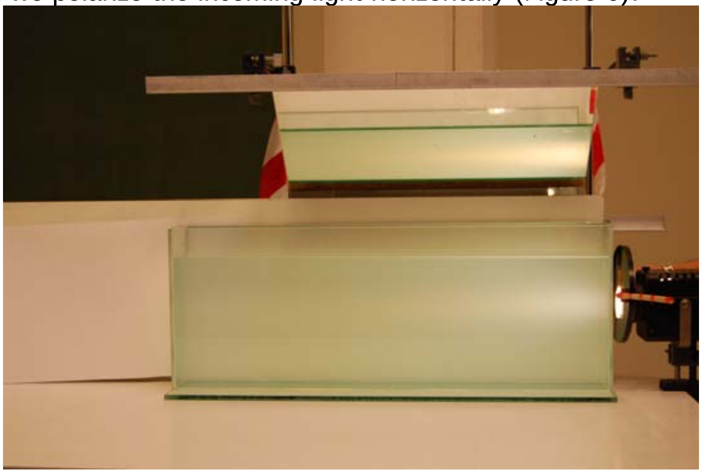
We observe that with this normal light (randomly polarized), the two reflections. (Figure 5).



no polarization

Figure 5

Then we polarize the incoming light horizontally (Figure 6):



horizontally polarized

Figure 6

The forward scattering from the water tank disappears.

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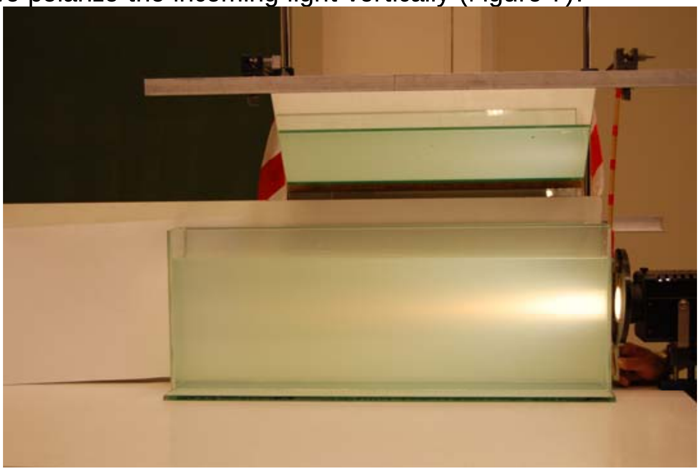
Next we polarize the incoming light vertically (Figure 7):



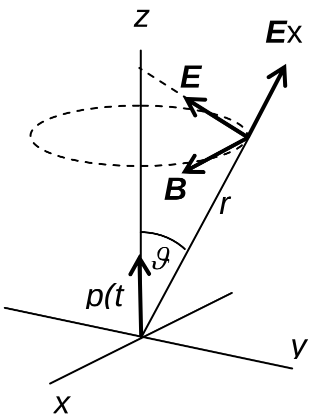
vertically polarized

Figure 7

The upward scattering from the water tank disappears.

Explanation: The light entering the water tank hits the “milk molecules”. These molecules can be considered as tiny dipoles who will oscillate when hit by light. This oscillation is the whitish light we see as a beam in the milky water.

For the intensity of the light produced by this dipole oscillation we can write:



$$I(\vartheta) = \frac{p_0^2 \omega^4}{32\pi^2 \varepsilon_0 c^3} \frac{\sin^2 \vartheta}{r^2}$$

Figure 8

<u>Explanation for **part 1**:</u>

We see the ω^4 -dependence, so the light emitted by the oscillating milk molecules is much more intense in the blue light then in the red light (supposing a factor 2 in frequency between these two colours means a factor 16 in difference in intensity).

<u>Explanation for **part 2**:</u>

When the milk molecule oscillates in the vertical direction (as in Figure 8) there is no intensity emitted into the vertical direction (along the vertical line you see no oscillation). At the same time the intensity into the horizontal direction is maximum. This is what we have seen in the demonstration of Figure 7. the demonstration of Figure 6 is explained in a similar way.

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Remarks:

- Fill the water tank at least a day before the actual demonstration. Because time is needed for air bubbles to collect and small dirt particles to deposit. Otherwise these air bubbles and dirt particles will show as reflections: the water is not clear and an undesired reflection of the light beam is observed. (This was the situation when we made the picture of Figure 2. After one night, the reflection that is seen there, has disappeared and the water shows clear!)
- Just pour a very little milk into the water tank. Very soon it is too much.

Sources:

- Hecht, E. Optics , third edition, pag. 63-66 and 85-90.
- Sutton, Richard Manliffe, Demonstration experiments in Physics, 1938, pag. 424.
- Giancoli, D.G., Physics for scientists and engineers with modern physics, third edition, pag. 911.