Photometric law of distance - inverse square law

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/5f45a2879a658b00033e0335

General information

Application

Photometer

The applications of photometry can be found in:

- Chemistry: to measure the amount of organic or inorganic material in a solution, to determine nutrients in soils and so on.
- Astronomy: to determine characteristics and brightness of stars and other celestial bodies.

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Other information (1/2)

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Prior knowledge

The solid angle is a measure of the space around the light source, which is by the ratio of the spherical surface to the square of it radius $\Omega = \frac{A}{r^2}$.

Scientific principle

The luminous intensity emitted by a punctual source is determined as a function of distance.

Other information (2/2)

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Learning objective

The luminous intensity is a function of the distance of the light sensor from the light source. The law for point light sources on which this is based should be determined.

Tasks

1. The luminous intensity emitted by a punctual source is determined as a function of distance from the source.
2. The photometric law of distance is verified by plotting luminous intensity as a function of the reciprocal value of the square of the distance.

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Safety instructions

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

Theory (1/3)

A punctual light source of luminous intensity (Candela/cd) emits a light flux Φ (Lumen/lm) throughout a solid angle ω . The luminous intensity in a solid angle element $d\omega$ results to

$$I = \frac{d\Phi}{d\omega}\,[cd]$$

For luminous sources extended in space (also such which emit no light by themselves, but which are reflecting), luminance B is given by :

$$B = \frac{dI}{d\alpha}\,[\frac{cd}{cm^2}]$$

If an area dA^* is illuminated by a luminous flux $d\Phi$, illuminance E (Lux/lx) is given by:

$$E = \frac{d\Phi}{dA^*}\,[lx]$$

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Theory (2/3)

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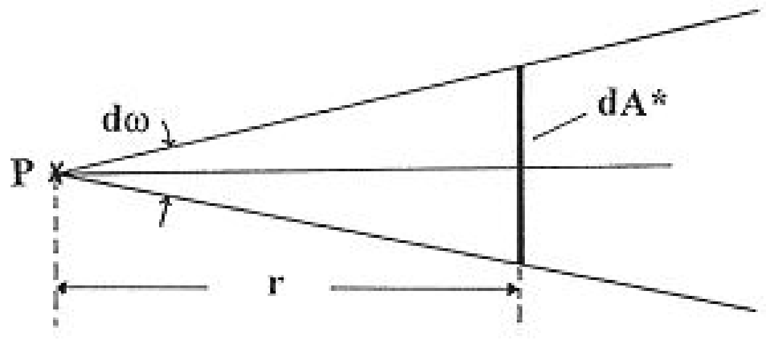

Schematic determination of the photometric law of distance

Figure gives a schematic representation of the illumination of a surface element dA^* through a punctual light source *P*. The luminous intensity of the source is $I$and its distance from the surface element is *r*, the line perpendicular to the surface element points in the direction of the connecting line with the light source.

Theory (3/3)

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The illuminance *E* is given by:

$$E = \frac{d\Phi}{dA^*} = \frac{d\Phi/d\omega}{d\omega/dA^*}\ .$$

With $d\omega = dA^*/r^2$ one obtains the equation:

$$E = \frac{I}{r^2}$$

This equation describes the photometric law of distance. According to this, the illuminance *E*of a surface decreases proportionally to the square of distance *r*for a constant luminous intensity *I*.

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Equipment

Position	Material	Item No.	Quantity
1	Cobra SMARTsense - Motion, 0,2 ... 2 m (Bluetooth + USB)	12908-01	1
2	Cobra SMARTsense - Light, 1 ... 128 kLx (Bluetooth + USB)	12906-01	1
3	measureLAB, multi-user license	14580-61	1
4	Lamp holder E 14,on stem	06175-00	1
5	Filament lamp 6V/5A, E14	06158-00	1
6	PHYWE Power supply, 230 V, DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A	13506-93	1
7	Stand tube	02060-00	1
8	Barrel base expert	02004-00	2
9	Scale for demonstration board	02153-00	1
10	Bench clamp expert	02011-00	1
11	Screen, metal, 300 x 300 mm	08062-00	1
12	Holder for Cobra SMARTsense	12960-00	2
13	USB charger for Cobra SMARTsense and Cobra4	07938-99	2
14	Support rod, stainless steel, l = 250 mm, d = 10 mm	02031-00	2
15	Right angle clamp expert	02054-00	2
16	Support rod,stainl.steel, 100mm	02030-00	1

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Additional equipment

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Position	Material	Quantity
1	PC/Android tablet or iPad	1

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Setup and procedure

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Setup (1/3)

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Experimental setup

Set up the equipment as shown.

Align the filament of the lamp such that it faces the Cobra SMARTsense-light. Adjust the sensor in such a manner that it remains oriented towards the lamp's filament when moved. Both of them must be mounted at the same height above the table.

Use one of the two support bases to set up the lamp.

Setup (2/3)

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Cobra SMARTsense - Light

Use the second support base to attach the Cobra SMARTsense "Light" horizontally, facing the lamp.

The initial separation between the lamp and the sensor should be approximately 15 cm. In favour to do so, place the stand tube of the lamp with its end on the one meter marking and place the end of the sensor stand tube 15 cm away.

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Setup (3/3)

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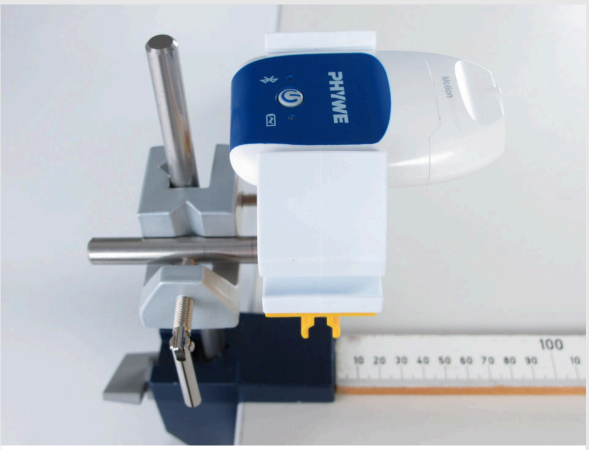

Cobra SMARTsense - Motion

Clamp the CobraSMARTsense - motion at the end of the table.

Darken the room or shield the experiment from direct sunlight.

Procedure

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Switch on the Cobra SMARTsense "Light" by pressing the power button. Start the PHYWE measureLAB and ensure that Bluetooth is activated on the device. Choose the sensor "Light" in the sensor list and light intensity (E) as the measured value. Set 'distance' as the measured value on x-axis.

To measure the path with the motion sensor, place the light sensor in the initial position (15 cm away from lamp filament). For instance, if the motion sensor gives a value of 0.70 m you would change the value to 0.85 (0.75 m + 0.15 m) to obtain the distance between the light sensor and the lamp.

Start the measurement by pressing on and move slowly (about 0.5 cm/s) the light sensor along the meter scale away from lamp filament. At a distance of approximately 70 cm you can terminate the measurement by pressing stop, as the luminous intensity has now become very low and in addition the diffuse light fraction is relatively large.

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Evaluation (1/4)

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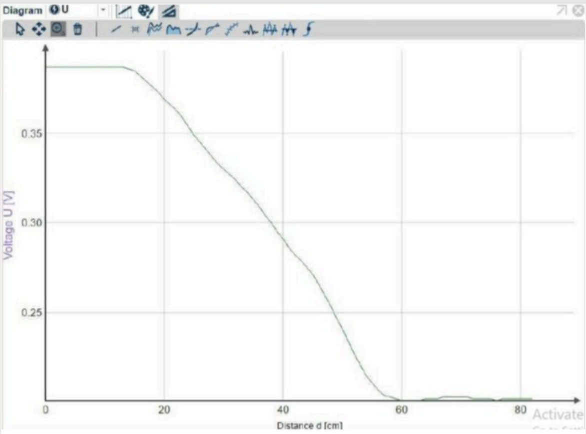

Luminous intensity as a function of distance

The luminous intensity is plotted as a function of actual distance between the lamp filament and sensor.

Evaluation (2/4)

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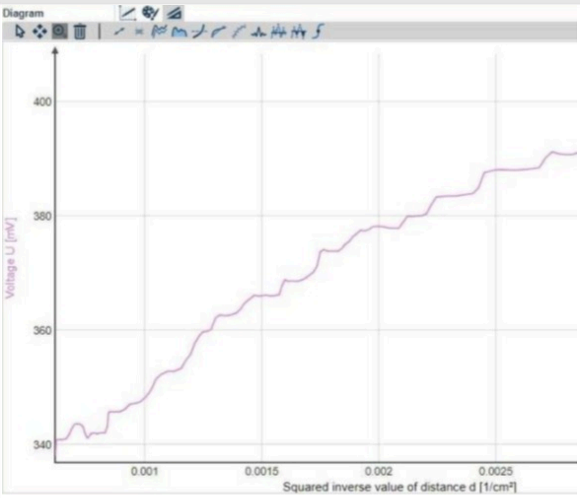

Luminous intensity versus one over squared distance *d*

For further analysis of the inverse value:

- Create a channel conversion of the squared inverse value. Simply drag your measured values for distance *d* into the Data pool and type in the formula. Select the generated squared inverse value and your measured luminous intensity values.
- Choose the option diagram to plot the inverse value against the luminous intensity. In the displayed diagram, select the inverse value as x-axis.

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Evaluation (3/4)

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Fill in the blanks:

Luminous intensity is defined as the amount of emitted ______ throughout ______ in the direction. Since the surface area of a sphere is ______ to the square of the radius, the illuminated area ______ as it gets farther from the source. Hence, the luminous intensity is ______ proportional to the square of the distance between the surface and source.

- solid angle
- increases
- luminous flux
- proportional
- inversely

Check

Evaluation (4/4)

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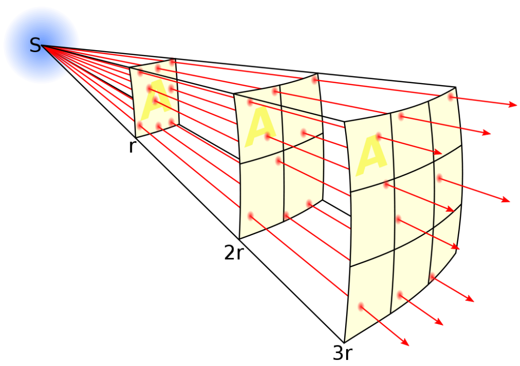
The illumination of a surface depends upon:

- [ ] the direction
- [ ] the illuminating power of light source.
- [ ] distance of the surface from source.

Check



Inverse-square law

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Slide	Score / Total
Slide 18: Luminous flux	**0/5**
Slide 19: Illumination of a surface	**0/3**

Total Score 0 / 8

Show solutions

Retry

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