Lambert's law of radiation on optical base plate

Physics | Light & Optics | Dispersion of light

Difficulty level	Group size	Preparation time	Execution time
-	-	-	-

This content can also be found online at:

http://localhost:1337/c/5f0ec6e1b6127b000304478d

General information

Application

A softbox diffuser

The amount of light reflected by an object, and how it is reflected, is highly dependent upon the smoothness or texture of the surface. In the real world, most objects have convoluted surfaces that exhibit a diffuse reflection, with the incident light being reflected in all directions. Diffuse reflection is used to form ambient lighting applications, such as frosted glass bulbs. Ideal diffuse reflection results in equal luminance in all directions at the half-plane adjacent to the surface, known as Lambertian reflectance.

Basically diffuse light can be easily obtained by reflecting light from a white surface. In photography, lighting diffusers that are made of white nylon or polyester, are used to spread the light or to soften the light on the scene being shot.

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Other information (1/2)

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Prior knowledge

Diffuse reflection can be defined as the type of reflection of light where scattering happens at many angles and not just at one angle.

Scientific principle

The illumination of a surface at any point is proportional to the cosine of the angle between the normal at the point and the direction of the luminous flux.

Other information (2/2)

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Learning objective

The diffuse reflection of a sheet of paper is examined according to Lambert's law of radiation in relation to characteristic emission of radiation.

Tasks

Measure the voltage of the photocell as a function of the corresponding angle.

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Safety instructions

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For this experiment the general instructions for safe experimentation in science lessons apply.

The generally applicable rules for handling lasers according to the ANSI and IEC Laser Classification must be considered.

Theory (1/2)

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The emission characteristic of a diffusely reflecting surface O is determined by the fact that every surface element dO scatters incident light uniformly in all directions. This is the case, e. g., for a sheet of paper consisting of a large number of thin and transparent cellulose fibres.

As the beam density *L* of a diffusely reflecting surface is constant, to the observer, the total surface O appears to have the same luminosity whatever direction it is being looked at from. In the figure, it can however be seen, that the apparent surface which is seen by the observer varies with the angle of observation ϕ. In the boundary case, $\phi = 90^\circ$ the apparent surface vanishes and thus also the irradiation *E* perceived by the observer.

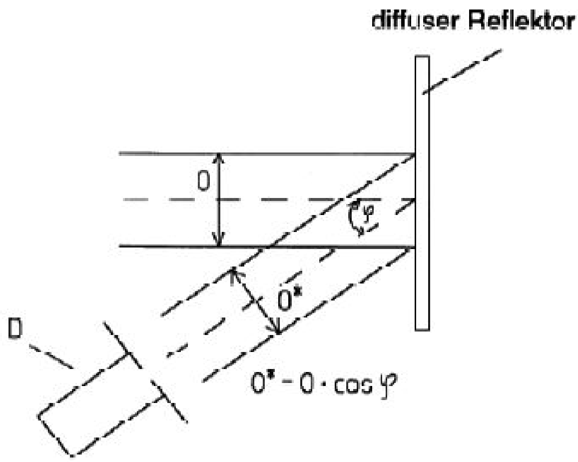

Diagram of the principle of measurements with the used magnitudes (with O* as apparent magnitude of surface O)

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Theory (2/2)

As photocell LD only can ”see” a small angle with its slit orifice, and as the receiving surface remains constantly at the same distance and perpendicular to the direction of observation during the whole measurement, influences due to the used reception surface may be neglected in the present case (that is, the radiation intensity *E* of the photocell is proportional to beam intensity I of the reflecting surface).

In general, Lambert’s cosine law is valid for the reflecting surface:

$$I = L \cos \phi . O$$

where I: beam intensity and *L*: beam density (=constant). Under the given circumstances, one then obtains the following relation of proportionality:

$$E(\phi) \propto \cos \phi$$

Irradiance intensity *E* is proportional to the measured voltage *U* of the photocell.

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Equipment

Position	Material	Item No.	Quantity
1	Optical base plate 450 x 600 mm	08750-00	1
2	He-Ne Laser, 632 nm, 1 mW, linear polarised	08182-93	1
3	Adjusting support 35 x 35 mm	08711-00	2
4	Surface mirror 30 x 30 mm	08711-01	2
5	Magnetic foot for optical base plate	08710-00	5
6	Lensholder for optical base plate	08723-00	2
7	Lens, mounted, f +100 mm	08021-01	1
8	Diaphragm holder for optical base plate	08724-00	1
9	Rotational guide rail with angular scale	08717-00	1
10	Photoelement	08734-00	1
11	PHYWE Universal measuring amplifier	13626-93	1
12	Digital multimeter, 600V AC/DC, 10A AC/DC, 20 MΩ, 200 µF, 20 kHz, −20°C… 760°C	07122-00	1
13	Connecting cord, 32 A, 500 mm, red	07361-01	2
14	Accesory set for optical base plate	08750-50	1

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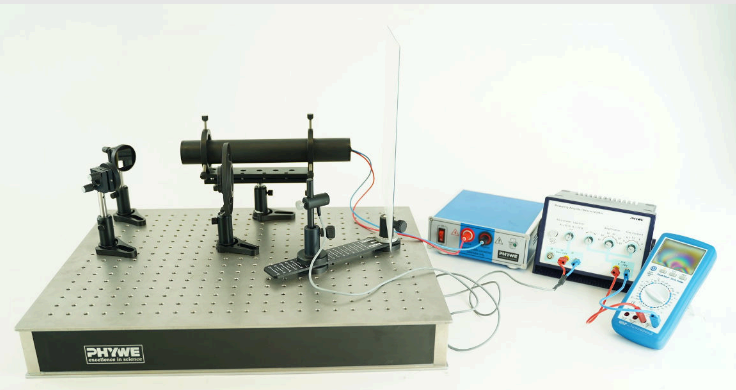
Setup and procedure

Setup (1/3)



Experimental set-up

- The recommended set up height (height of beam path) should be 130 mm. A sheet of paper is inserted in the diaphragm support.
- The laser beam is adjusted with the mirrors M1 and M2 in such a way that it impinges perpendicularly on the surface of the paper and on the rotation axis of the rotating guide rail.

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Setup (2/3)

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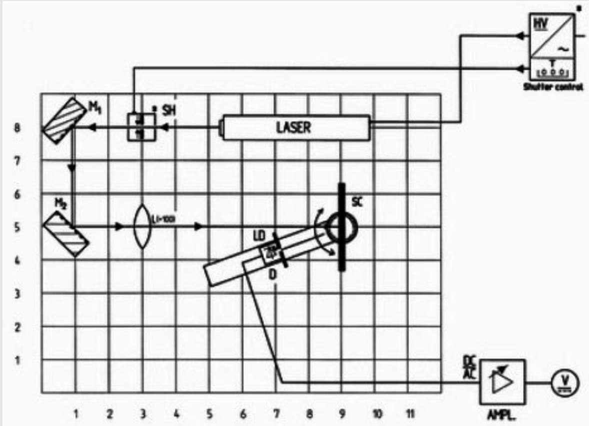
- Light intensity is measured as a function of the angle by means of photocell LD on the rotating guide rail. The smallest adjustable angle ϕ which can be comprehended between the perpendicular to the surface of the paper (that is, the direction of incidence of the laser beam) and the direction of the detector is 15°.
- After the laser has warmed up for about half an hour, the experiment should be carried out in a darkened room, in order to keep luminous intensity constant.



Drawing of the experimental set up

Setup (3/3)

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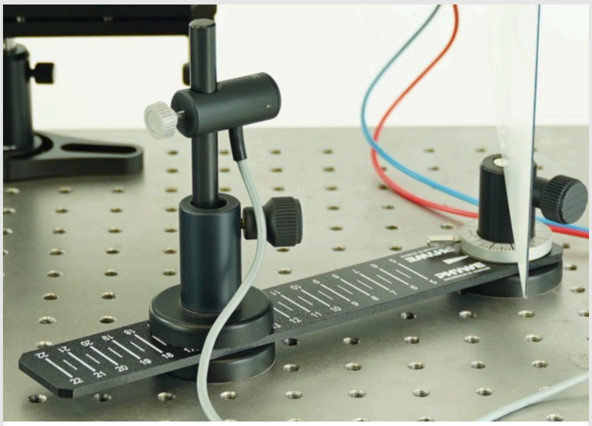
Set up of the rotating unit:

- To begin with, the stop screw of a magnet foot is removed. The circular orifice of the rotating guide rail is pushed over the foot. Furthermore, the angular scale is set over the magnet foot, above the rotating guide rail. The magnet foot is fastened to the optical base plate, the rotating guide rail being sufficiently mobile.
- Photocell LD can then be set at the centre of the rotating guide rail by means of a magnet foot. Angular distribution should be sensible when set up is made on the optical base plate, that is, the 0° scale line should point in the direction of the incident laser beam.



Set up of the rotating unit

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Procedure

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- At the beginning of measurement, an adequate amplification is selected on the universal measurement amplifier (voltage should not be higher than the maximum output voltage of 10 V).
- The laser beam is interrupted and zero adjustment is carried out on the universal measurement amplifier.
- Angle is adjusted between 15° and 80° in steps of 5° with the assistance of the rotating guide rail and the angular scale. The corresponding intensities (or respectively voltages $U(\phi)$) are measured. The measurement should be repeated several times under the same conditions and voltages should be averaged.

Evaluation (1/3)

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$\phi/^\circ$	U/V	$\frac{U(\phi)}{U(15^\circ)}$	$\frac{\cos\phi}{\cos(15^\circ)}$
15			
20			
25			
30			

Voltage $U(\phi)$ as a function of angle at the photocell, with corresponding angular adjustments ϕ

- Measure the voltage U of the photocell for the corresponding angle ϕ.
- Plot a graph of the normalised value of the measured voltage $\frac{U(\phi)}{U(15^\circ)}$ against the normalized value of the angular adjustments $\frac{\cos\phi}{\cos(15^\circ)}$ for the confirmation of Lambert's law.

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Evaluation (2/3)

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Lambert's Law of Radiation explain that:

When a surface is radiated by a light, the ______ of certain idealized optical sources is proportional to the ______ of the angle between the illuminating source and the normal. When observing the source ______ to the source's surface, $\cos\theta = 1$ and $I(\theta)$ is ______. When observing the source obliquely, $\cos\theta < 1$ and $I(\theta)$ is approaching ______ as θ approaches 90°.

- cosine
- zero
- radiant intensity
- maximal
- perpendicular

Check

Evaluation (3/3)

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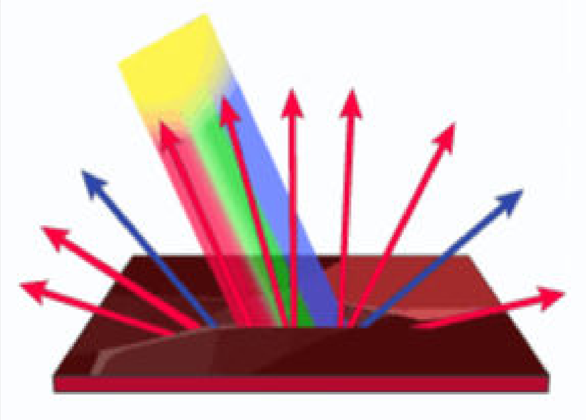
What are the properties of Lambertian reflectance?

- [ ] Its luminance appears the same from any angle of view
- [ ] Scattering happens at many angles and not just at one angle
- [ ] Its radiance depends on the viewer's angle

Check



Diffuse reflection according to Lambert's Cosine Law

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Slide	Score / Total
Slide 15: Lambert's Law of Radiation	**0/5**
Slide 16: Lambertian's Law	**0/2**

Total Score 0/7

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