Related topics

luminous flux, light quantity, light intensity, illuminance, luminance.

Principle and task

Visible light impinges on a diffusely reflecting surface. The luminance of this surface is determined as a function of the angle of observation.

Equipment

Housing for experiment lamp	08129.01	1
Halogen lamp, 12 V/50 W	08129.06	1
Holder G 6.35 f. 50/100 W halo.lamp	08129.04	1
Double condenser, f 60 mm	08137.00	1
Lens holder	08012.00	1
Lens, mounted, f +200 mm	08024.01	1
Zinc sulfide screen	08450.00	1
Right angle clamp -PASS-	02040.55	4
Tripod base -PASS-	02002.55	1
Barrel base -PASS-	02006.55	1
Stand tube	02060.00	1
Support rod, stainl.steel, 100 mm	02030.00	1
Support rod -PASS-, square, l 250 mm	02025.55	1
Support rod -PASS-, square, l 1000 mm	02028.55	1
Articulated radial holder	02053.01	1
Graduated disk, f. demonstration	02053.02	1
Universal clamp with joint	37716.00	1
Power supply 0-12V DC/6V, 12V AC	13505.93	1
Lux meter, hand-held	07137.00	1
Measuring module lux	12107.00	1

Problems

1. The luminous flux emitted reflected by a diffusely reflecting surface is to be determined as a function of the angle of observation.
2. Lambert's law (cos-law) is to be verified using the graph of the measurement values.

Set up and procedure

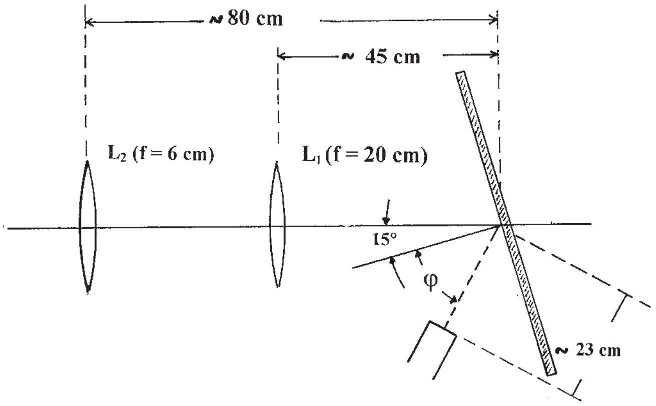
The stand tube is introduced into the articulated radial holder, which is fitted with an angular scale, until it goes no further. The articulated radial holder is then attached to the tripod base, after which the tripod rods are clamped each with an edge facing upward. The luxmeter probe is attached to the short support rod using the universal clamp in such a way that it points to the pivoting centre whilst being aligned with the rod. The rest of the set up is shown in Fig. 1. The distances of the components from the pivot centre are shown in Fig. 2.

On the luminous screen, the surface of which is directed perpendicularly to the optical axis to start with, a circular surface (∅ approx. 6 cm) with a sharp edge is uniformly illuminated by shifting lens L_1 and the lamp holder. The screen is then turned so that a line perpendicular to its surface forms an angle of 15° with the optical axis. The luxmeter probe now points towards the centre of the circle.

The luxmeter should be calibrated before carrying out the actual measurement. Luminous intensity is measured for angular steps of 5°–10°, keeping the screen stationary. For every step, the residual background light must be measured with the lamp switched off and the obtained value taken into account for evaluation.

Fig. 1: Experimental set-up: Lambert's law.

Fig. 2: Schematic sketch of component positions.



Due to its rough surface, the zinc-sulphide screen provides a practically ideal diffuse reflecting Lambert source.

Theory and evaluation

A punctual light source which has a luminous intensity I (Candela/cd) emits a light flux (Lumen/lm) throughout the spatial angle. Luminous intensity within a spatial angle element $d\omega$ is:

$$I = d\Phi / d\omega \quad [\text{ cd }] \qquad (1)$$

For extended light sources(also such which are not luminous by themselves, but reflecting) the following relation is valid if luminance is called B

$$B = dI / dA \quad [\text{ cd/cm}^2] \qquad (2)$$

If a surface dA* is illuminated by a light beam with flux $d\Phi$, illuminance E (Lux/lx) is:

$$E = d\Phi / dA^* \; [\text{ lx }] \qquad (3)$$

The luminance of a surface which reflects diffusely and uniformly in all directions (Lambert-Reflector) in the direction of an angle φ against the normal to the surface is given by the following relation (Fig.3):

$$B = dI_\varphi / dA' = dI_\varphi / dA \cos\varphi = dI_0 \; / dA \qquad (4)$$

Thus:

$$dI_\varphi = dI_0 \; \cos\varphi \qquad (5)$$

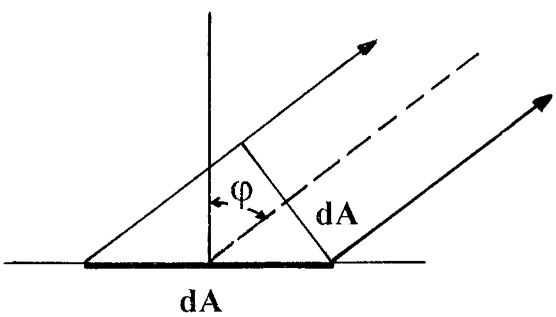
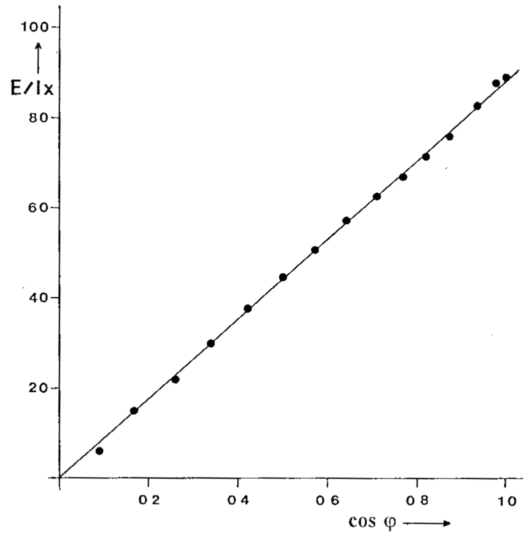


Fig. 3: Dependence between luminance and direction of observation.

Fig. 4: Illuminance as a function of cos φ.



According to (1), the luminous flux is proportional to cos φ within a spatial angle (Lambert's law). According to (3), this also is valid for the illuminance, which can be determined by means of a luxmeter.

Fig.4 shows the measured illuminance values E as a function of cos φ. Linearity is the verification of Lambert's law.

If the illuminance values are plotted as intensity vectors in a polar co-ordinate system against $\varphi* = 90° - \varphi$ (Fig.5), then the extremities of the vectors are located on a circle with centre co-ordinates ($\rho = E_0 /2$; $\varphi* = 90°$).

Note: circle with radius R and centre (x = 0; y = R/2)

$x^2 + (y - R)^2 = R^2$

Transformation to polar co-ordinates with

$x = \rho \cos \varphi*$ and $y = \rho \sin \varphi*$

$\rho = 2 R \sin \varphi*$, with $\varphi* = 90° - \varphi$ yields

$\rho = 2 R \cos \varphi$

With $2R = E_0$ and $\rho = E$, Fig.5 is verified.

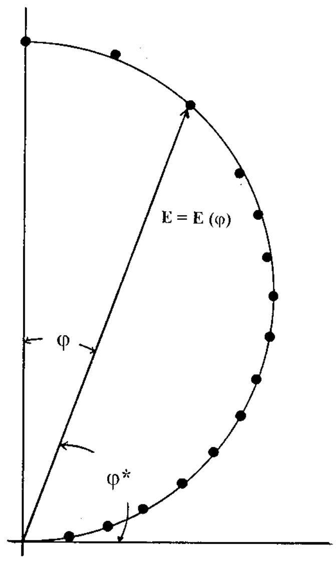


Fig. 5: Illuminance as a function of $\varphi*$ in polar co-ordinates.