Related topics

Luminous flux, quantity of light, luminous intensity, illuminance, luminance, use of an interface.

Principle and task

The illumination intensity depends on the distance between the detector and the light source. It is based on the law for punctual light sources, which is to be deduced.

Equipment

COBRA-interface 2	12100.93	1
PC COBRA data cable RS232, 2 m	12100.01	1
Movement sensor with cable	12004.10	1
Adapter, BNC-socket/4 mm plug pair	07542.27	1
Adapter, BNC socket - 4 mm plug	07542.20	1
Softw. COBRA Rotation (Win)	14295.61	1
Right angle clamp -PASS-	02040.55	1
Stand tube	02060.00	3
Distributor	06024.00	1
Barrel base -PASS-	02006.55	2
Bench clamp -PASS-	02010.00	1
Plate holder	02062.00	1
Meter scale, demo. l = 1000 mm	03001.00	1
Silk thread, 200 m	02412.00	1
Weight holder for rim apparatus	02407.00	1
Slotted weight, 10 g, black	02205.01	2
PEK photo diode / 33 f 2 /	39119.01	1
PEK carbon resistor 1 W 5 % 22 Ohm	39104.59	1
Filament lamp 6V/5A, E14	06158.00	1
Lamp holder E 14, on stem	06175.00	1
Power supply, universal	13500.93	1
Connecting cord, 2000 mm, red	07365.01	1
Connecting cord, 2000 mm, blue	07365.04	1
Basic Softw. f. PHYWE Windows prog.	14099.61	1

PC, WINDOWS® 3.1 or later

The PHYWE WINDOWS® Basic Software (14099.61) must have been installed once on the used computer for the software to work.

Set-up

– According to Fig. 1, the thread is wound once over the smaller of the two thread grooves. The cable of the movement recorder is connected to the COBRA interface according to Fig. 2. The photodiode is connected to the resistor and to the analogue input 3 of the COBRA interface, as shown in Fig. 3.

– At the beginning of measurement, the distance between the photodiode and the filament of the light bulb is 0.1 m.

Procedure

– According to whether the COBRA interface is connected to the computer port COM 1 or to COM 2, "CH3(x)_COM1" or "CH3(x)_COM2" is started by clicking twice on the icon.

– Press the ⟨Start⟩ button. The sampling rate can be modified by shifting the ⟨Delta t/ms⟩ slide. For every used computer, there is a maximum sampling rate. If the sampling time is

Fig. 1: Experimental set-up: Photometric law of distance with PC interface.
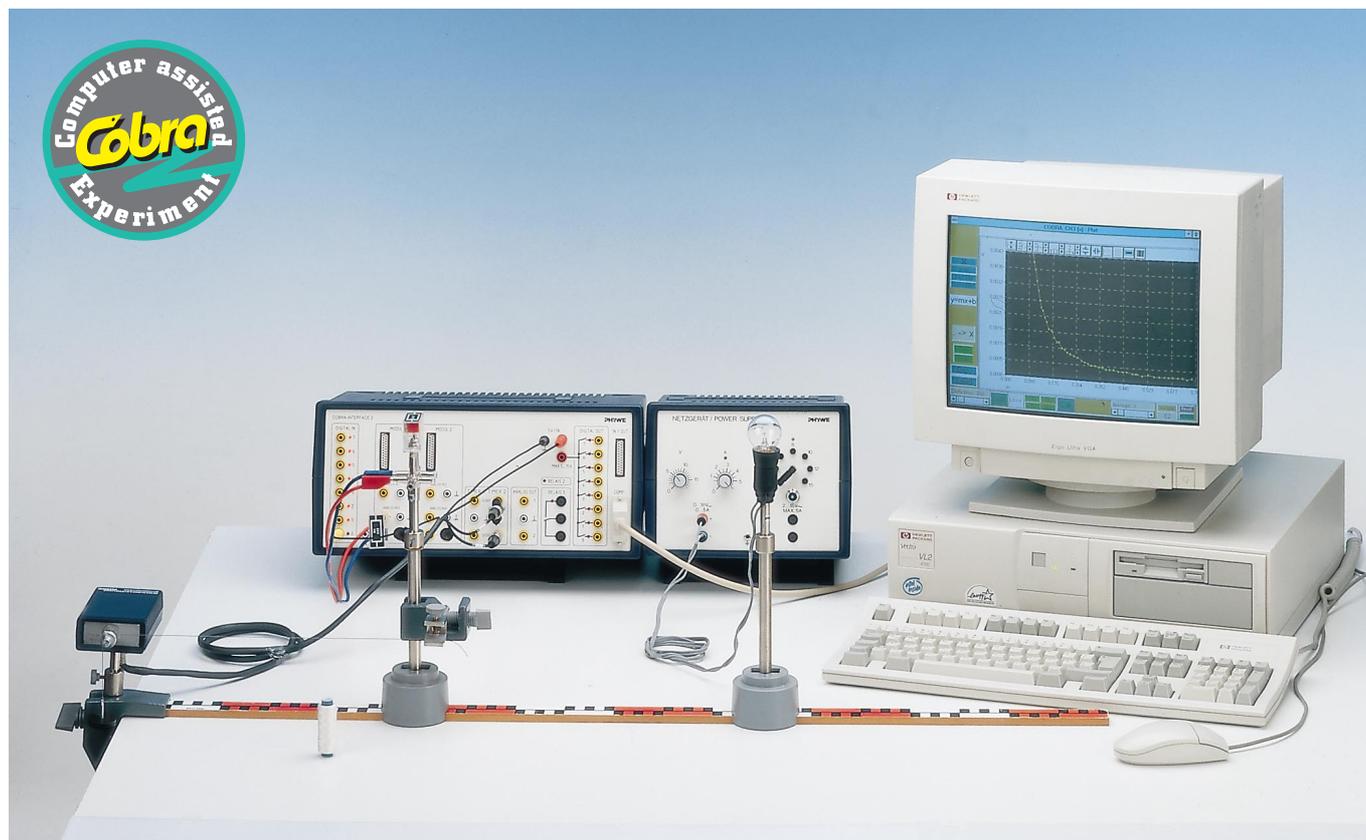
too short, data communication errors may occur. It must be made sure that when ⟨Digit⟩ is pressed, the number of displayed measurements values corresponds to the adjusted sampling rate. For ⟨Delta t/ms⟩ = 300 ms, the analogue voltage display "y" should thus change about three times every second. If display changes are less frequent, although the photodiode is obscured part of the time, sampling time ⟨Delta t/ms⟩ must be increased.

– To verify the law of distances, the measurement range (CH3 / V) ⟨0.1⟩ is recommended.

– If strong fluctuations of the measured voltages occur during measurement, it is possible to reduce noise through averaging over the displayed number of measurement values by shifting the ⟨Average⟩ slide. Voltage display becomes "quiter" when the figure for ⟨Average⟩ increases. However, a certain inertia occurs in this case, that is, if voltage is modified suddenly, it lasts a few seconds until the correct new value is reached; this can cause errors of the **p**ermanent automatic path measurement. For the measurement described here, an ⟨Average⟩ value between 1 and 5 is recommended.

– Calibration of the movement recorder.
to measure the path with the movement recorder, only the smaller of the two thread grooves is used. As the relation between the linear path and the number of revolutions of the thread groove depends on the used thread and on the sampling time ⟨Delta t/ms⟩, the path measuring system must be calibrated once.
On edge of the barrel foot is situated exactly on a dm subdivision of the scale (e.g. 800 mm). Now a path length, (e.g. 0.1 m), is entered into the corresponding input window "x0" and the "Enter" key is pressed on the keyboard. If the ⟨Stop⟩

button is displayed, it is clicked at to start with and then the appearing ⟨Start⟩ button is pressed. If the ⟨Start⟩ button was visible from the beginning, it is pressed only once. In any case, measurement value recording must be switched off once and then on again. This switching off and on causes the value of the path sensor to be reset to 0.000 m. The value 0.0 must be displayed in the input field "d0". Press the ⟨Digit⟩ and the ⟨X Sensor⟩ buttons. The barrel foot is now slowly and regularly shifted towards the movement recorder by the distance "x0" set on the scale. The length "x0" relates to the scale and not to the value displayed on the monitor.
After this, the ⟨Cal⟩ button situated below the "x0" input window is pressed. Calibration is now concluded. For every new start of the measurement programme, this calibration is automatically taken into account and need thus not be repeated. New calibration only is required if the thread is changed or another sampling time ⟨Delta t/ms⟩ is set. If a negative path is measured, although this is not expected, the corresponding numerical value "-" must be entered with a - sign and calibrated again.

– Measurement of illumination intensity (voltage at the analogue input 3 of the COBRA interface), as a function of path:

1. Measurement with path sensor and **p**ermanent automatic measurement value recording:

– Set the barrel foot to the inital position (10 cm form the centre of the light bulb) and press ⟨X Sensor⟩ and ⟨P⟩.

– Now a path length of 0.1 m is entered into the input window "d0" and the "Enter" key is pressed on the keyboard.

– Switch ⟨Start⟩ ⟨Stop⟩ off and on once, the red ⟨Stop⟩ button must no longer be visible after this. If ⟨Digit⟩ is pres-
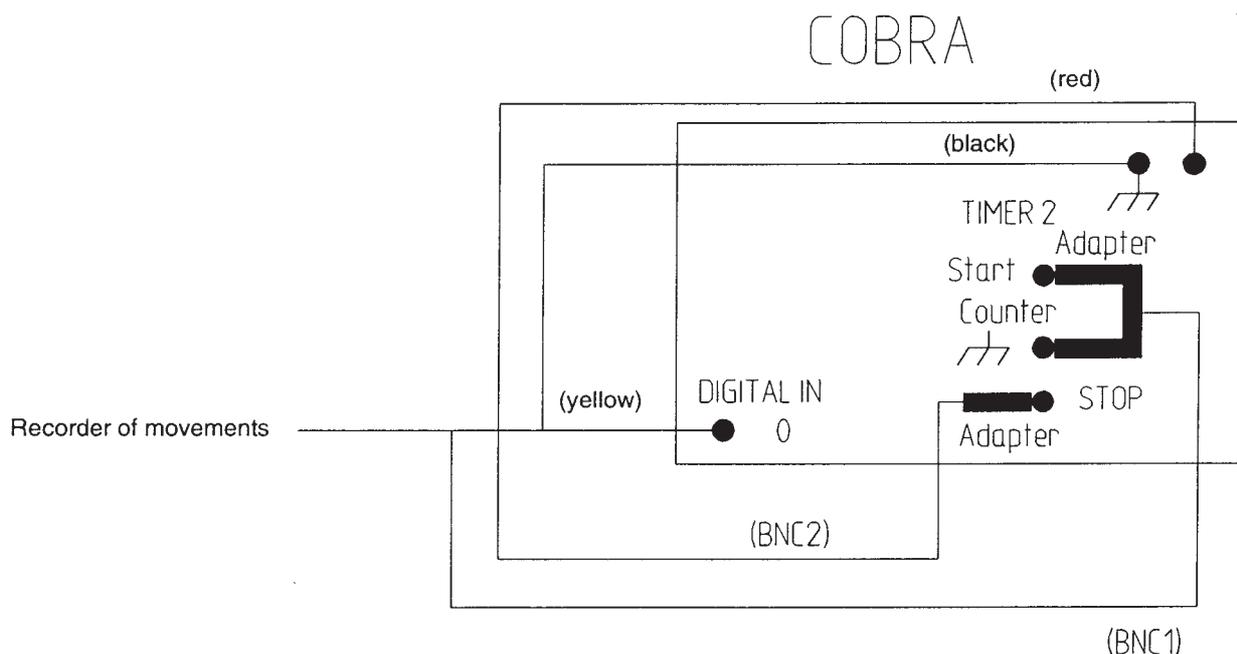

Fig. 2: Connection of the movement recorder to the COBRA interface. If the COBRA interface with the turning knob is used, please notice that the stop and mass sockets of the timer are inverted as compared to the disposition for the COBRA interface 2. The voltage knob must be set to 5 V, that is, the knob is completely turned to the left.

sed, voltage y is displayed in volts and the path x as 0.100 m. During the recording of measurement values, one may switch continuously back and forth between ⟨Digit⟩ and ⟨Plot⟩. For the ⟨Plot⟩ function, a yellow measurement point appears at the position x at the beginning of the measurement. This moves up and down due to fluctuations of luminous intensity.

– Press ⟨Reset⟩ to set the number of measurement points back to zero and to delete the graph.

– The barrel foot is slowly (about 1 cm/s) and regularly moved away from the light source. A measurement plot is being recorded continuously. Measurement points are only entered into the graph if the thread groove of the movement recorder is moved. If the barrel foot is stopped, no new measurement points appear in the graph. Recording of measurement values stops after about 70 cm. For this, the ⟨P⟩ button is pressed, followed by the ⟨X Sensor⟩ button and finally by the ⟨Stop⟩ button.

2. Measurement without path sensor:

– Set the barrel foot in the initial position. Button ⟨X Sensor⟩ may not be pressed.

– Switch ⟨Start⟩ ⟨Stop⟩ off and on once, the red ⟨Stop⟩ button must be visible after this.

– Press ⟨Reset⟩ to set the number of measurement points back to zero and to delete the graph.

– Enter the value 0.1 into the input window "d0" and press "Enter" on the keyboard. After clicking on the ⟨Enter⟩ button, the first measurement point is recorder.

– The barrel foot is shifted to the next wished position and the path length is again entered into the input window "d0" (press "Enter" after this!). ⟨Enter⟩ records the new pair of measurement values (x, y).

Result

The luminous intensity is defined as the light stream Φ (falling perpendicularly onto a unit area A. The light stream falling onto the unit area thus is:

$$E = \frac{\Phi}{A} \ .$$

This is also called the illumination intensity E. If we lay two concentric spheres with radii r_1 and r_2 around a punctual light source acting as the centre, the space angle Ω cuts out surfaces $\Omega\, r_1^2$ and $\Omega\, r_2^2$ from the spheres. If the light stream radiating in space ange ω is Φ, the luminous intensity on both surfaces is

$$E_1 = \frac{\Phi}{\Omega\, r_1^2} \quad \text{and} \quad E_2 = \frac{\Phi}{\Omega\, r_2^2} \ .$$

As

$$\frac{\Phi}{\Omega} = I$$

is the luminous intensity of the light source, one obtains

$$E_1 = \frac{I}{r_1^2} \ , \quad E_2 = \frac{I}{r_2^2} \ .$$

and from this the law of distances

$$E_1 : E_2 \ = \ \frac{1}{r_1^2} : \frac{1}{r_2^2} \ .$$

The following is thus valid:
the luminous intensity generated by a punctual light source on two areas onto which the light beams fall perpendicularly, is inversely proportial to the square of the distance between these surfaces and the light source.

– After the autoscaling buttons was pressed, ⟨x/m⟩ represents the illumination intensity as a function of distance. The ⟨. -⟩ x⟩ button furthermore shows the single measurement points. The non linearity is clearly seen in Fig. 4.

– The button ⟨1/x / 1/m⟩ shows the inverse value of the distance on the x-axis. The graph is also non linear (cf. Fig. 5).

– Only the plot of illumination intensity as a function of the square of the inverse of the distance ⟨1/x² / 1/m²⟩ gives a straight line (Fig. 6). This can be confirmed by a regression line ⟨y=mx+b⟩. The law of distances is thus verified.
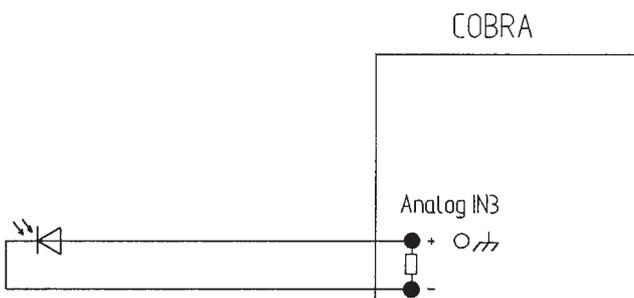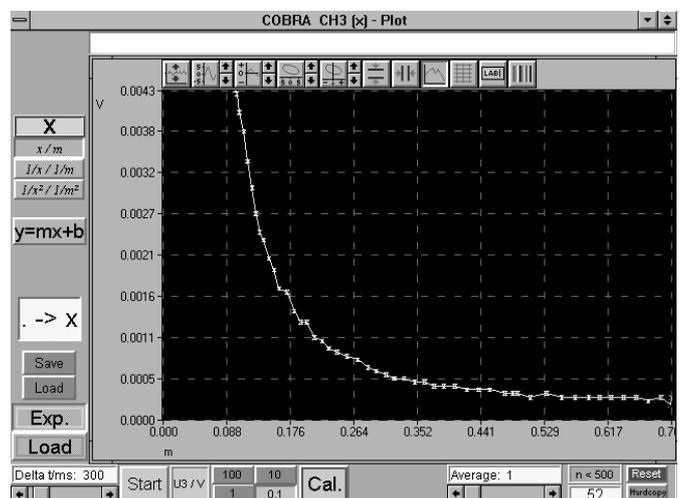

Fig. 3: Wiring diagram.

Fig. 4: Illumination intensity as a function of distance.

Indications

– If the room is not well darkened, background light can be set to zero by pressing the ⟨Cal.⟩ button in the lower line of the screen. However, if background light is too strong, a strong loss of dynamics will result.

– The current generated by the photodiode is measured at the analogue input CH3 of the COBRA interface over a shunt resistor of about 20 Ω. Only this current is proportional to the illumination intensity.

– ⟨Save⟩ (green) saves the recorded measurement data as ASCII file on the hard disc or on a floppy disk. These data can be read and processed by usual sheet spread or text processing programmes. The files should have *.AFD as a suffix (**A**SCII **F**ile **D**ata), so that the measurement data file can be easily identified.

– ⟨Load⟩ (green) loads a previously saved measurement file into the RAM memory of the computer. In order to display the thus loaded measurement series graphically, the blue ⟨Load⟩ button situated below the ⟨Exp.⟩ button must be pressed. If, on the contrary, the ⟨Exp.⟩ button is pressed, the graph of the actual **exp**eriment will always be displayed. The ⟨Exp.⟩ and ⟨Load⟩ buttons thus switched between the loaded measurement and the actual measurement.

– Above the graph there is a white line into which a title may be entered after clicking on it.

– The ⟨Hardcopy⟩ button is used to print out the complete screen on the printer running under WINDOWS®. Before using this button, however, the colour combination of the diagram should be modified in order to save ink ribbon or cartridge. To achieve this, the button with rainbow colours situated on the right side above the graph (to the right next to the ⟨LAB⟩ button) is pressed. The following setting is recommended for print out:

Chart white

Data black.

– Starting from the left side, the other buttons above the graph are used for the following purposes:

  – Autoscale function, so all measurement points will appear on the graph.

  – Extending and compressing the *y*-axis, the arrows do this in steps, the button with the curve allows to enter maximum and minimum values over the keyboard.

  – Shifting the measurement curve in the y direction without changing the scale (arrows).

  – Extending and compressing the *x*-axis, the arrows do this in steps, the button with the curve allows to enter maximum and minimum values over the keyboard.

  – Shifting the measurement curve in the x direction without changing the scale (arrows).

  – Introduction of horizontal cursor lines which can be moved with the left mouse buttons. The absolute and relative values of each position are displayed below the graph.

  – Connection of the measurement points through polygonal lines.

  – Introduction of a grid, of an origin coordinate system or of a single coloured background.

  – Modification of the *x*- and the *y*-axis indications.

  – Modification of the graph colours.

– When displayed and pressed, the ⟨. -⟩ x⟩ button introduces the measurement points magnified into the polygonal line of the graph. According to the number of measurement points, carrying out of the function may last a few seconds.

– The programme is terminated when the symbol situated in the uppermost left corner of the screen is clicked on twice.

– The used graphic set-up has a resolution of 640×480 pixels. If a monitor with a higher resolution is used, the programme will only use a corresponding picture segment on the upper left corner of the monitor.
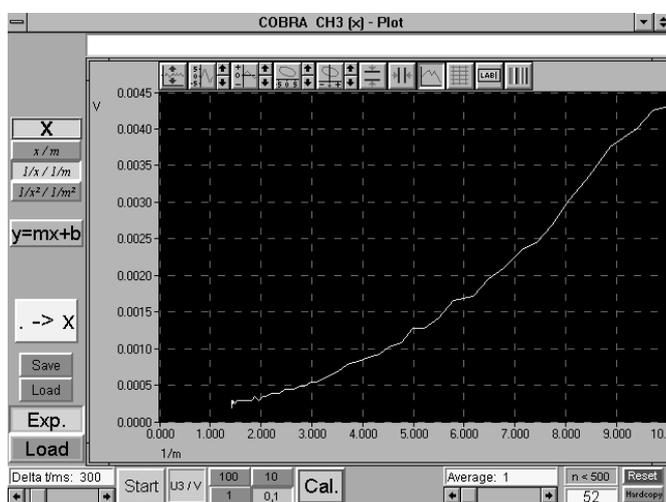

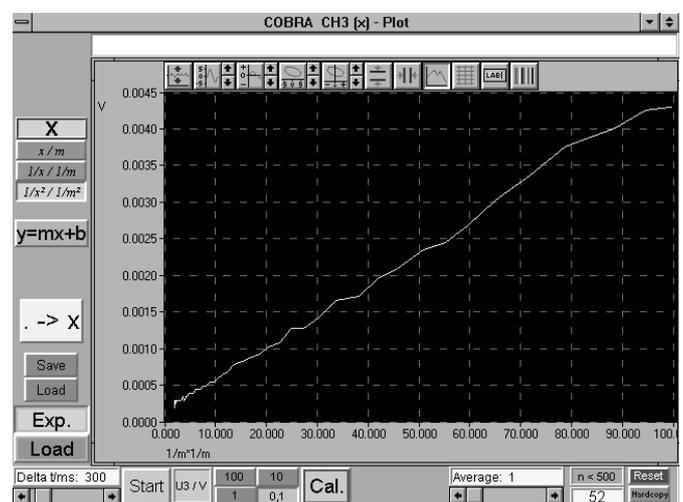Fig. 5: Illumination intensity as a function of the inverse value of distance.

Fig. 6: Illumination intensity as a function of the square of the inverse value of distance.