The Lambert-Beer law with liquids

Task and equipment

Information for teachers

Additional information

• It has turned out that this experiment does not work with ink made by Lamy because the solution becomes lighter with time. Printer ink and food colouring have been tried and tested.
• The experimental setup is relatively susceptible to stray light.
• If there are any problems with reading the multimeter it is recommended to work with the HOLD function.
• Because the light sensor is very sensitive, care has to be taken that the setup is not shifted during the measurement (for this reason the pipette is used).
• If the coloured water is too dark, the measurement will be made more difficult - good results are obtained with slight cloudiness.
• To prevent the cell from becoming scratched too quickly it is recommened to place all the four cells side by side into the holder at the same time and to observe the correct orientation so that the structured side points outwards.

Background

The reduction of intensity is described by the Lambert-Beer law

$$I = I_0 \times e^{-\alpha c I}$$

with l being the distance passed through the liquid and αc the substance-specific reduction coefficient, with depends on the wavelength of the incident light and the liquid.
For the calculation the equation is rearranged:
$\alpha c = -(ln(I/I_0)/I.$
The percentage reduction for each unit of length is calculated using $p = (1 - e^{-\alpha c}) \times 100\%.$
In this case for each cell the intensity therefor drops by approx. 30%.

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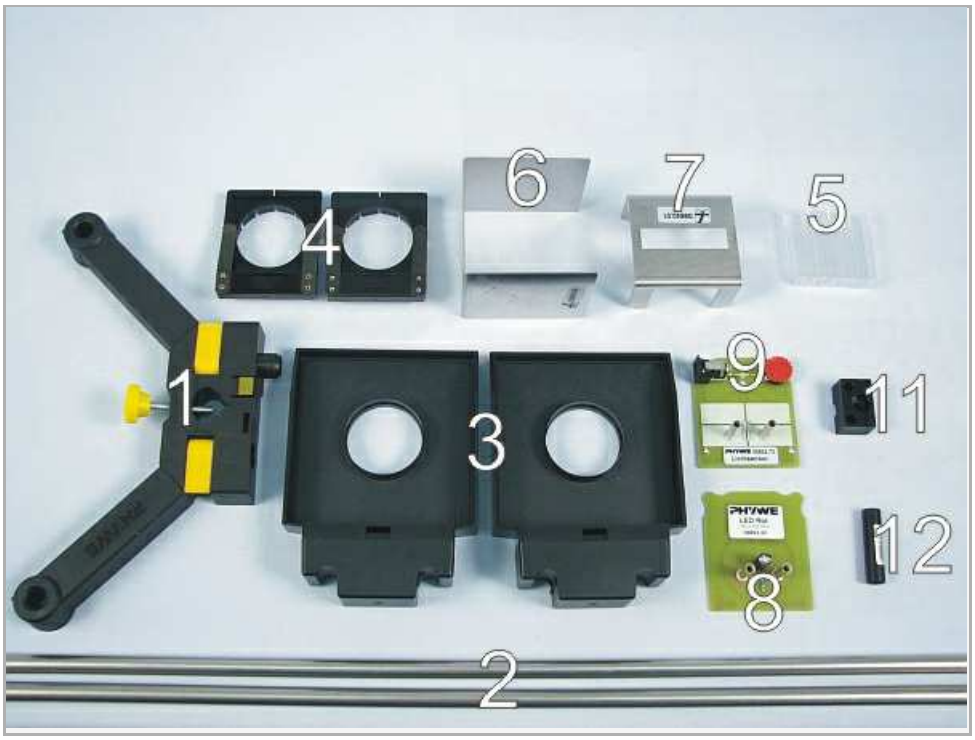
Task

How is light attenuated by liquids?

If light passes through a substance, irrespective of wether it is solid or liquid, it is, in general, less intense when it leaves than when it entered. In this experiment you will develop a rule about how the light is attenuated when it passes through coloured liquids.

Equipment



Student's Sheet

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Position No.	Material	Order No.	Quantity
1	Support base, variable	02001-00	1
2	Support rod, stainless steel, l = 600 mm, d = 10 mm	02037-00	2
3	Slide mount without angle scale	09851-02	2
4	Diaphragm holder, attachable	11604-09	2
5	Macro-cuvettes, PS, 4ml,100 pcs	35663-10	4
6	Universal bench	09840-00	1
7	Cell holder	09840-01	1
8	LED - red, with series resistor and 4 mm plugs	09852-20	1
9	Light sensor with amplifier, adjustable	09852-70	1
10	Power supply, 5 V DC	09852-99	1
11	Stray light tube	09852-71	1
12	Stray light tube for LED, Di = 8 mm, l = 40 mm	09852-01	1
Additonal material			
13	PHYWE power supply DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A	13506-93	1
14	DMM with NiCr-Ni thermo couple	07122-00	1
	Connecting cord, 32 A, 750 mm, red	07362-01	2
	Connecting cord, 32 A, 750 mm, blue	07362-04	2

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Set-up and procedure

Set-up

- Set up as shown in figure 1-5 - the structured sides of the cells point outwards and are not in the path of the light.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

- Push the parts close together on the optical bench so that the tube on the LED makes contact with the cells and also so that the tube on the light sensor is as close as possible to the last cell.

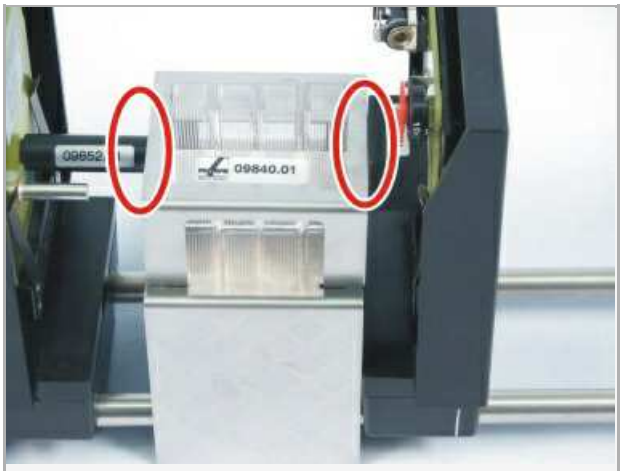


Fig. 6

- Fill the cell with water (reference).

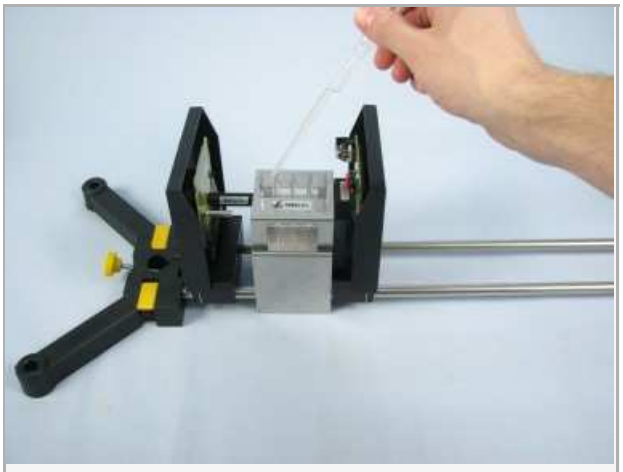


Fig. 7

Fig. 8

- Connect the LED to the power supply - observe the correct polarity!

Fig. 9

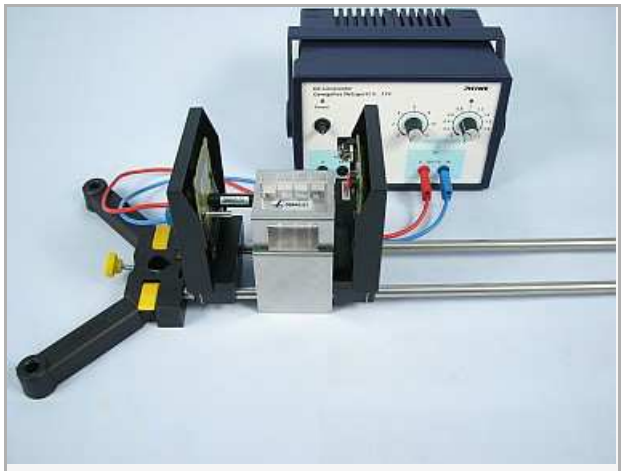


Fig. 10

- Connect the light diode to the 5 V DC power supply and connect it to the multimeter (measuring range above 4 V).

Fig. 11

Fig. 12

Procedure

• Fill the beaker with approx. 300 ml water and add a drop of ink.
• Warning: the coloration must not be too dark!
• Reference measurement: Adjust the power supply with the water-filled cell in such a way that the photodiode operates in the sensitive range. (When the adjustment knob on the light sensor is rotated clockwise to the stop a maximum voltage of approx. 3.9 V is
measured.)
• Record the value for the measurement with the water-filled cells in table 1

Fig. 13

Fig. 14

• With the pipette remove the water from the cell closest to the LED and replace it with coloured water.
• Record the value measured at the photodiode (table 1).

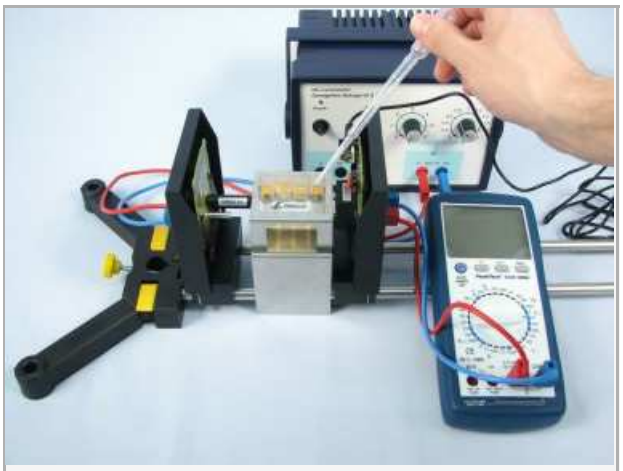


Fig. 15

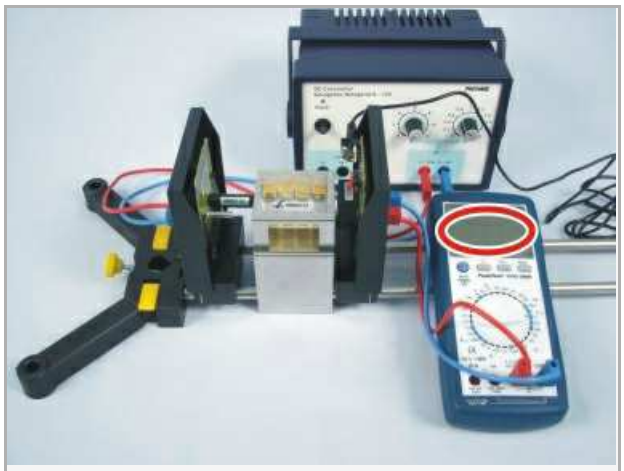


Fig. 16

- Repeat the two last steps until all the cells are filled with coloured water.

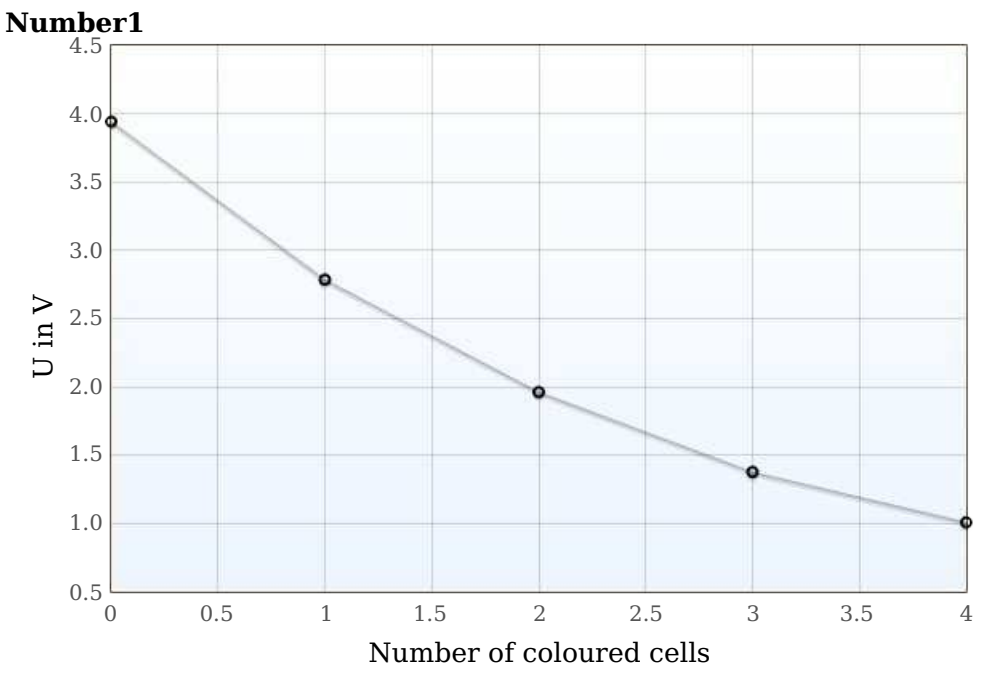
Fig. 17

Report: The Lambert-Beer law with liquids

Result - Table 1

Complete the table below.

Number of coloured cells	Voltage at the light cell in V
0	3.942 1
1	2.785 1
2	1.962 1
3	1.377 1
4	1.009 1



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Evaluation - Question 1

Formulate an assumption about the functional relationship between the number of ink-filled cells and the voltage at the light sensor. Reinforce your assumption with a calculated proof. (Here a pocket calculator or a spreadsheet can be used.)

Evaluation - Question 2

Calculate the gradient of the graph using the following formula: $m = (ln(y_0) - ln(y_4))/(x_0 - x_4)$.

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Evaluation - Question 3

Formulate your result in a sentence.

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