DESIGN AND IMPLEMENTATION OF A DIGITAL LUXMETER FOR INVESTIGATION OF A LIGHTING STANDARD

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Abstract:

The aim of this research is to design and implementations of a digital lighting meter (or Digital Luxmeter DLM) and use it to investigate, establish and test a proper standard for good lighting in our different living environments in order to have a good human health. An electronic circuit was designed and implemented experimentally as a digital lighting meter (or digital Luxmeter) and by using our digital Luxmeter we found tables of readings of that circuit which as decimal numbers related to the light intensity for making the good lighting standard. The standard was tested by taking different lighting, living environments and recording the response of groups of people. The results was discussed and founded the stander deviation of that's responses.

Finally, by conclusion, establishes this standard we tried to find the optimum of the good lighting conditions in our different living environments.

Keywords: light meter, digital Luxmeter, light standard, good lighting.

الخلاصة:

أن الهدف من هذا البحث هو لتصميم وبناء جهاز الكتروني رقمي لقياس شدة الضوء واستخدامه لتحقيق, أنشاء و فحص معيار مناسب للإضاءة الجيدة في مختلف الظروف والأماكن المعيشية لنا للحفاظ قدر الأماكن على بيئة صحية لنا.

قد صممت دائرة الكترونية رقمية لقياس شدة الضوء ونفذت مختبريا وباستخدام هذا المقياس وجدت جداول لقراءات هذه الدائرة على شكل أرقام عشرية متعلقة بشدة الإضاءة لعمل معيار إضاءة جيد.

وفحص هذا المعيار بأخذ شدة أضاءات مختلفة ومحيطات مختلفة وسجلت استجابات مجموعة من الناس على هذه الأضاءات ونوقشت النتائج ووجد الانحراف المعياري لها. وأخيرا باستنتاج وتحقيق هذا المعيار حاولنا أيجاد الصيغة المثالية للإضاءة الجيدة في مختلف الظروف والأماكن المعيشية لنا.

1- INTRODUCTION

Light is critical to human functioning in that it allows us to see things and perform activities .But it is also important because it affects human beings psychologically and physiologically .Several studies have documented the importance of light in reducing depression, decreasing fatigue, improving alertness, modulating circadian rhythms, and treating conditions such as among infants. [1]
Further ,the presence of windows in the workplace and access to daylight have been linked with increased satisfaction with the work environment. Studies also show that adequate light levels are linked to reduced medication-dispensing errors in pharmacies. Thus, incorporating light into healthcare settings can be beneficial for patients as well as the staff who work there.[1,2]

Lighting is the application of light. We have endless means of creating light these days; then, we have a variety of light bulbs, thousands of decorative luminaires, and more popular than ever the return of the candle. What we do with these tools, where we place them, how much area we light with them, what color "white" light we choose. Clearly the effects of lighting on human health and the interested of that field had early concerning. Light is indicative of purity. Light enables us to view, perceive and enjoy the various forms of visual communication. Good and efficient lighting is essential for every one, home, school, etc.

Light impacts human health and performance by four main mechanisms :
•Enabling performance of visual tasks
•Controlling the body's circadian system
•Affecting mood and perception
•Facilitating direct absorption for critical chemical reactions within the body.

Artificial lighting as needed to provide task illuminance and adequate visual environment to carry on the task when natural light is inadequate or not available. Good artificial illuminance enables well lit surroundings, visual contort, prevent accident, protects health by minimizing eye strain and also contribute to the beauty in our environment. Inadequate light may lead to problems like lack of interest, failure to concentrate, sleepiness and apparent laziness. Furthermore, eyestrain, headache, indigestion and irritability are the other problems due to inadequate light [2,3].

Study room / area is a very important area (in our schools, homes, and offices) which needed a proper and good lighting conditions where a lot of close visual tasks and skilled work are performed which require suitable type of lighting of adequate

quantity. Also, the living rooms in our houses were very important places since we spend almost time of our lives, speculate and also doing variety of task in it which required suitable types of lighting, so dependence on artificial light is needed of the hour [4] .

For literature review; Sheweta and P.Sandhu (2008) present a study in which it carried out in Punjab with the objective to survey the existing lighting conditions, to determine the light intensity in different rooms and to determine adequacy of amount of light (level of illumination) for the performance of selected task in the selected households.[4]
And Shilpa Nandi and Susheel Sawkar (2007) present a study in which it undertaken with an objective to determine the existing artificial lighting and compare with the recommended standards. Research on adequacy of the artificial lighting was undertaken in ninety residential homes with different income group.[5]

There are many lighting standard in the words recently like the Australia lighting standard and the India lighting standard (see tables(1&2) and figure(1).[4,5,6]

We were used the India standard for lighting in building and the recommendations given by National Building Code of India Part V111, 2002 [4,5] in our study for guiding, and comparing between our result in order to concludes, established this standard and we tried to find the optimums of the good lighting conditions in our different living environments. The chosen of the lighting India standard was since its situations and environments closed to our situations and environments.

In this research a design for a special digital Luxmeter (DLM) was put and implemented, in which this DLM give a decimal reading numbers from 0 to 9, and each decimal number represent a lighting intensity range.
The DLM consist of an input block which is a light sensor (light depending resister LDR) sense the light , output block which is a 7-segment display to shows a decimal numbers at the output of our system, a control block which is a timer (555) [7] to give a fixed and proper time for the main block, and a main block consists of two blocks which are the analog to digital converter (ADC) device for convert the analog voltage from the LDR to a digital binary numbers , the second block is the decoder with driver for the 7-segment display to convert the binary numbers to BCD code and then drive the 7-segment display.
The DLM used to establish and investigate a proper lighting standard in our environment, the results was compared with the Indian lighting standard and its discussed briefly. Finally, a table of lighting sources was suggested for proper lighting

in a particular areas [8, 9, 10]. Knowing that the lighting sources used here was only the artificial lighting sources.

The India standard for lighting in building can be summarized in table (1) shown below:

Table (1)
The India standard for lighting in building*

Particular area	*Recommended standard (Lux)***
Class room, studying area	*150*
Living room	*300*
Bedroom	*185*
Kitchen room	*375*
General daily work	*150-375*

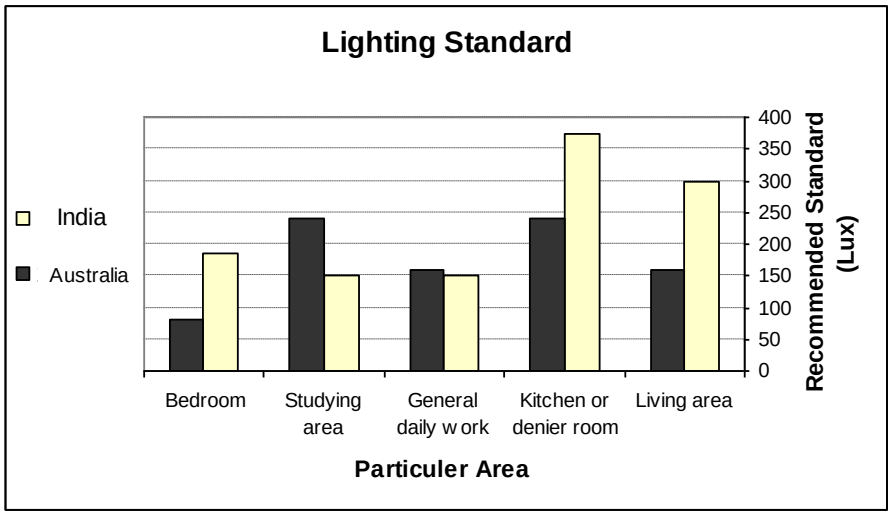
*Selected values of the India standard for lighting in building.
**lux is the unit of the illumination.
The Australia standard for lighting in building can be summarized in table (2) shown below:

Table (2)The Australia standard for lighting in building*

Particular area	**Recommended standard (Lux)**
Class room, studying area	**240**
Living room	**160**
Bedroom	**80**
Kitchen room	**240**
General daily work	**160**

*** Selected values of the Australia standard for lighting in building

The India and the Australia lighting standard were shown in figure(1) below:



Figure(1) lighting standard

2- DESIGN AND IMPLEMENTATION OF THE DLM

The work at this research was divided into two sections: The first section deals with the design of the circuit, implemented of the circuit, circuit calibration and the testing of this circuit.

The second section deal with the lighting standard, in which selections of people groups which are suitable for doing the test, to survey the existing lighting conditions in different types of environment, to determine the light – intensity in different types of environment, establish and test the lighting standard.

The First section we worked on the design of the digital electronic circuit, in order to design a Digital Luxmeter DLM we need to establish the rang that DLM will work with it, since the lighting standard that we chosen was the India standard with light intensity in Lux (150-375) and make the DLM reading compatible with that rang {making the output of the DLM were a decimal number from (0) to (9)}, a light intensity sensor device, here we were used a light depended resister (LDR) to sense and detect light intensity. The LDR putted into a voltage divider circuit in order to have a proper voltage drop related with the variations of resistance of the LDR due to the variations of the light intensity. The LDR have a very high resistance we putted on it a very low intensity of light and it have a very low resistance we putted on it a very high intensity of light ($400 \leq LDR \leq 1M\Omega$) , typically LDR have a resistance of $5k\Omega$ for light intensity of 100 lux (lux is the unit of the illumination).

The LDR used here was the NORP12 RS and by its characteristic we can find the relationship between light intensity and resistance in our circuit.

The value of the voltage drop produce from the LDR voltage divider was fed into an analog to digital converter (ADC 0804) in order to convert the analog voltage to a digital numbering (Binary) and these Binary numbers in the range (0-9 in decimal) were the same as in the Binary Coded Decimal (BCD).

And then putted on a decoder with driver for the 7-segment display (BCD to 7-segment Decoder/Drivers DM 7447A), the decoder convert the binary numbers to BCD numbers. So, with 7-segment display we can see a decimal numbers related to a certain light intensity.

Noting that we must not exceed the number (9), i.e., the rang of numbering (0-9).
Figure (2) shows the block diagram of the digital luxmeter and figure (3) shows the circuit diagram of the digital luxmeter.

The (ADC 0804) used here was a parallel output, 20-pin package, 8-bits resolution, and CMOS 8-bit successive approximation A/D converters that use a differential potentiometric ladder. This converter was designed to allow operation with NSC800 and INS8080A derivative control bus.
A timer circuit needed to control the timing of the starting conversion cycle for the ADC and the decimal numbers shown at the 7-segment display.

For designing the analog to digital converter (ADC) by taken the voltage reference for it ($V_{ref.}$=+5v) this reference voltage ($V_{ref.}$) can be divided into (2^8 = 256) levels of voltage according to the ADC resolution bits thus one bit voltage is (+5v/256 = 0.0195v) and by using equation (1).

$$V_{out} = [N_{MSB}/16 + N_{LSB}/256] \times V_{ref.} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where N_{MSB} is the decimal number of the most significant number.
N_{LSB} is the decimal number of the lest significant number.

Example: for the BCD number (1011 0110) we find the:
N_{MSB} = 11, N_{LSB} = 6.

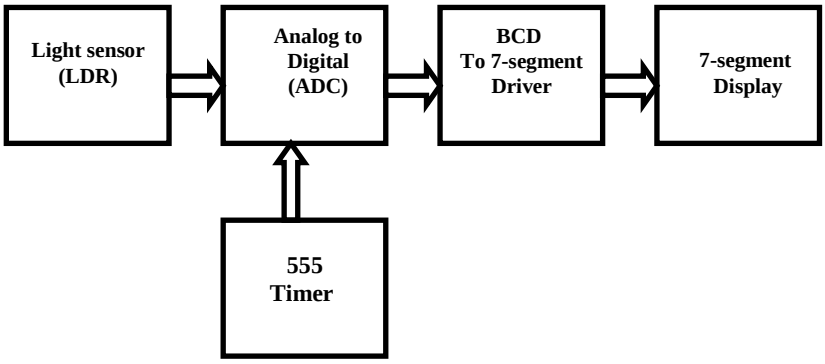


Figure (2) The block diagram of the digital luxmeter DLM

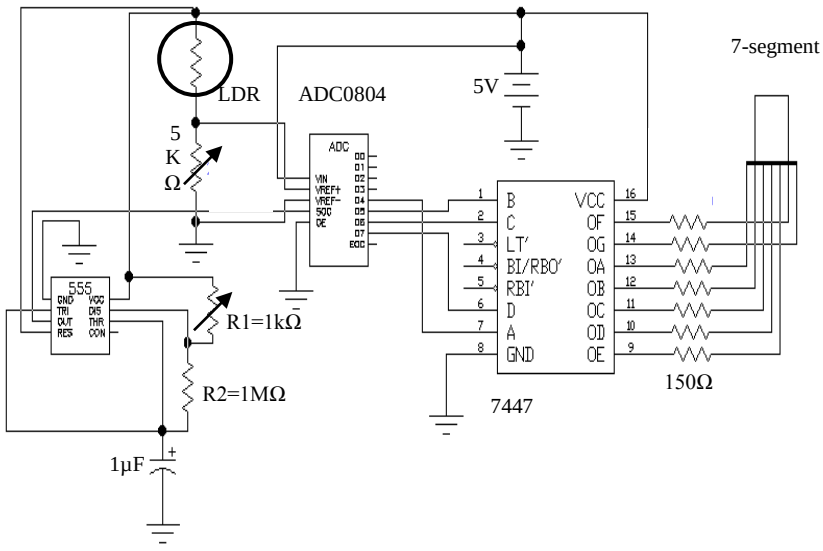


Figure (3) The circuit diagram of the digital luxmeter DLM

And we have taken the four most significant bits (2^4 = 16) in order to have a wide range of lighting intensity reading as compared with the four lest significant bits and to produce the most significant number which were from (0 to 9 in decimal), so the voltage of the one most significant number was (+5v/16 = 0.3125v).

Then we found a table for the decimal numbers from (0 to 9), which represent the most significant numbers of the ADC and their related voltages depending on the reference voltage ($V_{ref.}$) and the data shown in table (3).

Table (3)

The relation between voltages and the Decimals Numbers for DLM

Decimals Numbers for DLM	Related Voltages In volt
0	0< V <0.3125
1	0.3125< V <0.625
2	0.625< V <0.9375
3	0.9375< V <1.25
4	1.25< V<1.5625
5	1.5625< V <1.875
6	1.875< V <2.1875
7	2.1875< V <2.5
8	2.5< V <2.8125
9	2.8125< V <3.125
Decimals Numbers for DLM	Related Voltages In volt
0	0< V <0.3125
1	0.3125< V <0.625
2	0.625< V <0.9375
3	0.9375< V <1.25
4	1.25< V<1.5625
5	1.5625< V <1.875
6	1.875< V <2.1875
7	2.1875< V <2.5
8	2.5< V <2.8125
9	2.8125< V <3.125

In order to design the voltage divider that give the voltage drops to the ADC , these drops must be compatible with the ADC numbering ranges (from 0 to 9 in decimal) so that the digital luxmeter worked probably . In which we designed the series resistance that connected with the LDR give a voltage drop of the related decimal number of (4) and that can be done for a typical value of the LDR of 15kΩ) at lighting strength of 100 lux.

The voltage divider: $V_{\text{to the ADC}} = V_{\text{ref.}} \times R/(R + LDR)$.……...(2)

$V_{\text{to the ADC}}$ - 5v × R/(R + 5kΩ)

R (Ω) is the series resistance in the divider. And if we putted a 100 lux it was referred a decimal number of (4) in our digital luxmeter, the related voltage for the decimal number of (4) in table (1) was (1.5625v)

» R=2.27kΩ and by using a typical value of a variable resistance (R= 5kΩ) and adjust it until it reach (R= 2.27 kΩ) the design of the ADC was done.

By using the equation (2) we founded the relationships between the decimal numbers from (0 to 9) and the resistance values of the LDR and hence the strength of lighting (in lux) .This is shown in table (4).

Table (4)

The relationships between the decimal numbers for DLM and the resistance values of the LDR and hence the strength of lighting (in lux)

Decimals Numbers for DLM	Related Voltages In volt	Resistance (maximum) of the LDR in kΩ	Strength Of Light in lux
0	0< V <0.3125	1M≤ LDR ≤33	0< Lux <8
1	0.3125< V <0.625	15.4 ≤LDR ≤33	8< Lux <20
2	0.625< V <0.9375	9.534≤LDR ≤15.4	20< Lux <45
3	0.9375< V <1.25	6.6≤LDR ≤9.534	45< Lux <80
4	1.25< V<1.5625	4.84≤LDR ≤6.6	80< Lux <140
5	1.5625< V <1.875	3.67≤LDR ≤4.84	140< Lux <300
6	1.875< V <2.1875	2.83≤LDR ≤3.67	300< Lux <375
7	2.1875< V <2.5	2.2≤LDR ≤2.83	375< Lux <420
8	2.5< V <2.8125	1.71≤LDR ≤2.2	420< Lux <530
9	2.8125< V <3.125	1.32≤LDR ≤1.71	530< Lux <720

The timing circuit or clocked circuit was build from the (NE555) timer integrated circuit in connection that give a pulses with low frequency of (1 Hz) in order to give enough time for the ADC to complete the conversion cycle of the analog to digital conversion and also to give enough time for us to see a fixed decimal number at the output of the Luxmeter and by using the equation, ($f=1.44/(R_1+2\times R_2)\times C$) we designed the (555) I.C. as a stable multivibritor, in which we was used a typical value for a variable resistance (R_1= 1kΩ) and adjusted it until it reach the required frequency, R_2=1MΩ & C=1µf will give us f ≈1HZ . Its opiate the work of the 7-segment deriver (BCD to 7-segment Decoder/Drivers DM 7447A). It convert the binary code decimal numbers to a certain value of voltage in a sequence that enables the 7-segment display to work probably and give a decimal numbers related to the BCD code. Finally, we was used a 7-segment display in order to show a decimal numbers at the output of the digital luxmeter.

For calibration, the electronic circuit of the digital luxmeter was tested by putting a two 60 watt bulb at distance of (1) meter far from the sensor of the digital luxmeter

this will produce about 100 lux and thus our digital luxmeter was shown a decimal number of (4), and that reading approximately matching the numbers in table (2). This calibration was done by calculation and comparing the result with standard results and we can also calibrated the circuit by using a standard or calibrated light meter like (HHLM-2) Digital light meter.

The second section deal with the lighting slandered, in which selections of people groups which are suitable for doing the test, here we was selected a total of 75 people referenced to different education groups. The classification of the groups given by the Education Group [EG] (45 people from the college students hose aged between 19-23 year), the Semi-Educated Young Group [SEYG] (20 people know how to read and write whose aged between 20-30 year) and also the Semi- Educated Group [SEG] (10 people know how to read and write whose aged between 45-60 year). We try here by selected that's groups satisfied the requirements of a small and good statistic process based on a good and corrected answered from that's groups.

The study surveyed the existing lighting conditions in different types of environment like in class rooms, libraries, laboratories, & common rooms in a College of Engineering, living rooms, sleeping (bedrooms) rooms, study areas in the participated people houses that participate in the study in Baghdad/ Iraq.

The descriptions of the class rooms were: the area was little more than (50 m^2), the artificial lighting in that class rooms were by a (16 fluorescent tube with wattage of (40w) fixed at the roof of the class rooms at equal distances on that roof at height of (3.45 m), the class room was contain a single big window covered by curtain and a small door, so the effect of the sun light on our study was little. Furthermore, the descriptions of the rooms in houses were: in general the area was little more than (20 m^2), the artificial lighting in that rooms were by a (fluorescent tube with wattage of (20-40)w and tungsten bulbs of wattage (100w) fixed at the walls of the rooms at different distances at height of approximate of (2.5 m) the room was contain a small window(s) covered by curtain and a small door, so the effect of the sun light on our study was little.

Also the study determined the light – intensity in different types of environment (as shown above), and finally established and tested the lighting standard .

3 - THE RESULTS

The results were carried out by putting the DLM in the middle of the place that we needed to find its lighting intensity and in different places, environments for the different groups that we were chosen as described above.

The responses on different lighting intensity for different groups, places were tabled; by asking all the peoples that we selected about the area of their rooms and how many

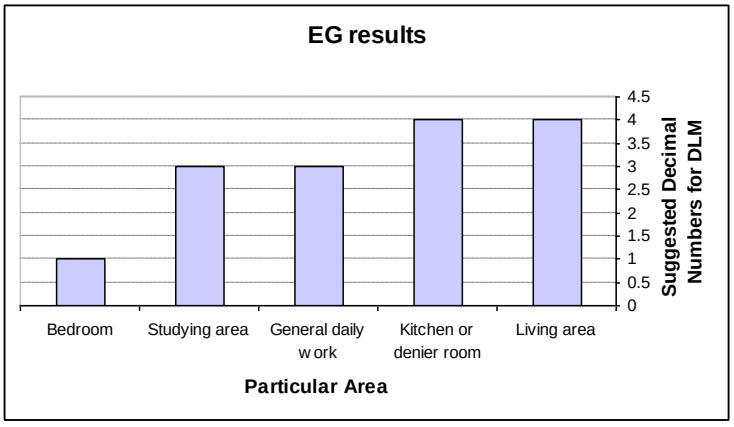
and what types of their artificial lighting and about what height, spaces dose this lighting placed and recorded the response of them, so, the standard division of those results was founded as shown in tables. So the results were as below:

In which the Existing mean of the decimal numbers of the DLM are the average decimal number of the reading of the DLM for a certain group in a certain particular area and the Suggested decimal numbers of the DLM are the approximate integers decimal numbers of the Existing mean of the DLM readings in all tables.

The results of the [EG] were tabled in table (5) and figure(4) shown below:

Table (5)EG results

Particular area	Existing mean of the Decimal Numbers of the DLM	Suggested Decimal Numbers for DLM	Standard Deviation SD
Class room, studying area	3.076923	3	0.27735
Living room	3.769231	4	0.83205
Bedroom	1.307692	1	0.630425
Kitchen room	3.846154	4	1.068188
General daily work	3	3	1.080123

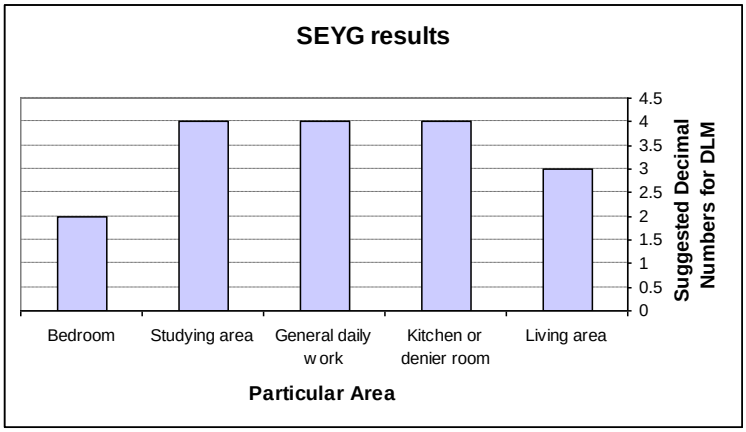


Figure(4) EG results

The results of the [SEYG] were tabled in table (6) and figure(5) shown below:

Table (6)
SEYG results

Particular area	Existing mean of the Decimal Numbers of the DLM	Suggested Decimal Numbers for DLM	Standard Deviation SD
Class room, studying area	3.569874	4	1.102548
Living room	3.752143	3	0.897454
Bedroom	1.862545	2	1.042587
Kitchen room	4.132584	4	0.992548
General daily work	3.854786	4	1.088475

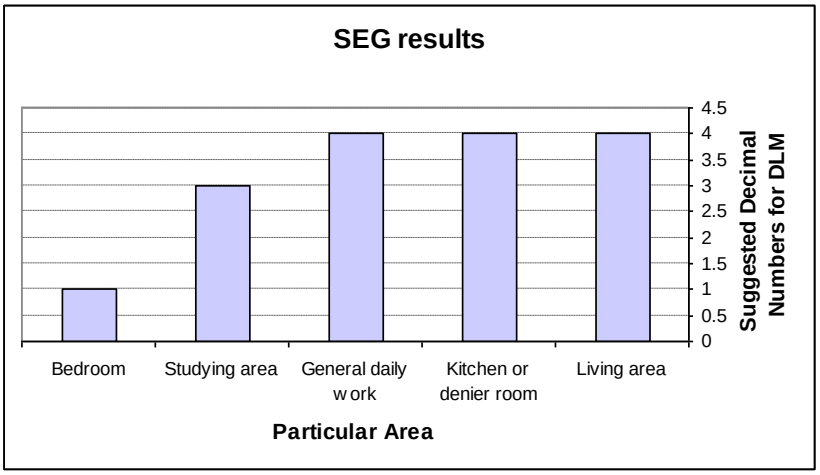


Figure(5) SEYG results

The results of the [SEG] were tabled in table (7) and figure(6) shown below:

Table (7)
SEG results

Particular area	Existing mean of the Decimal Numbers of the DLM	Suggested Decimal Numbers for DLM	Standard Deviation SD
Class room, studying area	3.153846	3	0.987096
Living room	4.258761	4	1.095472
Bedroom	0.984572	1	0.845762
Kitchen room	4.012587	4	1.066874
General daily work	3.652148	4	1.084257



Figure(6) SEG results

4 - DISCUSSIONS

The results can be discussed for each of the three groups alone as follows:

For the (EG) group the results were summarized in table (4). First we noted that as compared by the lighting standard that we chose in table (1) all results were less than the recommended standard due to different reasons, the reasons could be caused by their not a good knowledge and understanding to the lighting standard in our life and what could this caused a serious lighting problem and its effect. Secondly, we

justified the existing mean of the decimal numbers of the (DLM) to a decimal numbers who greater than the old one's by one to an integer decimal number according if it's fraction more than (0.5) of the decimal number (i.e. 3.769231 » 4) and if the existing mean of the decimal numbers of the (DLM) fractions more less than (0.5) of the decimal number we discarded the fractions (i.e. 3.076923 » 3) as shown in table (4).

In order to have an integer numbers that out from the DLM and to take it into the standard of lighting.

Finally, the standard deviation (SD) for EG group it's has the minimum value between the standard deviations (SD) of all groups due to the (EG) high credibility.

For the (SEYG) group the results were summarized in table (5). First we noted that as compared by the lighting standard that we chose in table (1) all results were less the then recommended standard due a different reasons, and also we noticed that the existing mean of the decimal number of the (DLM) for the general daily work more than in the (EG) group, due to this group work more time than the (EG) Secondly, we justified the existing mean of the decimal numbers of the (DLM) to a decimal numbers by the same way above (used in EG group).

Finally, the standard deviation (SD) for SEYG group it's approximately the same as in SEG group since approximately they had the same age levels.

For the (SEG) group the results were summarized in table (6). First we noted that as compared by the lighting standard that we chose in table (1) all results were less than the recommended standard due a different reasons, and also we noticed that the existing mean of the decimal number of the (DLM) for the general daily, studying area, Bedroom and more than in the other groups due to this group needed more light than the other groups. Secondly, we justified the existing mean of the decimal numbers of the (DLM) to a decimal numbers by the same way above (used in EG group). Finally, the standard deviation (SD) for SEG group it's differ from all the standard deviation (SD) of the three groups due to their ages, tempers, and pressman.

The possible reasons that we respected for our results that came less the recommended standard might be the improper placements of bulbs and florescent tubes and mounting height of the light fixtures, its numbers, and use of lower wattages of bulbs / florescent tubes and improper cleaning schedule.

The major contributing reasons were due to the lake of awareness regarding the light intensity required to perform the different tasks.

5 - CONCLUSION

Artificial Lighting may become significant matter when we reducing the dependence on day light (sky and sun light), so lighting may become a problem where it is

excessive, poorly designed, badly installed or poorly maintained. We could conclude that for all groups (EG, SEYG & SEG); the mean intensity of the artificial lighting was lower than the recommended standard which is a disadvantages.

The (SEG) needed more light intensity than the other groups (due to their ages).

Among all the three groups the EG group has the greater credibility due to they had lower standard deviation (SD).We could achieve the India lighting standard by putting the proper lighting for each selected area; this can be done as shown in the table (8). Table (8) shows each area and how it need for lighting {lighting by using artificial lighting such as bulbs (100W) and florescent tubes (40W) (4 ft)}, we also assumed that the particular area in general was little more than (20 m^2) at height of approximate of (2.5 m).

Table (8)
The proper lighting

Particular area	Recommended standard (Lux)	Number of florescent tubes (40W)(4 ft)	Number of bulbs (100W)
Class room, studying area	**150**	**1**	**-**
Living room	**300**	**1**	**3**
Bedroom	**185**	**1**	**-**
Kitchen room	**375**	**2**	**-**
General daily work	**150-375**	**1-2**	**-**

So, we need to great awareness about the serious lighting problem and its effect.

Finally, the recommended standard of our country for lighting also badly needed to be popularized.

"Light is the life itself"

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