*Recent Research in Science and Technology 2011, 3(1): 97-100*
*ISSN: 2076-5061*
*www.recent-science.com*

PHYSICS

# ABSORPTION COEFFICIENT OF GLASS MEDIUM – EXPOSED TO SODIUM LIGHT USING LDR

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## Abstract

The absorption coefficient of glass medium (green and violet color glasses) of various thicknesses, when the medium is exposed to sodium light has been studied using LDR. The value of absorption coefficient has been found almost constant in all cases as expected.

Keywords: Absorption Coefficient; Anisotropic Solid; EM wave; LDR

## Introduction

"Absorption coefficient is a measure of the rate of decrease in intensity of electromagnetic radiation when it passes through a given substance".

Generally, the absorption spectrum of a substance can be observed by passing white light through it and examining the transmitted light with a spectroscope and from that the absorption coefficient will be calculated. . In this work, the absorption coefficient is calculated using Light Dependent Resistor (LDR). The basic principle of LDR is that the resistance depends on the intensity of the light falling on it. We know that current flowing through LDR is proportional to intensity of light falling on it and resistance is inversely proportional to current. So, resistance is inversely proportional to intensity.

## Experimental setup

Light would be removed from the transmitted beam by scattering as well as absorption, but the scattering is reduced if the substance is in a homogenous state such as a single crystal, a liquid, or an amorphous solid. In true absorption the light disappears, the energy being converted into heat. The absorption depends on the nature of the body as well as on the radiation used.

Ordinary glasses with green color and violet color of various thicknesses have been used in this work. Sodium light (15 Watts) is placed inside a dark room. The given glasses, one by one, of a particular color is placed at a specified distances from the lamp. LDR with multi-meter is placed next to glass plates. The knob of multi meter is in 20k ohms range. The value of resistance in multi-meter without any glass plate is taken as $R_o$. The value of resistance in multi-meter with glass plate is taken as $R_x$. The distance of LDR from sodium lamp is taken as'd'. The thickness of the glass plate is taken as 'x'. The readings are tabulated as shown in the below tables.

No medium (except vacuum) is perfectly transparent when light passes through it. When light passes through a medium, its energy is partially absorbed; increasing the internal energy of the medium and the intensity (power per unit area) is correspondingly attenuated. The decrease in intensity (dI) is found to be proportional to the initial intensity (I), and the thickness (dx) through which the light passes. Mathematically it is given by $dI = - \alpha I dx$, …(1) where the proportionality constant α is called absorption coefficient, which depends on the material.

The intensity after passage through a slab of thickness x can be obtained by integrating the equation (1), we get $I_x = I_o e^{-\alpha x}$… (2) Where $I_o$ is the intensity at x = 0, $I_x$ is the intensity at a distance x.

In this work the intensity is measured indirectly by measuring the change in the resistance of the LDR before and after the light passing through the medium of given thickness. So the formula in terms of resistance becomes, $R_x = R_o e^{\alpha x}$… (3) Where $R_o$ is the resistance at x = 0, $R_x$ is the resistance at a distance x.

From equ.(3) the absorption coefficient is given by

$\alpha = [\log (R_x/R_o)] / x$.

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## Tabulation

Table 1: To find the absorption coefficient of green glass plate

| No. | 'd' cm | Value of Resistance in Multimeter | | | |
|---|---|---|---|---|---|
| | | without glass $R_o$ (KΩ) | with green glass of thickness $x_1 = 4.876x10^{-3}$m $R_{x1}$ (KΩ) | with green glass of thickness $x_2 = 9.752x10^{-3}$m $R_{x2}$ (KΩ) | with green glass of thickness $x_3 = 14.628x10^{-3}$m $R_{x3}$ (KΩ) |
| 1 | 15 | 3 | 6 | 13 | 40 |
| 2 | 30 | 4 | 10 | 19 | 44 |
| 3 | 45 | 5 | 13 | 26 | 59 |
| 4 | 60 | 7 | 18 | 37 | 94 |
| 5 | 75 | 10 | 23 | 47 | 124 |

## Model Calculation:

d=15cm

1) $R_o$ = 3K. $R_{x1}$ = 6K. $x_1$ = 4.876x10^-3^m.

$\alpha = [\log(6/3)] / 4.876x10^{-3}$.

$\alpha = 61.737$.

d=45cm

2) $R_o$ = 5K. $R_{x2}$ = 26K. $x_2$ = 9.752x10$^{-3}$m.

$\alpha = [\log(26/5)] / 9.752x10^{-3}$.

$\alpha = 73.4211$.

d=30cm.

3) $R_o$ = 4K. $R_{x3}$ = 44K. $x_3$ = 14.628x10$^{-3}$m.

$\alpha = [\log(44/4)] /14.628x10^{-3}$.

$\alpha = 71.19173$.

Table 2: Absorption coefficient of green glass plate

| No. | 'd' cm | Absorption coefficient α ( $m^{-1}$) | | |
|---|---|---|---|---|
| | | $x_1 = 4.876x10^{-3}$m. | $x_2 = 9.752x10^{-3}$m. | $x_3 = 14.620x10^{-3}$m. |
| 1 | 15 | 61.737 | 65.301 | 76.903 |
| 2 | 30 | 81.611 | 69.390 | 71.191 |
| 3 | 45 | 85.105 | 73.421 | 73.276 |
| 4 | 60 | 84.121 | 74.149 | 77.114 |
| 5 | 75 | 74.185 | 68.918 | 74.741 |

Table 3: Ratio of change in the resistance value and the absorption coefficient value in the multi-meter, when the green glass plate's thickness increases two times. (From 4.888mm to 9.776mm)

| No. | 'd' cm | $R_{x2}$ (9.752mm) / $R_{x1}$(4.876mm) | $\alpha_{x2}$(9.752mm) / $\alpha_{x1}$(4.876mm) |
|---|---|---|---|
| 1 | 15 | 13 / 6 = 2.166 | 65.301 / 61.737 = 1.057 |
| 2 | 30 | 19 / 10 =1.90 | 69.390 / 81.611 = 0.850 |
| 3 | 45 | 26 /13 = 2.00 | 73.421 / 85.105 = 0.862 |
| 4 | 60 | 37 / 18 = 2.05 | 74.149 / 84.121 = 0.881 |
| 5 | 75 | 47 / 23 = 2.04 | 68.918 / 74.185 = 0.919 |

Table 4: Ratio of change in the resistance value and the absorption coefficient value in the multimeter, when the green glass plate's thickness increases three times. (From 4.888mm to 14.628mm)

| No. | 'd' cm | $R_{x3}$(14.628mm) / $R_{x1}$(4.876mm) | $\alpha_{x3}$ (14.628mm) / $\alpha_{x1}$(4.876mm) |
|---|---|---|---|
| 1 | 15 | 40 / 6 = 6.66 | 76.903 / 61.737 = 1.245 |
| 2 | 30 | 44 / 10 = 4.4 | 71.191 / 81.611 = 0.872 |
| 3 | 45 | 59 /13 = 4.5 | 73.276 / 85.105 = 0.861 |
| 4 | 60 | 94 / 18 = 5.2 | 77.114 / 84.121 = 0.916 |
| 5 | 75 | 124 / 23 = 5.3 | 74.741 / 74.185 = 1.007 |

Table 5: Ratio of change in the resistance value and the absorption coefficient value in the multimeter which is connected in parallel to the LDR, when the green glass plate's thickness increases one and half times. (From 9.752mm to 14.628mm)

| No | 'd' cm | $R_{x3}$ (14.628mm) / $R_{x2}$(9.752mm) | $\alpha_{x3}$(14.628mm) / $\alpha_{x2}$(9.752mm) |
|---|---|---|---|
| 1 | 15 | 40 / 13 = 3.07 | 76.903 / 65.301 = 1.177 |
| 2 | 30 | 44 / 19 = 2.31 | 71.191 / 69.390 = 1.025 |
| 3 | 45 | 59 /26 = 2.26 | 73.276 / 73.421 = 0.998 |
| 4 | 60 | 94 / 37 = 2.5 | 77.114 / 74.149 = 1.039 |
| 5 | 75 | 124 / 47 = 2.6 | 74.741 / 68.918 = 1.084 |

Table 6: To find the absorption coefficient of violet glass plate

| No. | 'd' cm | Value of Resistance in Multimeter | | | |
|---|---|---|---|---|---|
| | | without glass $R_o$ (KΩ) | with violet glass of thickness $x_1 = 4.888x10^{-3}$m $R_{x1}$ (KΩ) | with violet glass of thickness $x_2 = 9.776x10^{-3}$m $R_{x2}$ (KΩ) | with violet glass of thickness $x_3 = 14.628x10^{-3}$m $R_{x3}$ (KΩ) |
| 1 | 15 | 3 | 10 | 37 | 94 |
| 2 | 30 | 4 | 15 | 52 | 117 |
| 3 | 45 | 5 | 20 | 69 | 134 |
| 4 | 60 | 7 | 27 | 83 | 151 |
| 5 | 75 | 10 | 35 | 110 | 193 |

## Model calculation:

d=15cm.

1) $R_o$ = 3K. $R_x$ = 10K. x = $4.888x10^{-3}$m.

$\alpha = [\log(10/3)] / 4.888x10^{-3}$.

α = 106.971.

d=30cm.

2) $R_o$ = 4K. $R_x$ = 52K. x = $9.776x10^{-3}$m.

$\alpha = [\log(52/4)] / 9.776x10^{-3}$.

α = 113.946

d=75cm.

1) $R_o$ = 10K. $R_x$ = 193K. x = $14.664x10^{-3}$m.

$\alpha = [\log(193/10)] / 14.664x10^{-3}$.

α=87.667

Table 7: Absorption coefficient of violet glass plate

| No. | 'd' cm | Absorption coefficient α ( $m^{-1}$) | | |
|---|---|---|---|---|
| | | $x_1 = 4.888x10^{-3}$m. | $x_2 = 9.776x10^{-3}$m. | $x_3 = 14.664x10^{-3}$m. |
| 1 | 15 | 106.971 | 111.608 | 102.018 |
| 2 | 30 | 117.436 | 113.946 | 99.981 |
| 3 | 45 | 123.171 | 116.599 | 97.390 |
| 4 | 60 | 119.939 | 109.858 | 90.962 |
| 5 | 75 | 111.306 | 106.525 | 87.667 |

Table 8: Ratio of change in the resistance value and the absorption coefficient value in the multimeter, when the violet glass plate's thickness increases two times. (From 4.888mm to 9.776mm)

| No | 'd' cm | $R_{x2}$(9.776mm) / $R_{x1}$(4.888mm) | $\alpha_{x2}$(9.776mm) / $\alpha_{x1}$(4.888mm) |
|---|---|---|---|
| 1 | 15 | 37 / 10 = 3.7 | 111.608 / 106.971 = 1.043 |
| 2 | 30 | 52 / 15 = 3.46 | 113.946 / 117.436= 0.970 |
| 3 | 45 | 69 / 20 = 3.45 | 116.599 / 123.171 = 0.946 |
| 4 | 60 | 83 / 27 = 3.07 | 109.858 / 119.939 = 0.915 |
| 5 | 75 | 110 / 35 = 3.14 | 106.525 / 111.306 = 0.957 |

Table 9: Ratio of change in the resistance value and the absorption coefficient value in the multimeter, when the violet glass plate's thickness increases three times. (From 4.888mm to 14.628mm)

| No | 'd' cm | $R_{x3}$(14.628mm) / $R_{x1}$(4.888mm) | $\alpha_{x3}$ (14.628mm) / $\alpha_{x1}$(4.888mm |
|---|---|---|---|
| 1 | 15 | 94 / 10 = 9.4 | 102.018 / 106.971 = 0.953 |
| 2 | 30 | 117 / 15 = 7.8 | 99.981 / 117.436 = 0.851 |
| 3 | 45 | 134 / 20 = 6.7 | 97.390 / 123.171 = 0.790 |
| 4 | 60 | 151 / 27 = 5.6 | 90.962 / 119.939 = 0.758 |
| 5 | 75 | 193 / 35 = 5.5 | 87.667 / 111.306 = 0.787 |

Table 10: Ratio of change in the resistance value and the absorption coefficient value in the multimeter, when the violet glass plate's thickness increases one and half times. (From 9.776mm to 14.664mm)

| No | 'd' cm | $R_{x3}$(14.664mm) / $R_{x2}$(9.776mm) | $\alpha_{x3}$(14.664mm) / $\alpha_{x2}$(9.776mm) |
|---|---|---|---|
| 1 | 15 | 94 / 37 = 2.5 | 102.018 / 111.608 = 0.914 |
| 2 | 30 | 117 / 52 = 2.25 | 99.981 / 113.946 = 0.877 |
| 3 | 45 | 134 / 69 = 1.94 | 97.390 / 116.599 = 0.835 |
| 4 | 60 | 151 / 83 = 1.81 | 90.962 / 109.858 = 0.828 |
| 5 | 75 | 193 / 110 = 1.75 | 87.667 / 106.525 = 0.823 |

## Discussion and Conclusion

In the case of green glass plate,

- When the thickness increases twice, the ratio of resistance for those two thicknesses also varies twice at the corresponding distances.
- When the thickness increases thrice, the ratio of resistance for those two thicknesses varies from 4.5 times to 6.5 at the corresponding distances.
- When the thickness increases one and half times the ratio of resistance for those two thicknesses varies from 2.2 times to 3 times at the corresponding distances.

In the case of violet glass plate

- When the thickness increases twice, the ratio of resistance for those two thicknesses varies from 3.0 to 3.7 at the corresponding distances.
- When the thickness increases thrice, the ratio of resistance for those two thicknesses varies from 5.5 times to 9.4 times at the corresponding distances.
- When the thickness increases one and half times, the ratio of resistance for those two thicknesses varies from 1.75 to 2.5 at the corresponding distances.

The variation in absorption coefficient is due to the following fact:

- When attempting to determine the absorption coefficient, it must be remembered that in the equation $I = I_o e^{-\alpha x}$, $I_o$ is the intensity of the light that enters the body; since some light is reflected at the first surface, it is not the intensity of the incident light. Again owing to reflection at the second surface, I is not the emergent intensity for a body of total thickness x.
- The variation in absorption coefficient in this work is due to the fact that the instrument used in this experiment may not be very sensitive to reflect the actual nature of glass plate.
- When the thickness increases, it need not necessarily increase linearly as absorption formula is exponential.

The losses due to reflection as mentioned in the first point can be eliminated by measuring the emergent intensity for two different thicknesses.

1. In all cases, the absorption coefficient for a given type of glass plate is almost constant, as expected.
2. From the above fact, it seems that violet glass plate absorbs more yellow light than that of green glass plate.

## Reference

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