Plant Shaded Area: A Nice Place To Stay?

Soe Myat*, San Nyein Khine, Khin Kyaut New***,**
Aye Nyunt*, Than Shwe*, Khin Su Su Aung*

*Department of Physics, Sittway University
**Faculty of Computer System and Technology, University of Computer Studies(Sittway)
***Department of Natural Science, University of Computer Studies(Sittway)

DOI: 10.29322/IJSRP.9.08.2019.p9260
http://dx.doi.org/10.29322/IJSRP.9.08.2019.p9260

Abstract- Plants have evolved on the earth' surface together with human beings, and then they depend on each other like a friend. Plants produce many different types of sunscreens. Some of these are physical sunscreens (trichomes) to reflect UV-B and some are chemical sunscreens (anthocyanins) to absorb UV-B. The high level UV radiation can increase trichome density and anthocyanin content. On the other hand, plants' leaves in the high level UV radiation have high concentration of absorbing pigments. In this work, the absorbance spectra and the light harvesting efficiency (LHE%) of absorbing pigments extracted from the leaves of pink-flowered rain tree (*Samanea saman*) at sea level and at 1200 m above sea level, have been studied by UV-VIS spectroscopy to protect the effects of UV attack. According to the absorbance spectra, two plants can absorb nearly 100% of UV-A and UV-B, and the absorbing species in higher elevation plants are more concentrated than that in lower elevation plants.

Index Terms- absorbance, LHE%, sinapoyl malate, sunscreen, UVR8

1. INTRODUCTION

Plants need to protect themselves from damaging ultraviolet rays because they bask in the sun for several hours in a day. While they absorb light for photosynthesis, many plants use a group of chemicals called sinapate esters to defend against the sun. These aromatic compounds sit in the upper cell layers of the plants' leaves. One type of these compounds is sinapoyl malate which provides the bulk of the UV protection. On the other hand, they filter out the entire spectrum of ultraviolet-B radiation, known to damage plants and human DNA. The range of UV wavelengths blocked by sinapoyl malate is the same as those that damage human tissues. And then there is the relation between leaf thickness and UV-B absorbing pigments of plants with an elevation gradient. Terrestrial plant species vary widely in their adaptation to solar UV-B radiation. The various responses of plants in higher position to enhanced UV-B protection are increasing leaf thickness and increasing concentrations of UV-B absorbing compounds[4].

Electromagnetic radiation is broadly divided into infrared radiation (IR), visible light (VIS), and ultraviolet radiation (UV). Heat is part of IR radiation, which is not visible to the human eye. VIS is the wavelength range of general illumination. UV radiation is also divided into three distinct bands in order of decreasing wavelength and increasing energy: UV-A (315~400 nm), UV-B (280~315 nm), and UV-C (100~280 nm). Different wavelengths and energies associated with UV subdivision correspond to distinctly different effects on living tissue. The wavelengths and the photon energies of UV-A, UV-B and UV-C are listed in Table 1.1.

Table 1.1 Wavelength and Energy of UV spectra

Spectrum	Wavelength(nm)	Energy(eV)
UV-A	400~315	3~3.9
UV-B	315~280	3.9~4.4
UV-C	280~100	4.4~12.3

The amount of solar UV-A and UV-B reaching the earth's surface is affected by latitude, altitude, season, time of the day, cloudiness, and ozone layer. The highest irradiance is at the higher elevations and the equator. UV radiation is strongest between 10 am and 4 pm. During a sunny day, the UV spectrum that reaches the earth's surface consists of 3.5% UV-B and 96.5% of UV-A. UVB is primarily associated with erythema and sunburn. It can cause immunosuppression and photocarcinogenesis[3].

The unfiltered UV radiations have been prevented by ozone layer (O_3) for living things and non-living things. The thickness of ozone layer (about 3 mm at STP) varies seasonally and geographically. Every 0.01 mm thickness of the layer is equal to one Dobson Unit (1 DU). The average amount of ozone in the stratosphere layer across the globe is about 300 DU or thickness of only 3 mm at STP. Ozone layer cannot absolutely absorb UV-A, but it can absorb all of UV-C and most of UV-B. So, most UV-A and less UV-B can reach on the earth's surface, shown in Fig 1.1. The decrease of thickness of ozone layer or its depletion can cause the problems for human beings and living things due to the falling of the intense unfiltered UV radiation. UV-B can cause the burn of the skin, the skin cancer and the damage of cornea. The ozone layer is now still being damaged by the CFC emission. CFC is man-made chemical that contains chlorine, fluorine and carbon. When the chlorine and bromine react with ozone layer, the fission of O_3 causes ozone layer depletion. The substances that decrease the thickness of ozone layer are called Ozone Depleting Substances (ODS): Chlorofluoro carbon (CFC). So, everybody should avoid outdoor exposure from 10 am to 4 pm. World Health Organization and World Meteorological Organization provide the UV Index, shown in Table 1.2, for every day to the public. UV Index reading of 0 to 2 means low danger from the sun's UV rays for the average person. Index of 3 to 5 causes moderate risk of harm from unprotected sun exposure and 6 to 7 of UV Index is high risk of harm. At this time, protection against skin and eye damage is needed. UV Index of 8 to 10 means very high risk of harm. People need to take extra precautions because unprotected skin and eyes will be damaged and can burn quickly. 11 or more means extreme risk of harm from unprotected sun exposure. All precautions must be done because unprotected skin and eyes can burn within a few minutes[6].

Table 1.2 UV Index

UV INDEX	DANGER CATEGORY
11+	Extreme
8 to 10	Very High
6 to 7	High
3 to 5	Moderate
1 to 2	Low

1 2 3 4 5 6 7 8 9 10 11+ UV INDEX

According to the literature, plants' leaves can prevent the UV attack although the ozone layer is still damaged by CFC emission. Plants sense UV light through specific UV photo-receptors called UV Resistance Locus 8 (UVR8). It is important for a plant to be able to sense UV wavelengths because they can cause damage to DNA. Upon sensing UV light, UVR8 photo-receptors send signals to other parts of the plant that causes changes in growth and development. The plant will begin to make DNA repair enzymes for fixing damaged DNA and "sunscreen" for preventing more damage. Together, these protective mechanisms prevent further damage to plant cells.

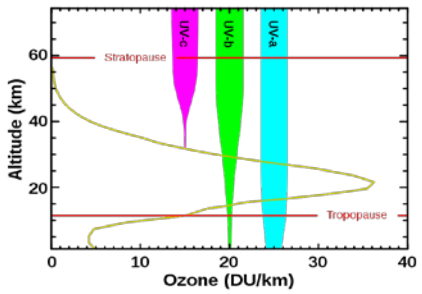


Fig 1.1 UV protection of ozone layer

There are many UV photo-receptors in the plants' leaves such as UVR8 for UV-B and cryptochrome for UV-A. The absorption of these rays by UVR8 induces physiological responses that enable the plant to acclimatize and survive. Indeed, plants produce enzymes that repair damage caused to DNA during sun exposure, as well as powerful antioxidants that neutralize free radicals produced by the action of UV. UVR8 receptors accumulate within the cell nucleus and participate in a cascade of biochemical reactions. UVR8 receptors are ultrafast photoprotecting sunscreens in natural plants. The response of UVR8 with UV-B by trans–cis photoisomerization is shown in Fig 1.2[5].

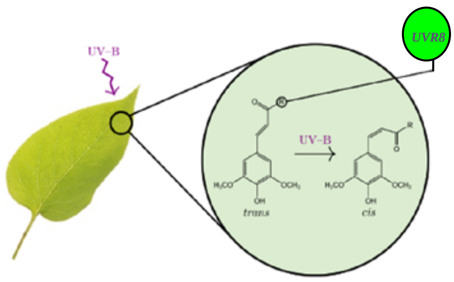


Fig 1.2 Response of UVR8 in plants'

ISSN 2250-3153

In this work, the comparative study of optical properties of light absorbing pigments extracted from pink-flowered rain tree leaves at sea level and at 1200 m above sea level in Rakhine state, Myanmar, have been analyzed spectrophotometrically for the protection of UV attack. Fig 1.3 shows the electromagnetic spectrum of solar radiation with UV-A and UV-B[7].

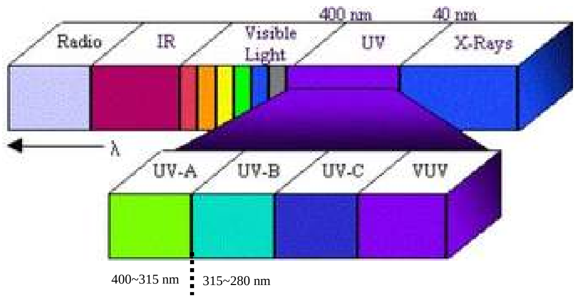


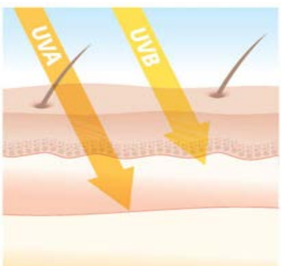
Fig 1.3 Electromagnetic spectrum

II. BACKGROUND THEORY

2.1. Classification of the Effects of Ultraviolet (UV) Radiation and UV-VIS spectroscopy

Ultraviolet (UV) radiation are classified into three groups according to their wavelength. They differ in their biological activity and the extent to which they can penetrate the skin. The shorter the wavelength, the more harmful the UV radiation. However, the shorter wavelength of UV radiation is less able to penetrate the skin. UV-C with the shortest wavelength is the most damaging type of UV radiation. But it is completely filtered by ozone layer and does not reach the earth's surface. UV-B is very biologically active but cannot penetrate beyond the superficial skin layers, shown in Fig 2.1. It is responsible for delayed tanning and burning. In addition to these short-term effects, it enhances skin ageing and significantly promotes the development of skin cancer. But most of UV-B are filtered by ozone layer.

As shown in Fig 2.1, UV-A can penetrate into the deeper layers of the skin and is responsible for the immediate tanning effect. Furthermore, it also contributes to skin ageing and wrinkling. For a long time it was thought that UV-A could not cause any lasting damage. Recent studies strongly suggest that it may also enhance the development of skin cancers[1].



To protect UV attack, the materials used in UV protection have to be analyzed for the optical properties of these materials. The absorbance of a material is directly proportional to the path length of material and the concentration of the absorbing species in material. So, UV-VIS spectroscopy is also called the absorption spectroscopy in UV-VIS spectral region.

$$A = \varepsilon\ c\ L = \log_{10} \frac{I_0}{I}$$

A = absorbance

ε = molar absorptivity or extinction coefficient

c = concentration of the absorbing species

L = path-length

I_0 = intensity of light before passing through the sample I = intensity of light after passing through the sample

This is Beer-Lambert law for absorption spectroscopy. The light harvesting efficiency (LHE%) of absorbing pigments can be calculated by the below formula.

$$\%LHE = (1 - 10^{-A})x100\%$$

LHE = light harvesting efficiency

A = absorbance

The materials with high energy UV photons absorption and broader absorption band should be selected as UV protectors. And then they need to have non-toxicity, good adhesion and stability to use in sunscreen.

III. EXPERIMENTAL SET-UP

3.1. Preparation and Characterization of Light Absorbing Pigments

The pink-flowered rain tree leaves, shown in Fig 3.1, were dried in air at first and cut into small pieces. And then they were pounded with motor and pestle. After that, the powder was mixed with ethanol for 24 h, in Fig 3.2(a). Before the UV measurement, the solution was made by using VOTEX-MIXER for more pigments extraction, in Fig 3.2(b) and was created to filter by TABLE TOP CENTRIFUGE, in Fig 3.2(c)[2].

Fig 3.1 Leaves of pink-flowered rain tree

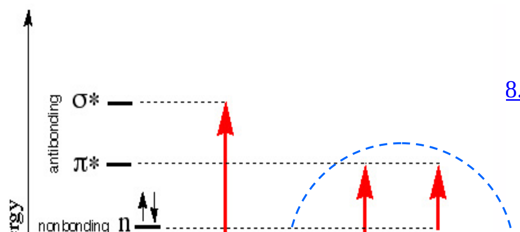
Fig 3.2 shows the pigment extracting process and the photograph of UV-1800 spectrophotometer, in Fig 3.2(d).

Fig 3.2 Preparation and characterization of UV-VIS spectrophotometry

3.2. Analysis of UV-VIS Spectroscopy

UV-1800 spectrophotometer is a double-beam instrument in which the light is split into two beams before it reaches the sample. One beam is used as the reference while other beam passes through the sample. The reference beam intensity is taken as 100% Transmittance (or 0 Absorbance), and the measurement is displayed in the ratio of the two beam intensities.

UV-VIS radiation interacts with the sample which causes electronic transitions (promotion of electrons from the ground state to the high energy excited state). The following electronic transitions are possible, shown in Fig 3.3: (i) **π →π***, (ii) **n →π***, (iii) **σ →σ***, (iv) **n →σ***. Among them, **σ to σ*** transition requires an absorption of a photon with a wavelength less than 200 nm and **n to σ*** is initiated by light whose wavelength is in the range 150 ~ 250 nm. The two are not in the UV-VIS range. Thus, only **π to π*** and **n to π*** transitions in the region of the spectrum (200 ~ 700 nm) are observed. Many inorganic species show charge-transfer absorption.



IV. RESULTS AND DISCUSSION

4.1 Absorbance and Light Harvesting Efficiency of Pigments Extracted from Rain Tree Leaves

For the protection against UV attack, the high energy UV photon absorption is important. The broader absorption gives the high performance for UV protection. In this work, absorbance data are grouped into three regions such as UV region, visible region and IR region for the UV protection and the production of sunscreen. And then light harvesting efficiencies of pigments extracted from rain tree leaves at sea level and at 1200 m above sea level have also studied by UV-VIS spectroscopy. Absorbance spectra and light harvesting efficiency of pigments are shown in Fig 4.1 and Fig 4.2 respectively.

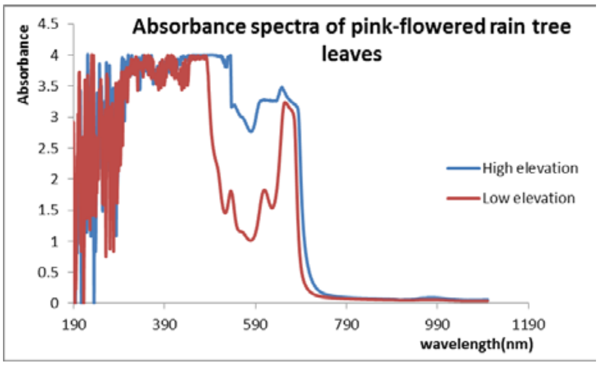


Fig 4.1 Absorbance spectra of two pigments

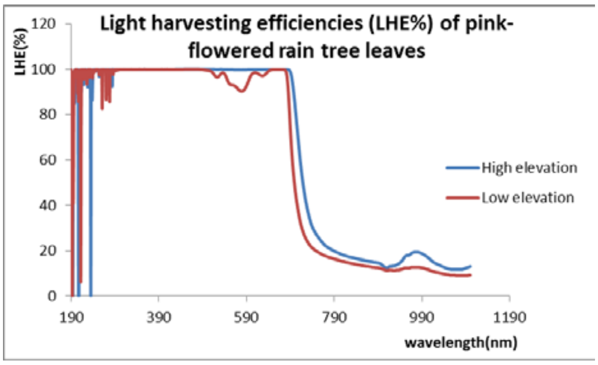


Fig 4.2 Light harvesting efficiencies of two pigments

The absorbance spectra and the light harvesting efficiencies of two pigments extracted from rain tree leaves at different elevations show that they can absolutely absorb UV-A and UV-B. Fig 4.3 and Fig 4.4 show UV-A & B absorbance and their LHEs. As shown in these figures, high elevation plant has more absorbing species than low elevation plant. Because there is more pigment concentration in high plant. But the sample preparation of two pigments should be carefully made for equal solvent and equal leaves' powder.

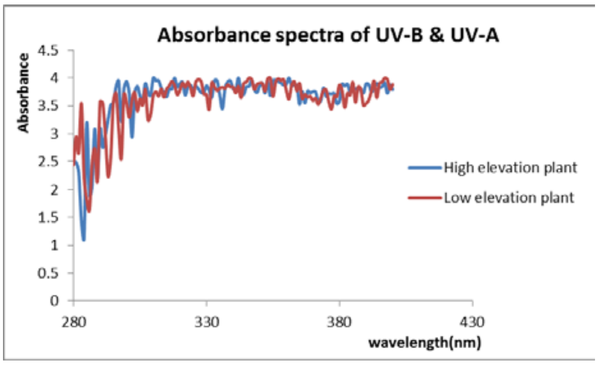


Fig 4.3 Absorbance spectra of UV-B & UV-A

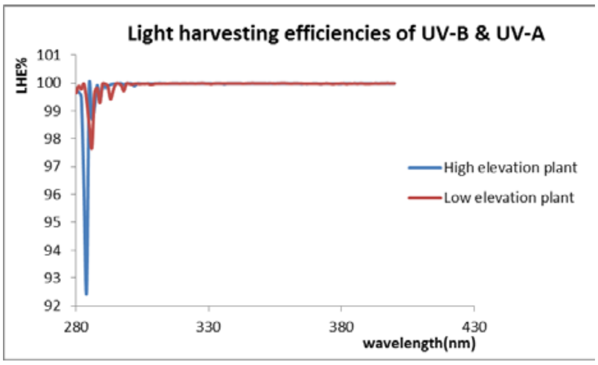


Fig 4.4 Light harvesting efficiencies of UV-B & UV-A

According to light harvesting efficiency of UV-A & B regions, the leaves of pink-flowered rain tree have more than 90% between the wavelength of 280 nm and 315 nm, and 99% of LHE between the wavelength of 315 nm and 400 nm. So pink-flowered rain tree leaves can protect UV-A and UV-B attack.

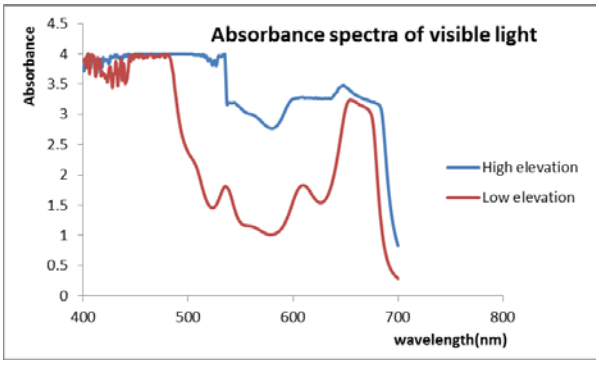


Fig 4.5 Absorbance spectra of visible light

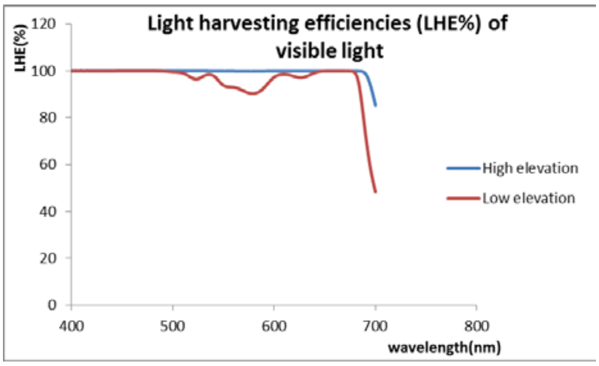


Fig 4.6 Light harvesting efficiencies of visible light

The pigment extracted from high elevation rain tree leaves has more absorbance than low elevation tree, shown in Fig 4.5. And then 100% LHE of high plant exists in the visible region.

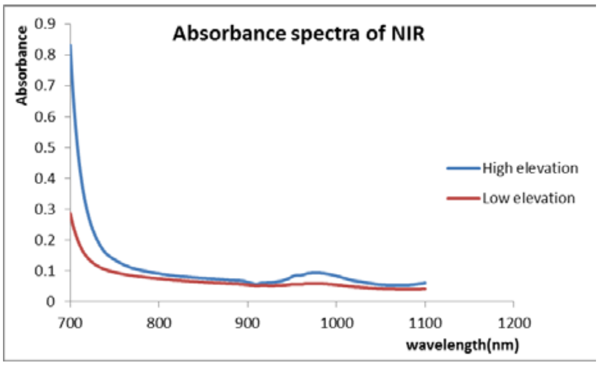


Fig 4.7 Absorbance spectra of NIR

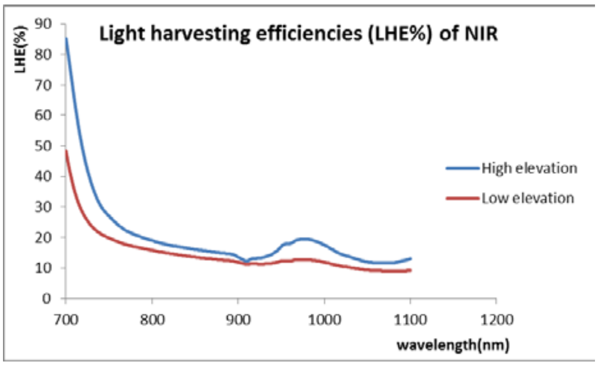


Fig 4.8 Light harvesting efficiencies of NIR

Pink-flowered rain tree has the broader absorption band up-to the wavelength of 1100 nm. On the other hand, the leaves can absorb both UV-VIS photons and NIR photons. The band-gap energy is 1.7 eV because the strong cut-off point is at the wavelength of 735 nm.

V. CONCLUSION

Ozone layer is the essential part of the earth's atmosphere to prevent the danger of unfiltered UV radiation for living things and non-living things. Due to the activities of human beings, the depletion of ozone layer has been caused by the large amount of chloroflurocarbon (CFC) emission in the earth's atmosphere. So the uses of ODS must be reduced all over the world. To avoid the outdoor exposure of UV radiation, World Health Organization and World Meteorological Organization announce UV-Index and many cosmetic companies produce the products of UV protection.

In this work, the absorbance properties and the light harvesting efficiencies of pink-flowered rain tree leaves at sea level and at 1200 m above sea level, have been studied by UV-VIS spectroscopy for UV protection and for the use in sunscreen cosmetic products. Both of plants can absolutely absorb UV-A and UV-B. Furthermore, high elevation plant has high concentration. On the other hand, pigments in high elevation plant can more absorb UV-VIS photons than that of low one. According to Fig 4.4, both the plants have nearly 100% light harvesting efficiency of UV-A and UV-B. And then the plants' leaves in the more higher elevation, greater than 1200 m above sea level, should be analyzed for the concentration of absorbing species which give the sensitizers of DSSCs. Therefore, the shaded areas under the pink-flowered rain tree are regarded as a nice place to stay, especially in summer.

ACKNOWLEDGEMENT

I would like to thank Mr. Htay Win for helping with this research work.

REFERENCES

[1] A. J. McMichael, 1993. *Planetary overhead: global environmental change and the health of the human species* (UK: Cambridge University Press)

[2] C. Giuseppe and D. M. Gaetano, 2008. "Red sicilan orange and purple eggplant fruits as natural sensitizers for dye-sensitized solar cells," *Sol Energy Mater Sol Cells*, vol. 92, pp. 1341-1346.

[3] D. T. Shindell, et al., 1998. "Increased polar stratospheric ozone losses and delayed eventual recovery owing to increasing greenhouse gas concentrations. *Nature*, 392 (6676): 589-592.

[4] E. W. C. Chan, et al., 2009. "Effects of different drying methods on the antioxidant properties of leaves and tea of ginger species," *Food Chemistry* 113 (1), 166-172.

[5] F. Allais, J. C. Dean, T. Zwier, R. Kusaks, 2014. "Plant Sunscreens in the UV-B: Ultraviolet Spectroscopy of Jet-Cooled Sinapoyl Malate, Sinapic Acid, and Sinapate Ester Derivatives" *Journal of the American Chemical Society*, 136(42).

[6] G. Horneck, 1995. "Quantification of the biological effectiveness of environmental UV radiation," *Journal of Photochemistry and Photobiology B: Biology*, 31(1-2): 43-49.

[7] M. Z. Jacobson, 1999. *Fundamentals of atmospheric modeling* (UK: Cambridge University Press)

AUTHORS

First Author – Dr Soe Myat, Associate Professor in Physics, Sittway University, Myanmar and email address- soemyatsu1@gmail.com.

Second Author – Daw San Nyein Khine, Associate Professor, Faculty of Computer System and Technology, University of Computer Studies(Sittway), Myanmar and email address- sannyeinkhaing969@gmail.com.

Third Author – Dr Khin Kyaut Nwe, Associate Professor, Department of Natural Science, UCSP, Myanmar and email address- drkhinkyautnwe@email.com.

Fourth Author – U Aye Nyunt, Lecturer, Department of Physics, Sittway University, Myanmar and email address- maungayenyunt333@gmail.com.

Fifth Author – Daw Than Shwe, Lecturer, Department of Physics, Sittway University, Myanmar and email address- dawthanshwe2018@gmail.com.

Sixth Author – Daw Khin Su Su Aung, Assistant Lecturer, Department of Physics, Sittway University,

Myanmar and email address-
khinsusuaung559@gmail.com.