CONSTRUCTION OF THE SUNPATH DIAGRAMS FOR PEKAN AREA FOR SIMULATING THE SOLAR RADIATION EFFECTS TO A BUILDING

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Thesis submitted in fulfillment of the requirements
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APPROVAL DOCUMENT

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I hereby declare that the work in this project is my own except for quotations and summaries which have been properly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of another degree.

Signature :
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Dedicated to my beloved parents, Mohd bin Ibrahim and Ramlah binti Ismail, family, and all my friends

Thank you so much for always being there for me and support me.

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I would like to express my gratitude to Allah by His permission I am done with my project and it ran smoothly and successfully. Alhamdulillah, His Willingness has made it possible for me as the author to complete the final year project in time.

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ABSTRACT

This thesis deals with the sun is a valuable source that provided to the earth because the sun produce renewable energy and do not pollute the surroundings. However, the sun can create the problem to the population of the earth. Extreme heat produced by the sun radiate directly to the building and may cause lower energy efficiency. This study concentrates on the solar geometry and constructing of sunpath diagram for Pekan Area by simulating the solar radiation that the effect of a building. Pekan, Pahang is taken as my reference location at a latitude 3^{o} 29' North for construct sunpath diagram. There are parameters used for constructing a diagram which is the latitude of the object, declination angle, altitude angle, azimuth angle and hour angle. The sunpath diagram is a way of representing annual changes in the path of the sun through the sky on a single 2D diagram. Based on the sunpath diagram of Pekan Area, shows the altitude angle is highest at the 21st of March in the northern hemisphere, it is also same for September, 21^{st} at southern hemisphere. It is because the sun is directly in line with the equator, it is called as the equinox, where the declination angle for equinox is equal to zero. The equinox occurs when the sun crosses the equator in which day and night are of the same length. Different for in June, 21^{st} and December 21^{st} is a minimum altitude angle at northern and southern hemisphere. The declination angle for both months is the maximum and minimum 23.45^{o} . Summer solstice occurs when northern hemisphere gets more daylight longer than a night, meanwhile winter solstice occurs when southern hemisphere gets more night time rather than daytime. There are many applications for sunpath diagram can be used by architect or engineers. For the example, they can use the sunpath diagram to calculate the solar radiation that radiates the building and how to control. Hence, the sunpath diagram can be used to find the best position for Solar Photovoltaic Cell and Solar Panel, window shading and water solar heating system.

ABSTRAK

Thesis ini membentangkan tentang matahari mengeluarkan sumber yang berguna kepada bumi kerana matahari mengeluarkan tenaga yng boleh diperbaharui dan tidak mencemarkan keadaan sekeliling.Walau bagaimanapun, matahari juga boleh memberi masalah kepada penduduk di bumi. Haba yang berlebihan yang terhasil daripada matahari boleh memancarkan terus ke bangunan dan menyebabkan kecekapan tenaga yang lebih rendah. Mengambil Pekan sebagai rujukan utama tempat iaitu latitud 3^o 29' untuk membentuk kedudukan matahari dari terbit hingga terbenamnya matahari, setiap 21 haribulan dalam satu tahun. Kedudukan matahari ditentukan dengan mengetahui pengetahuan tentang geometri suria dan sudut suria. Ada beberapa asas parameter yang digunakan untuk membentuk kedudukan matahari iaitu latitud sesuatu objek, sudut cerun, sudut ketinggian matahari, sudut azimuth dan sudut jam. Parameter tersebut digunakan untuk membentuk gambar rajah posisi matahari. Berdasarkan gambar rajah kedudukan matahari di Pekan, Pahang menunjukkan sudut ketinggian matahri paling tinggi adalah pada bulan Mac, 21 haribulan dalam hemisfera utara, begitu juga pada bulan September, 21 haribulan dalam hemisfera selatan. Ini kerana, matahari berada di kedudukan sama garis dengan khatulistiwa ataupun ekuinoks dan sudut kecerunannya adalah kosong. Ekuinoks terjadi apabila cahaya matahari sama lurus apabila melintasi khatulistiwa, menyebabkan bumi mengalami kejadian siang malam dalam waktu yang sama lama. Berbeza pula dengan bulan Jun, 21 haribulan dan bulan Disember, 21 haribulan kerana kedua-dua bulan tersebut menunjukkan sudut ketinggian matahri yang paling rendah dalam hemisfera utara dan juga selatan. Sudut kecerunan matahari adalah maksimum 23.45^o dan juga minimum 23.45^o. Pada Solstis musim panas, bumi mengalami siang lebih lama kerana hemisfera utara bumi mendapat lebih cahaya matahari manakala pada solstis musim sejuk, hemisfera selatan bumi mengalami malam lebih lama. Terdapat banyak kegunaan gambar rajah kedudukan matahari yang boleh digunakan oleh arkitek mahupun jurutera.Contohnya, mereka menggunakan kedudukan matahari untuk mengira bilangan radiasi yang menembusi bangunan dan cara mengawalnya.Selain itu, mereka mengunakan gambar rajah kedudukan matahari untuk mencari posisi terbaik untuk memasang Tenaga Suria Fotovolta dan Suria Panel, teduhan tingkap dan juga Tenaga Suria sistem pemanas air

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LIST OF SYMBOLS

β	Altitude angle
γ	Azimuth angle
δ	Declination angle
I_{DN}	Direct radiation
h	Hour angle
ℓ	Latitude
ξ	Incident angle
θ	Surface azimuth angle
ρ	Reflectivity
Σ	Tilt angle
n	Total number of days of the year
I_t	Total irradiation
F_{ws}	View factor
α	Wall solar azimuth angle
Ψ	Zenith angle

LIST OF ABBREVIATIONS

AST	Apparent Solar Time
DST	Daylight Saving Time
FKM	Faculty of Mechanical Engineering
GMT	Greenwich Mean Time
LST	Local Standard Time
UMP	Universiti Malaysia Pahang
ST	Solar Time
PV	Photovoltaics

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

The sun is closely related to the earth. It not only provides light to the earth, it gives life to the earth. The sun is the brightest star in the Earth's solar system. And not only does the sun gives us light, but is also a valuable source of heat energy. The sun can be considered as the life giver to living things on this earth, because without the sun, many living thing organism would not exist and survive. However, the sun will also create problems for humans. For example, extreme heat produced by the sun may radiate directly into buildings and may cause lower energy efficiency. The earth rotates every 24 hours, and while it rotates give effect on night a day, it also revolves around the sun making one complete revolution in 365 days. There two movements follow a precise characteristics and geometry called the solar geometry, then giving rise to varying solar radiation which changes gradually. The movement of the sun relative to the earth therefore follows precise paths called sun paths and they can be plotted on a diagram called sun path diagram.

1.2 BACKGROUND

The earth rotates about on a fixed plane that is tilted 23.5^{o} with respect to its orbital plane around the sun. The earth needs 365 days to complete one year per rotation around the sun and the earth also needs 24 hours to complete one true rotation or one day around the sun. It is defined as the time taken for the sun to move from the zenith on one day to the zenith for the next day, or from noon today and to noon tomorrow. Thus, the length of the solar variability is calculated to be a day or 24 hr. Completing a year, a solar day may differ to as much as approximately 15 min. That is the reason why, for a Muslim, Azan time will be different by a few minutes from day to day and from year to year from Subuh to Isya' prayer's time. There are three reasons for this time difference. Firstly, it is because the earth's motion around the sun is not a perfect circle but it is eccentric. The second reason is due to the fact that the sun's apparent motion is not parallel to the celestial equator. The third reason is because of the precession of the earth's axis. The rotation of the earth also causes the day and night phenomenon. The length of the day and night is depends on the time of the year and the latitude of the location. But for Malaysia, being located close to the equator line, the length of the day and night are almost equal, 12 hours a day and night, but with some variation of about 30 min or so.

The path that the earth takes to revolve around the sun is called the elliptical path. However, to be exact, the number of the days the earth takes to revolve around the sun actually depends on whether referring to a sidereal year or solar year. A sidereal year is the time taken for the earth to complete exactly one orbit around the time interval between two vernal equinoxes. Equinoxes happen when the elliptic in the sun's apparent motion across the celestial sphere and celestial equator intersect. During the equinoxes every point on the earth gets exactly 12 hours of daylight, and 12 hours of night time. The earth is tilted 23.5^o the sun is at a maximum angular distance from the celestial equator. At the summer solstice which occurs around the 21st of June, the North Pole is pointing away towards the sun at a positive angle 23.5^o in the apparent declination of the sun. At winter solstice which occurs around the 21st of December the North Pole is pointing away towards the sun at a negative angle 23.5^o in the apparent declination of the sun.

Everyone knows that the sun rises in the east and sets in the west. This phenomenon has always amazed the mankind. The sun certainly brings about interest for everyone to study its movement and behavior especially its position at different times of the days and months during the year. The sun will rise and set from a different point of the horizon and move along different paths across the sky. Expect during the equinoxes, the sun does not rise exactly in the east and sets in the west. They are determined by the latitude of the locality. Measuring the angle of the sun in its motion across the sky is done by measuring altitude and azimuth angles. Altitude angle is the angular distance above the horizon measured perpendicularly to the horizon. The azimuth angle is the angular direction measured along the horizon in a clockwise direction. The sun paths are different due to the factors such as different local or local altitude, rising and setting position which is based on the time of the year and lastly due to the duration of the day and night. The sun path diagram is a way of representing the annual changes in the path of the sun through the sky on a single 2D diagram.

1.3 PROBLEM STATEMENT

The energy efficiency of a building is highly dependent on the solar geometry, and therefore the solar geometry must be fully understood for any initiative towards improving the energy efficiency of a building. This is especially true for buildings in a hot climate country like Malaysia, where air-conditioning takes up about 60 to 70 % of the total energy consumed in a building.

The solar geometry has many special effects on the earth. The movements of the earth with respect to the sun create unique characteristics to the earth. The rotation of the earth within the 24 hour period gives rise to day and night, whereas the revolution of the earth around the sun with the earth polar axis inclined at a certain fixed angle gives rise to the changing day and night hours as well as the seasonal changes, from spring to summer to autumn and winter, and back again to summer.

With both movements combined (rotation and revolution) gives rise to further implications to the earth, particularly the solar radiation. The rate of this solar radiation changes every hour of the day, and every day of the year, based on the solar geometry. The solar radiation in turn, gives rise to thermal behavior of a building, and for hot-climatic countries like Malaysia, solar radiation is the major contributor to the air-conditioning load of the building or a space.

Using the knowledge and science of solar-geometry, it is useful to construct Sun path Diagrams for any particular locality. From the sun path diagrams, the engineer and architect can determine the positions of the sun from which the building's orientation can be optimally chosen for the highest energy efficiency, together with the window size and possible use in other applications such as the design of window shade or overhang.

It is not easy to find the Sun path Diagrams ready made for the exact location of the Pekan town. This Final Year Project therefore aims at constructing the Sun path Diagrams for Pekan Town, using a computer program and also data are tabulated in Microsoft Excel Office that will be constructed using the solar geometry equations well established now, to help in the design of energy efficient buildings.

1.4 OBJECTIVE

The objectives of this study are:

1. To understand and study of the solar geometry.

2. To construct the sun path diagrams for a Pekan area with a computer programming and also Microsoft Excel Office with the intention of simulating the solar radiation effects to a building.

1.5 SCOPE

The purpose of this study is to study the solar geometry and construct the sun path diagram for Pekan area. This requires knowledge of the equations involved that determine the changing position of the sun with respect to the earth.

Based on the equations identified for the solar geometry, a computer program will be constructed and also calculating the data using equation provided. It is expected that the sun path diagram be plotted by the computer using Microsoft Excel Office.

The sun path diagram has its special uses, particularly in constructing horizontal shaded for windows, in determining the best position and angle for constructing photovoltaic panels, and in positioning solar hot water systems. This will be elaborated in the final part of the report.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter deals with the review of the solar geometry that would give effect on the earth especially toward energy efficiency in buildings and constructing the sun path diagram for any location or latitude. This chapter begins with a general review of explanations such as a simple definition of the key words and finally constructing the sun path diagrams using knowledge of solar geometry. In this literature review, previous works related to this study are discussed.

2.2 ENERGY EFFIENCY

Many engineers try to increase energy efficiency of the building after the building in completely ready. But without realizing it, the solar geometry is one effective initiative for engineers and architects to improve higher energy efficiency level of the building even before construction. Ramly and Hussain (2012) have stated that the main factor of energy efficiency in building design is to create buildings that utilize a minimum amount of energy. Energy efficiency is an important way of reducing carbon emission and possible climate changes as well as to contain the rapid growth of energy consumption in this world, contributing the preventing supply and mitigating the depletion of energy resources as be cited in Santos et al (2012) . The level of energy efficiency for decreasing the total energy consumption is not easily counted or measured. According to Brookes, Herring and Sorrell, increased energy efficiency may increase rather than reduce, energy consumptions. (Santos et al, 2012). This fact is due to rebound effect caused by reductions in the marginal cost of energy to promote the environments.

The simple definition of energy efficiency considers the relationship between how much the energy is introduced into a process and criteria to be analyzed. Decreasing energy demand at source is not only better in the long term of sustainability, but also in many instances may also endure very little cost (Madomercandy and Haris, 2006). Improving energy efficiency in the building will contribute to the good side of the environment in the future.

2.3 CLIMATE

The climate in Malaysia can generally be described as tolerable in terms of thermal requirements. Pereira, Silva and Turkienikz (2001) has stated that the main strategic control for making adequate is passive solar and shading of solar radiation to local climatic condition. The passive solar and shading of solar radiation especially true for buildings in hot climates like Malaysia where air conditioning takes up about 70% of total energy consumed in a building. Due to Malaysia's orientation located near to the equator plane, Malaysia is a categorized as an equatorial country which being hot and humid throughout a year.

2.4 SOLAR ENERGY

The sun is the brightest star in the Earth's solar system. In order to give our earth light, also gives valuable benefits to living things as a source of heat energy. Without the source of energy from the sun, living things in an ecosystem would hardly exist and survive. Since solar energy is a natural resource that does not require burning the fossil fuels and associated with the gas emission, solar energy is considered as renewable energy. Many developing countries have already implemented these energy resources in order to supplement the energy from fossil fuel. Replacing fossil fuels with renewable energy sources can also improve national security by reducing dependence on imported energy, hence the increasing focus on solar energy devices for their nonpolluting and renewable qualities has led to the recent interest in sustainability and in green buildings (ASHRAE, 2011).

2.5 SOLAR GEOMETRY

In the thermal or climatic design of buildings, the sun is the most influential. Understanding of solar geometry is one of the best ways to improving the energy efficiency of the building .Before the engineer or architect come up with the design of the building to control solar energy, it is important to understand the solar geometry and the relationship between sun and earth as the sun will directly affect the thermal behavior of the buildings.

2.5.1 ROTATION

The sun has a unique relationship with the earth and gives many special effects to the earth. In a fixed plane tilted at an angle of 23.45^o, the earth rotates 24 hours to complete one rotation or sidereal period. The earth's sidereal period will always be 24 hours since the speed of earth's rotation is constant throughout the year. In the course of the year, a solar day may differ to as much as 15 min. For simplicity, the earth completes one rotation every 24 hours based on the solar day and it moves at the rate of 15^o per hrs as full rotation is 360^o. Because of the sun appears to move at the rate of 360^o in 24 hours, its apparent rate of motion is 4min per degree of longitude has been carried out by ASHRAE (2011). The apparent path of the sun's motion across the sky will make the sun produces a daily solar arc at the different latitudes and at the different angles each day. This daily and hourly solar arc is also called the solar path or sun path. The rotation of the earth about its axis also causes the day and night phenomenon. The length of the day and night depends on the time of the year and the latitude of the location.

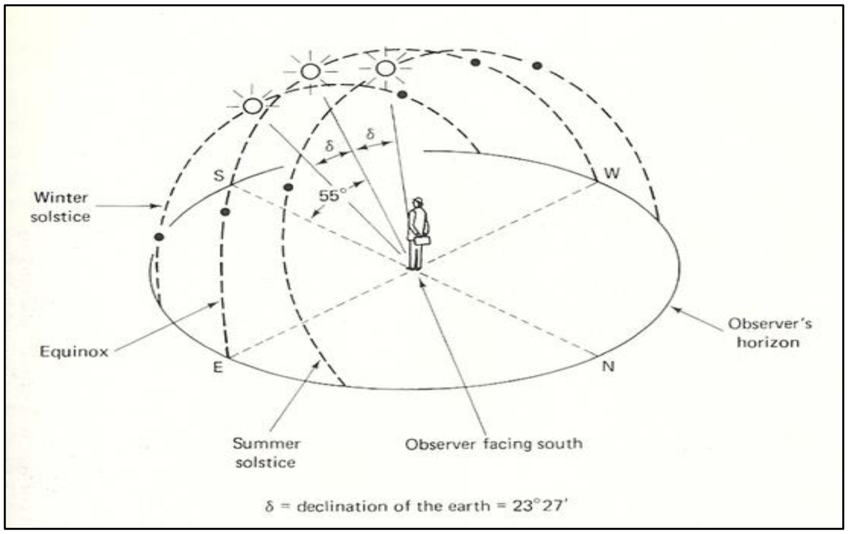


Figure 2.1 different angles of the sun

Source: Retrieved from
http://solarwiki.ucdavis.edu/The_Science_of_Solar/1._Basics/B._Basics_of_the_Sun/VI._The_Sun's_Motion (2012)

In Figure 2.1 shows that in the northern hemisphere, the shortest solar day occurs around December 21 which is called winter solstice and the longest solar day occurs around June 21which is the summer solstice. In theory at any time of the equator, the length of the day is equal to the length of the night. In Malaysia, since it is close to the plane, Malaysia equally enjoys almost equal day and night.

2.5.2 REVOLUTION

The revolution of the earth around the sun with the earth polar axis inclined at a certain fixed angle gives rise to the changing a day and night hours occur as well as the seasonal changes , from spring to summer to autumn and winter, and it's back again until summer. It is generally that the earth's complete revolution around the sun 365 days. This path that the earth takes to revolve around the sun in one year is called the elliptical path.

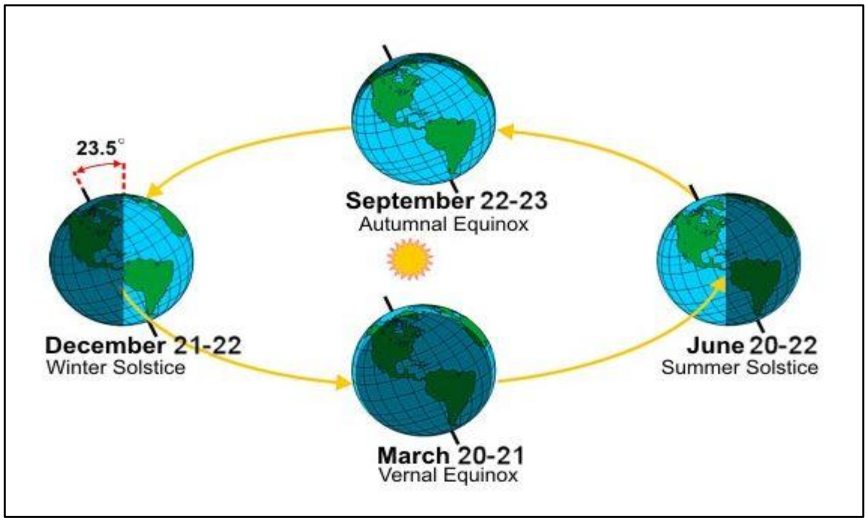


Figure 2.2 Earth's Elliptical Orbit around the Sun

Source: Retrieved from The Fall Equinoxes
http://www.srh.noaa.gov/abq/?n=clifeatures_fallequinox (2012)

In Figure 2.2 shows that the earth makes slightly elliptical orbit around the sun in one year per rotation. The elliptical orbit is formed by Earth's elliptical orbit around the sun. As the earth revolves around the sun, the orientation produces varying solar declination. Equatorial plane is tipped 23.45^o from the elliptical plane.

2.5.3 EQUINOX

Equinoxes happen when the ecliptic which is the sun's apparent motion across his celestial sphere and celestial equator intersection. The equinoxes are either of the two times when the sun crosses the equator in which day and night are of the same time length. The spring equinox occurs when the sun moves up from below the celestial equator to above it around the 20^{th} of March. The fall equinoxes occur when the sun moves down from upper the celestial equator around the 22nd of September. The earth experiences 12 hr of a day and a night during the equinoxes and that's how equinoxes get names as equinox mean equal night.

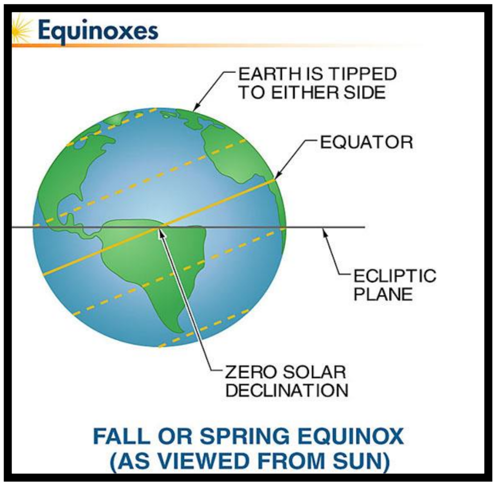


Figure 2.3 Equinoxes

Source: Kothari, D. P. Singal, K. C. and Ranjan, R. "Renewable Energy Source an Emerging Technologies, Reference Book" , New Delhi, 2008

Figure 2.3 shows the equinoxes occurs when the sun is directly in line with the equator. Usually, equinoxes happen on March 21st and September 21st when the sun crosses the equator in which day and night are of the same length.

2.5.4 SOLSTICE

At the summer solstice which occur on 21st June happen when the Northern Hemisphere tip towards the sun at an angle positive 23.45^{o} with respect to the celestial equator. Meanwhile at the winter solstice occur around 21st December when the Northern Hemisphere tip away from the sun at the angle negative 23.45^{o} with respect to the celestial equator. During the summer solstice, the sun travelling higher path across the sky meanwhile the sun path is the low sky during the winter solstice. The duration of the day is longer relative to the night when crossing the sky in the summer solstice.

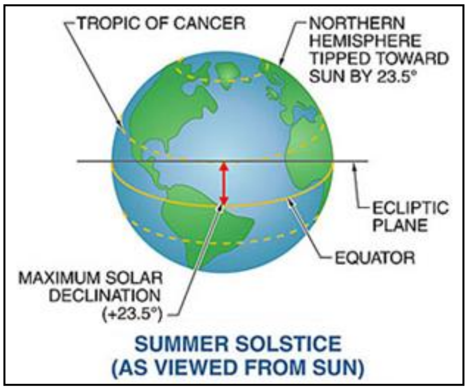


Figure 2.4 Summer Solstice

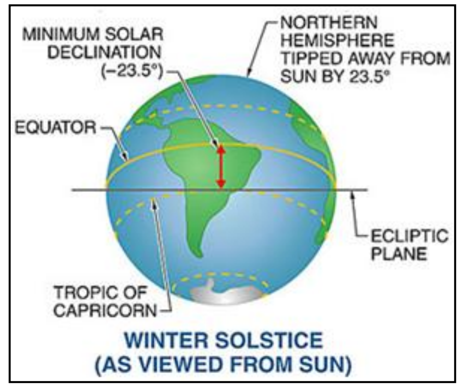


Figure 2.5 Winter solstice

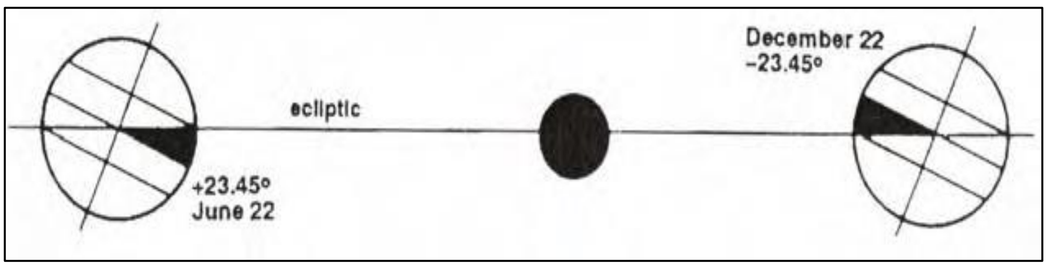


Figure 2.6 Solstices

Source: Kothari, D. P. Singal, K. C. and Ranjan, R. “Renewable Energy Source an Emerging Technologies, Reference Book” , New Delhi, 2008

In Figure 2.4, Figure 2.5 and Figure 2.6 shows that when summer solstice, the Northern Hemisphere tipped toward the sun by 23.45^{o} and get daylight longer than night time. Meanwhile when in winter solstice, the Northern Hemisphere tipped away from the sun and the duration of night longer than day time.

2.5.5 SEASONS

The season is caused by the earth axis which is tilted at 23.45^{o} with respect to the elliptic due to that fact the axis are always pointed in the same direction. The direction of the sun was pointed in the northern axis, it will be in winter in the southern hemisphere and summer in the northern hemisphere. The sun's ray reached that part of the surface directly and more concentrated when the northern hemisphere is experiencing summer hence enabling to heat up more quickly. The southern hemisphere receiving an equal amount of light ray at more glancing angle, hence spreading out the light ray therefore is less concentrated and cooler.

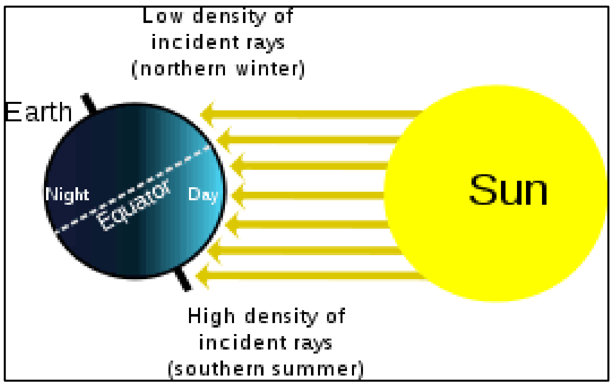


Figure 2.7 Tilt of the earth

Source: Retrieved from http://beyondweather.ehe.osu.edu/issue/the-sun-and-earths-climate/the-sun-earth%E2%80%99s-primary-energy-source (2012)

The Figure 2.7 shows that the sun's ray reached to the surface of the earth directly, it is caused seasons by earth axis.

2.6 SUNPATH

After studying about the knowledge and science of solar geometry, sun path diagram can be constructed at the specific location of orientation. Engineer and architect especially can determine the position of the sun from which the building's latitude from this sun path diagram. Sun path refers to the apparent significant seasonal and hourly positional changes of the sun and length of daylight as the Earth rotates and orbits around the sun.

The sun rises in the east and sets in the west but the uniqueness of this natural phenomenon is the sun is not exactly rises due east and set due west. There are three basic coordinate systems used to predict the solar position such as declination or the positions of celestial object, longitude and latitude of position on the earth and lastly used with time. Hence, affecting the behavior of the sun's lighting and heating characteristic will be effected on the sun path by this latitude and longitude.

2.6.1 LATITUDE AND LONGITUDE

Longitude and latitude are familiar geographic coordinates used on the earth. They are a system of polar coordinates. Longitude is measured from the Greenwich meridian, latitude is measured from the equator. Latitude ($\boldsymbol{\ell}$) is the angle subtended by the radial line joining the place in the center of the earth, with the projection of the line on the equatorial plane. Longitude is a geographic coordinate that specifies the east-west position of a point on the Earth's lane. By the longitude and latitude, any position on the Earth's surface can be specified.

2.6.2 ALTITUDE ANGLE AND AZIMUTH ANGLE

After explaining the latitude and longitude, the position of the sun can be measured with reference to the horizon. Measuring the angle of the sun in its motion crossing the sky, azimuth and altitude reading need to be taken. Altitude is the angular distance above the horizon measured perpendicular to the horizon. Meanwhile, azimuth is the angular distance measured along the horizon in a clockwise direction. Zenith angle (Ψ) is the vertical angle between the sun's ray and the line perpendicular to the horizontal plane through the point. For azimuth angle, it started exactly from the north at 0^o and increasing clockwise.

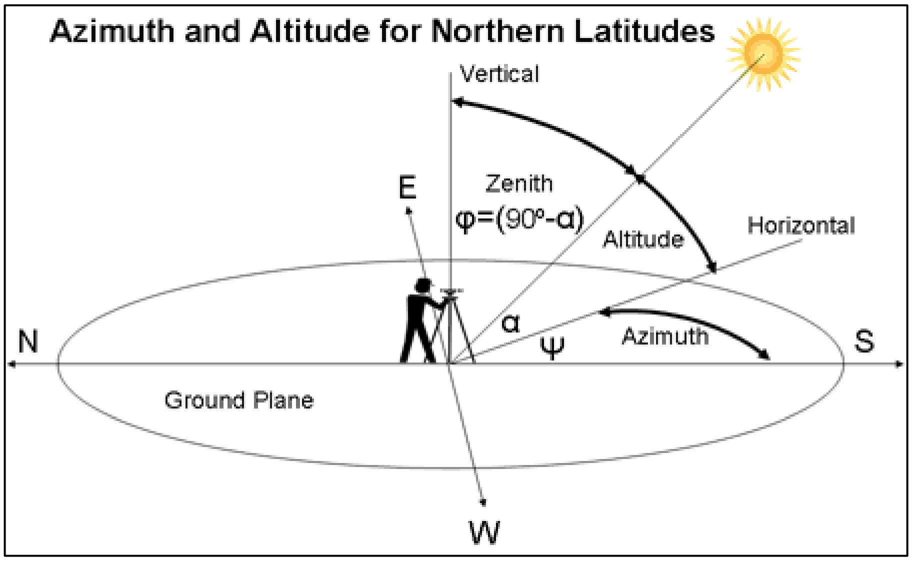


Figure 2.8 Path of sun in a location

Source : Retrieved from http://solarwiki.ucdavis.edu/The_Science_of_Solar/1._Basics/B._Basics_of_the_Sun/VI._The_Sun's_Motion, (2013)

As in Figure 2.8 show, a schematic of one apparent solar path. From this figure, can define three basic solar angles which are azimuth angle (γ) , zenith angle (Ψ) and altitude angle (β) which are required in the solar radiation.

Because the earth's daily rotation and its annual orbit around the sun are equal, same and predictable, the solar altitude and azimuth can be readily calculated for any data from the time of day when orientation location and declination angle are specified as has been carried out by ASHRAE (2011). Hence, constructing the sun path diagram is to representation on a flat surface of the sun's path across the sky. From this sun path diagram, it is easily and quickly determines the location of the sun at any time of the day and at any time of year because every orientation location has its own sun path diagrams.

2.6.3 SOLAR DECLINATION ANGLE

The solar declination (δ) means the earth's tilted axis results in a day by day variation of the angle between the earth-sun line and the earth's equatorial plane (ASHRAE, 2011). The relationship between declination angle and the date from year to year varies to significant degree. The declination angle changes from a maximum value of $+23.45^o$ on June 21 to a minimum of -23.45^o on December 22. Meanwhile, the declination will be zero to two equinox days which is March 22 which in fall equinox and September 22 which in the spring equinox. ASHRAE (2001) has stated that with their variation in the distribution of radiation of solar over the earth's surface and the varying number of hours of daylight and darkness, the daily change in the declination is the main reason for the changing the season.

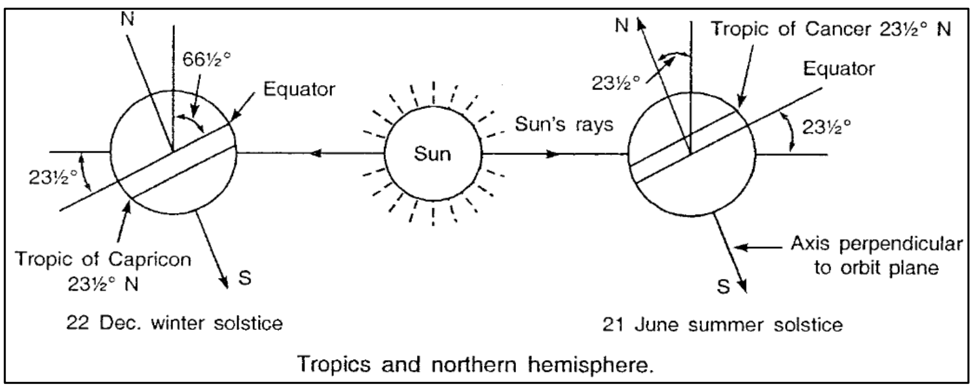


Figure 2.9 Tropic and northern hemisphere.

Source: Kothari, D. P. Singal, K. C. and Ranjan, R. "Renewable Energy Source an Emerging Technologies, Reference Book" , New Delhi, 2008

As shows in Figure 2.9 the declination angle is the angle subtended by a line joining the centers of the earth and the sun with its projection on the earth's equatorial plane. Declination occurs as the axis of the earth is inclined to the plane of its orbit at an angle 65^o.

The declination may be calculated as suggested by Cooper (1969),

$$\delta \text{ (in degrees)} = 23.45 \sin\left[\frac{360}{365}(284 + n)\right]$$

Where n is the total number of days counted from fist January till the date of calculation.

For June 21, 2006, n = 31 + 29 + 31 + 30 + 31 + 21 =173

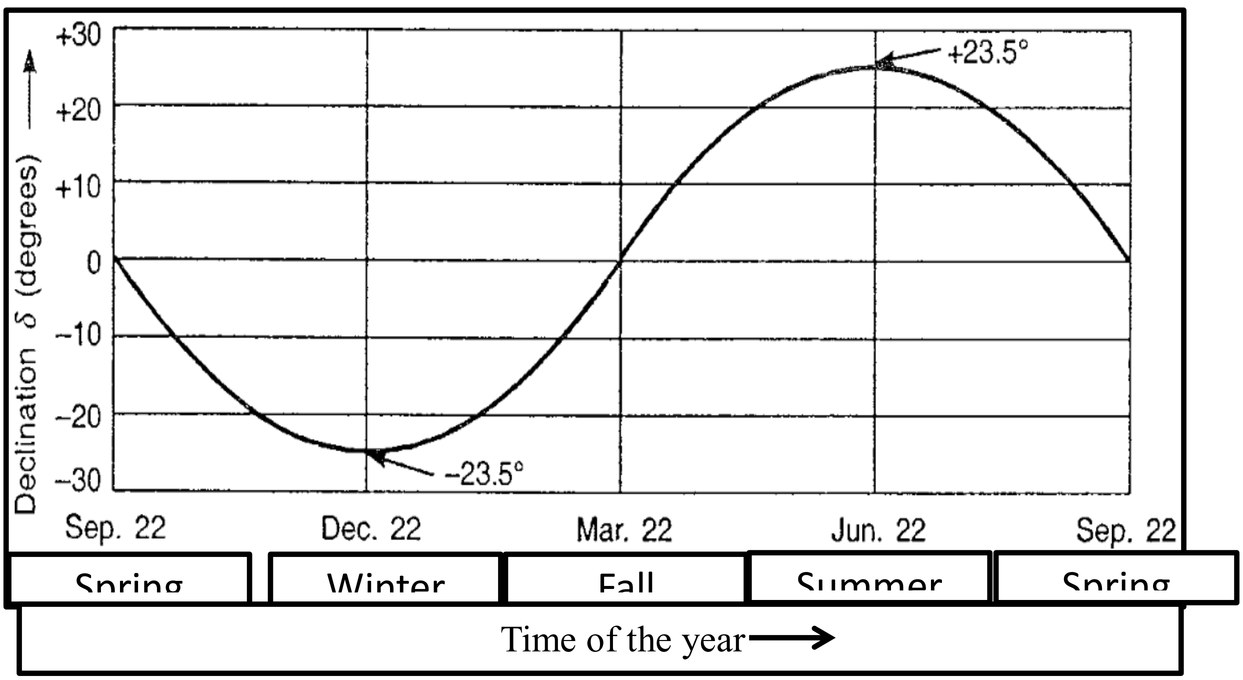


Figure 2.10 Variation of declination angle (*δ)* with the *nth* day of the year

Source: Kothari, D. P. Singal, K. C. and Ranjan, R. "Renewable Energy Source an Emerging Technologies, Reference Book" , New Delhi, 2008

2.6.4 TIME

In solar work, usually the solar time is used. Solar time is a measured from solar noon which is the time when the sun is appears to across the local meridian. Most the solar work deal only in solar time (ST). Apparent solar time (AST) generally differs from local standard time (LST) or daylight saving time (DST) and difference can be significant, particularly when daylight saving time is in effect. Its apparent rate of motion is 4min per degree of longitude because the sun appears to move the rate of 360^{o} in 24 hours.

2.7 SOLAR RADIATION

Solar radiation and daylight are essential to life on earth. It is because the sun is radiating considerable energy into the earth. Solar radiation is the energy given off by the sun in all directions and when this energy reaches the earth's surface it will call as insolation. Solar radiation gives out light and heat and approaches the earth as electromagnetic waves. When the direct solar radiation is not blocked by clouds, a combination of bright light and radiant heat or it is experienced as sunshine. When it is blocked by reflecting off another object, it is experienced as diffuse light. The entire living thing on the earth's surface is depending on the absorption of the electromagnetic radiation in the form of heat.

The solar radiation is a major part of building heat gain, to hardness solar energy beneficially it is possible selection of suitable material and landscaping. Thus it is important to be able to understand physic of solar radiation and daylight and particular determine the amount of energy intercepted by the earth's surface. The measuring the solar radiation at every location is not implemented and the engineer has developed empirical equations by utilizing the meteorological data such as number of sun hours, the day length and the number of clear days.

CHAPTER 3

METHODOLOGY

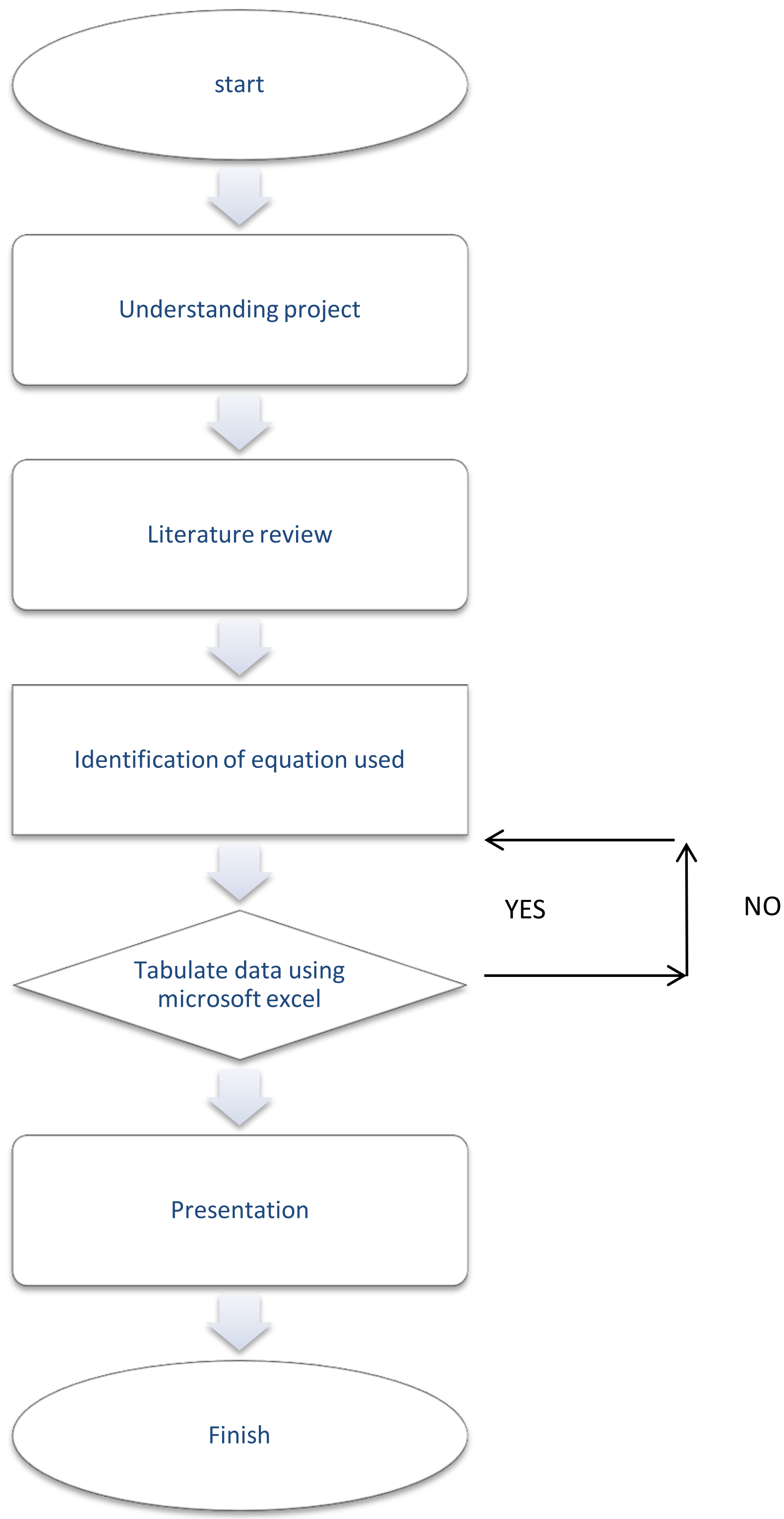
3.1 INTRODUCTION

This chapter represents and explained the methodology be used in this study and research method reading is conducted. For first stages are to identify the problems and the formulation of research objectives. The research objectives are formulated based on the identified problems. Research scopes are determined through data collection during the literature review of the solar geometry.

A literature review and study has been conducted and used to understand the existing standards such as ASHRAE Handbook and Renewable Energy Resources and Emerging Technologies Reference book to determine the solar geometric characteristics for those related to these standards. Understanding of solar geometry is one of the best ways to improving the energy efficiency of the building.

This study is a practical project assisted by computer simulation. This chapter overviews the approach that will be used in conducting the research. This chapter is divided into 3 sections. There are the concept of solar geometry, the equations that will use in the computer programming and also in Microsoft Excel, and lastly the flowchart.

3.2 FLOW CHART



3.3 THE CODING OF C++ PROGRAMMING

In computing, C in the letter C is a general purpose programming language. C is one of the most widely used programming languages of all time. Mostly C compiler is available for majority available computer architectures, engineers and operating systems. Hence, C++ programming is used in the declination angle equation.

3.3.1 THE EQUATION THAT WILL USED IN C++ PROGRAMMING

There is one of equation used in C++ programming to determine the solar position for any locality at any time of the year and any time of the day.

$$\delta = 23.25 \sin \; [360/365\ (n+284)]$$

Where *n* is the total number of days counted from first January till the date of calculation. The graph of declination angle can refer to Appendix.

The figure below show the coding for this declination angle,

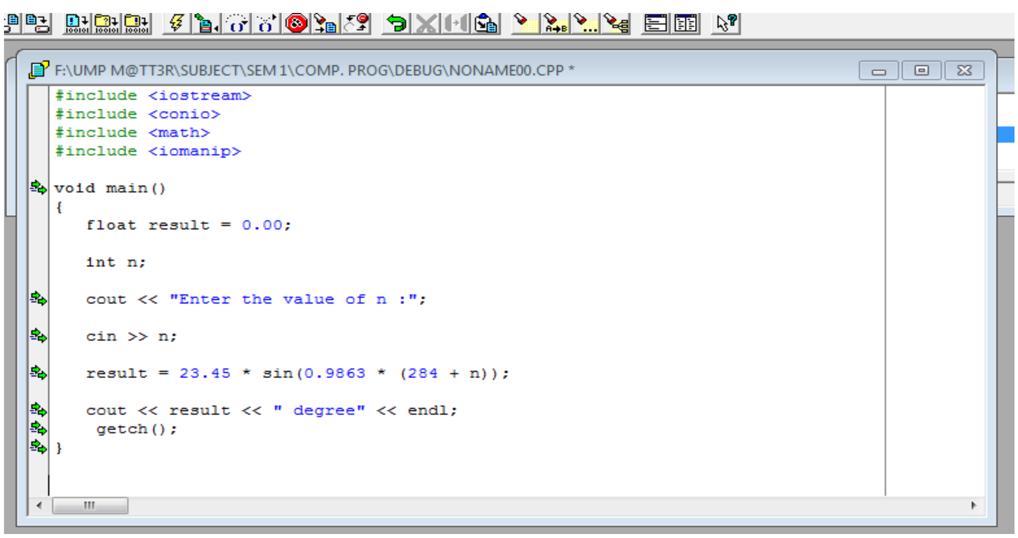


Figure 3.1 Coding C++ Programming

3.4 CALCULATE AND TABULATE THE DATA

There are a number of equations used and calculated using Microsoft Excel. To obtain the result, the equations are used to calculate the azimuth and the altitude angle. After finding the data for latitude, declination angle, and hour angle, so the data for altitude angle were obtained. Then, the azimuth angle can be calculated from the result of the altitude angle.

3.5 METHOD OF SUNPATH DIAGRAM

The sunpath diagram is a well known graphic traditionally used by architects and engineers to analyze the position of the sun to improve and control the solar radiation effect to the building. There are many methods of projection that can represent the sun path diagram and in this research, the technique used is an equidistant projection method. The equidistant is becoming a widely used method for constructing a sun path diagram and shading mask protractor in the United States as has been stated by John, Haberl and Degelman (2000). The equidistant method is a method in the projection solar altitude lines are not geometrically but equally spaced as concentric circles on a 2 D diagram. The equation that calculates the altitude angle and azimuth angle as an X and Y coordinate pair used to construct the sunpath diagram. The graph of altitude angle against the azimuth angle can be seen as a result.

3.6 PROCEDURE

1. Set up the N as equal to 1 to 365 days. The N is the day of the year (counted from 1^{st} January 2013).

$$N = \text{day of year with } 1^{st} \text{ January} = 1$$

2. Set up the latitude of Pekan as research location. Pekan's latitude is $3^{o}29'$ N with 33^{o} C of temperature.

3. The solar declination, δ will be set up by giving equation. The solar declination, δ equation is

$$\boldsymbol{Declination\ angle, \delta\ = 23.45 \sin\left(360\ \times \frac{284 + N}{365}\right)}$$

For example, the number of days counted is 21 June 2013.

$$N = 31 + 28 + 31 + 30 + 31 + 21$$

= 172 days.

For

$$Declination\ angle, \delta\ = 23.45 \sin\left(360\ \times \frac{284 + 172}{365}\right)$$

$$= 23.45 \sin(449.75°)$$

$$= 23.45°$$ (For June 21st)

Hence, it shows that the axis about which earth rotates is tilted with an angle of 23.45° to the plane of the earth's orbital plane and the sun's equator. On June 21st, summer solstice will occur when the Northern Hemisphere tips toward the sun of maximum tilt angle of 23.45°. Winter solstice happens on December 21st when the Southern Hemisphere tips toward the sun by negative 23.45°.

The calculation of the declination angle above is calculated manually. The declination angle also can be seen also in C++ programming. The coding, the result and the graph of declination angle are shown in the Appendix.

4. The values of N and δ can be seen in Table 3.1. However, the declination angle can be seen also in C++ programming.

5. Set up the hour angle, h from 0^o to 360^o. The hour angle is a measure of the time of the day with respect to solar noon. The hour angle was counted can be seen in Figure 3.1.

6. Define the values of altitude angle, β by using this equation

Altitude angle, β

$$= \mathbf{\sin^{-1}(\cos \mathit{l}.\cos \mathit{h}.\cos \mathit{d} + \sin \mathit{l}.\sin \mathit{d})}$$

Where:

$\ell = latitude$

h = *hour angle*

d = *declination angle*

An example is shown below for calculating the altitude angle after knowing the declination angle, latitude and hour angle. With the latitude for Pekan being $3^o29'$, declination angle be taken from previous calculation, and the hour angle is 0^o or 360^o.

Altitude angle, β $= \sin^{-1}(\cos l.\cos h.\cos d + \sin l.\sin d)$

$= \sin^{-1}(cos\ 3°29'.cos\ 0°.cos\ 23.45° + sin\ 3°29'.sin\ 23.45°)$

$= 70.03^o$.

7. Define the values of azimuth angle, γ by using the equation below. The values of azimuth angle will be

Azimuth angle, γ

$$= \boldsymbol{\cos^{-1}\left(\frac{\cos\ l.\sin d - \cos d.\cos h.\sin l}{\cos \beta}\right)}$$

$$= \boxed{\boldsymbol{\sin^{-1}\left(\frac{\cos d.\sin h}{\cos \beta}\right)}}$$

Where:

$\ell = latitude$

β = altitude angle

h = hour angle

d = declination angle

After getting the result for the altitude angle as shown above, the azimuth angle can be calculated as shown by the example below:

Azimuth angle, γ

$$= \cos^{-1}\left(\frac{\cos\ l.\sin d - \cos d.\cos h.\sin l}{\cos \beta}\right)$$

$$= \sin^{-1}\left(\frac{\cos d.\sin h}{\cos \beta}\right)$$

$$= \sin^{-1}\left(\frac{\cos 23.45° \times \sin 0°}{\cos 70.033°}\right)$$

$= 0^o$.

The result is tabulated in Table 4.1. However , the full results were calculated for all the months in a year as shown in Appendix.

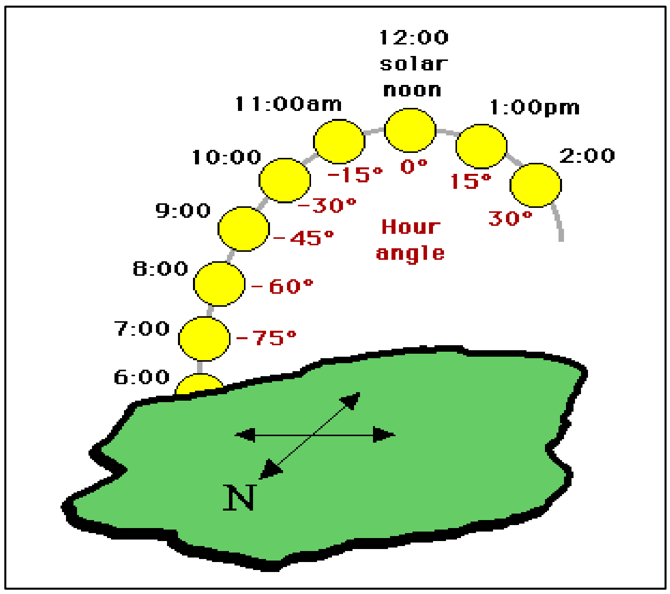


Figure 3.2 : This diagram depicts the relationship between the hour angle and local solar time in the Northern Hemisphere.

Source: Retrieved from Sustainable by Design: Hour Angle http://www.susdesign.com/popups/sunangle/hour-angle.php (2013)

Figure 3.1 shows that the hour angle at a specific hour of a day throughout the year on the position of the sun. Solar noon is a point when the sun is at its highest in the sky and can be appear to be due the North or the South. Hour angle is equal to positive angle forenoon, meanwhile hour angle is negative at evening.

3.7 TABULATE DATA ON THE TABLE GIVEN.

The table 3.1 below show the declination angle calculating with number a day of the year using the equation was given at procedure. For this research, the equation of time for the 21st day of each month of the year was being calculated.

MONTHS	DAY OF YEAR, *N*	DECLINATION ANGLE, δ
21 JANUARY	21	-20.16°
21 FEBRUARY	52	-11.24°
21 MARCH	80	-0.40°
21 APRIL	111	11.59°
21 MAY	141	20.16°
21 JUNE	172	23.45°
21 JULY	202	20.46°
21 AUGUST	233	11.76°
21 SEPTEMBER	264	-0.20°
21 OCTOBER	294	-11.76°
21 NOVEMBER	325	-20.46°
21 DECEMBER	355	-23.45°

Table 3.1: The result of Declination angle, δ for each 21st months per years

.

DATE : 21 JUNE 2013 (+VE)

δ=(23.45°)

L=3°29´

HOUR ANGLE, h	AZIMUTH ANGLE,γ	ALTITUDE ANGLE, β
-90	-66.569	1.385
-80	-66.763	10.555
-70	-66.294	19.715
-60	-65.05	28.815
-50	-62.762	37.786
-40	-58.959	46.516
-30	-52.709	54.796
-20	-42.268	62.197
-10	-24.932	67.799
0	0	70.033
10	24.932	67.799
20	42.268	62.197
30	52.709	54.796
40	58.959	46.516
50	62.762	37.786
60	65.05	28.815
70	66.294	19.715
80	66.763	10.555
90	66.569	1.385

Table 3.2 Result for 21st of June 2013

An example in Table 3.2 above was shown the data will calculate to represent the sun path diagram by using the equation azimuth angle and altitude angle. An example table starting day 21st January 2013 with counted number a day of the year and declination angle for this calculation. For hour angle, it's starting with 90^o with respect to solar noon. The solar noon occurs when the sun at the highest point in the sky and it is symmetric to hour angle. The hour angle is 0^o at solar noon and varies from 0^o to 360^o to complete one rotation since the sun takes 24 hours for one rotation. The equation of time for hour angle being positive in the afternoon and negative in the forenoon.

For January 21st , the sun path diagram will be plotted on negative graph or in the southern hemisphere. These cases an be same for another month such as February 21st, September 21st, October 21st, November 21st and also December 21st. This occurs due to southern hemisphere tip toward the sun and negative solar declination at equatorial plane.

For the next example on March 21st , the sun path diagram will be plotted on positive graph or in the northern hemisphere. These cases an be same for another month such as April 21st, May 21st, June 21st, July 21st and also August 21st. This occurs due to northern hemisphere tip toward the sun and positive solar declination at equatorial plane.

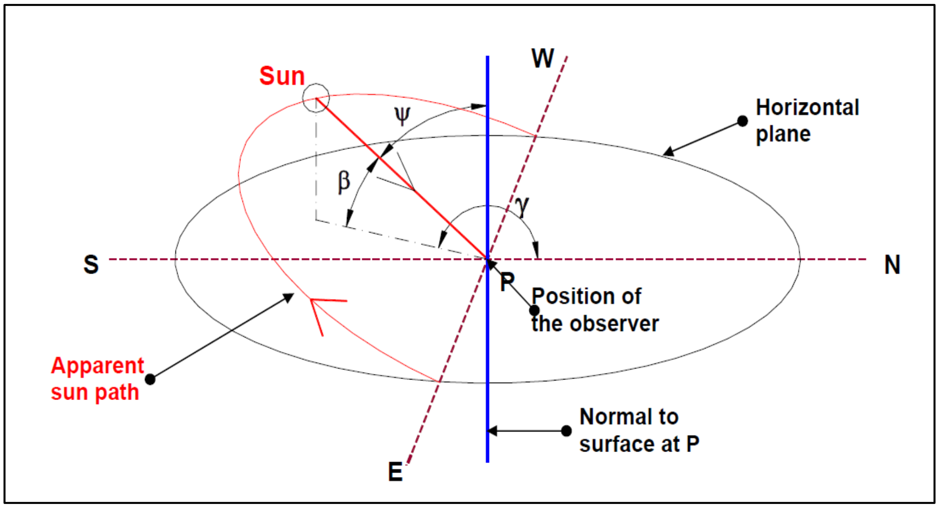


Figure 3.3 Definition of altitude angle and solar azimuth angle.

Source : Kharagpur, IIT. *Cooling and Heating Load Calculations –Estimation of Solar Radiation* (2010)

This figure shows the altitude angle, β is maximum at solar noon. Since the hour angle, at solar noon is equal to 0^o.

4.1.4 HOUR ANGLE EQUATION

The hour angle represents the position of the sun at a specific hour of the day throughout the year. The hour angle is paired with the declination to fully indicate the direction of a point on the celestial sphere in the equatorial coordinate system. The 360^o circumference of the earth, in term of time, represents 24 hours. One hour is equal 15^o longitude, or 4 minutes equal 1^o longitude. Hence, a reference longitude of saying, 90^o is 6 hours ahead as referring to Greenwich Mean Time (GMT). In solar angle perspective, at solar noon the hour angle is 0^o, with the time before solar noon expressed as negative degrees, and the local time after solar noon expressed as positive degrees. Thus, the daily time mentioned in sun path diagrams refer strictly to solar time.

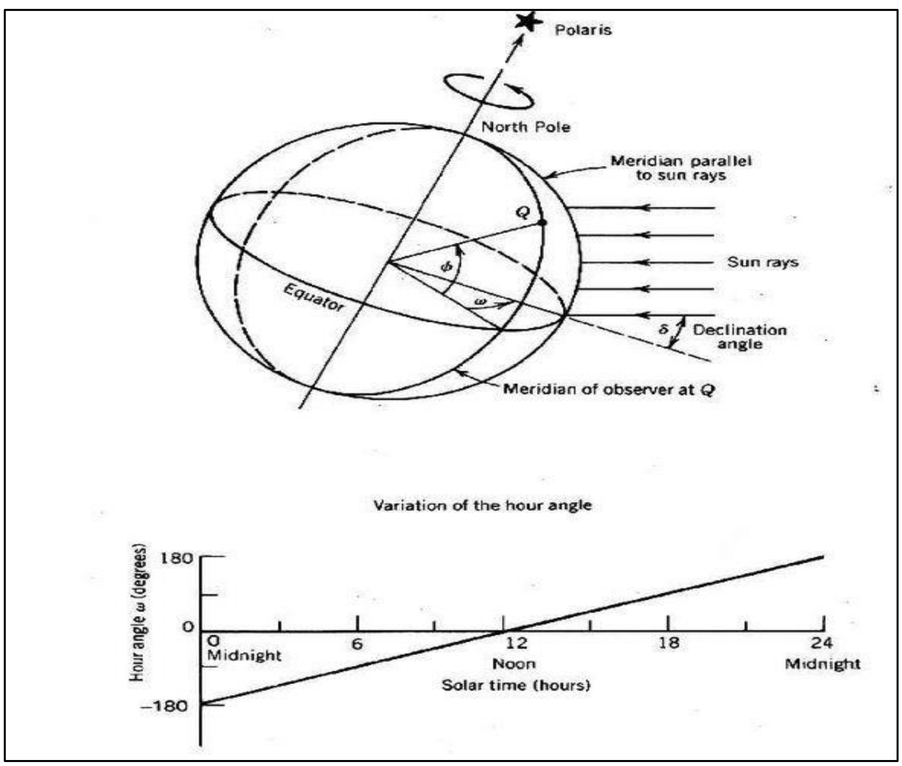


Figure 3.4 The hour angle

Source : Retrieved from The Sun's Position, http://www.powerfromthesun.net/Book/chapter03/chapter03.html (2013)

Figure 3.4 shows the hour angle, defined as the angle between the meridian parallel to the sun rays and the meridian containing the observer.

4.1.5 SOLAR TIME

Solar time was based on the 24 hour clock with 12:00 at the time that the sun exactly lie on the North-South plane. Because of latitude, longitude and reference time zones, solar time does not equate directly with the local clock time of each time. The hour angle is calculated based on local solar time. Since the earth's orbital velocity varies throughout the year, the local solar time as measured by a sundial varies slightly from the mean time kept by a clock running at a uniform rate.

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

A convenient way of representing the annual changes in the path of the sun through the sky using 2D diagrams is Sunpath Diagram. Thus, to get the full diagram position of the sun after knowing the latitude of the specific coordinates is by calculating, the declination angle using solar declination equations and then calculating the altitude angle. The angle of the sun in its motion is measured by using the equation of altitude angle and azimuth angle. But for declination angle, the data were determined by using C++ programming . The coding of the programming is included in the Appendix. After getting the result for these both equations, the graph of altitude angle against azimuth angle for the sunpath diagram is plotted using the Microsoft Excel. Refer to the Appendix for the result obtained from the equations. The sunpath diagram is a vertical version of the equidistant representation, where the horizontal lines of latitude are equally spaced.

4.2 ANALYSIS OF DATA FOR SUNPATH DIAGRAM

The result of the calculations obtained as shown in Table 4.1. The position of the sun at any time of the day of month of the year can be directly read from the diagram in Figure 4.2.1 and Figure 4.2.2. This figure shows the azimuth angle plotted along the horizontal X axis while the altitude is plotted vertically along the Y axis.

4.2.1 SUN PATH DIAGRAM FOR PEKAN LATITUDE

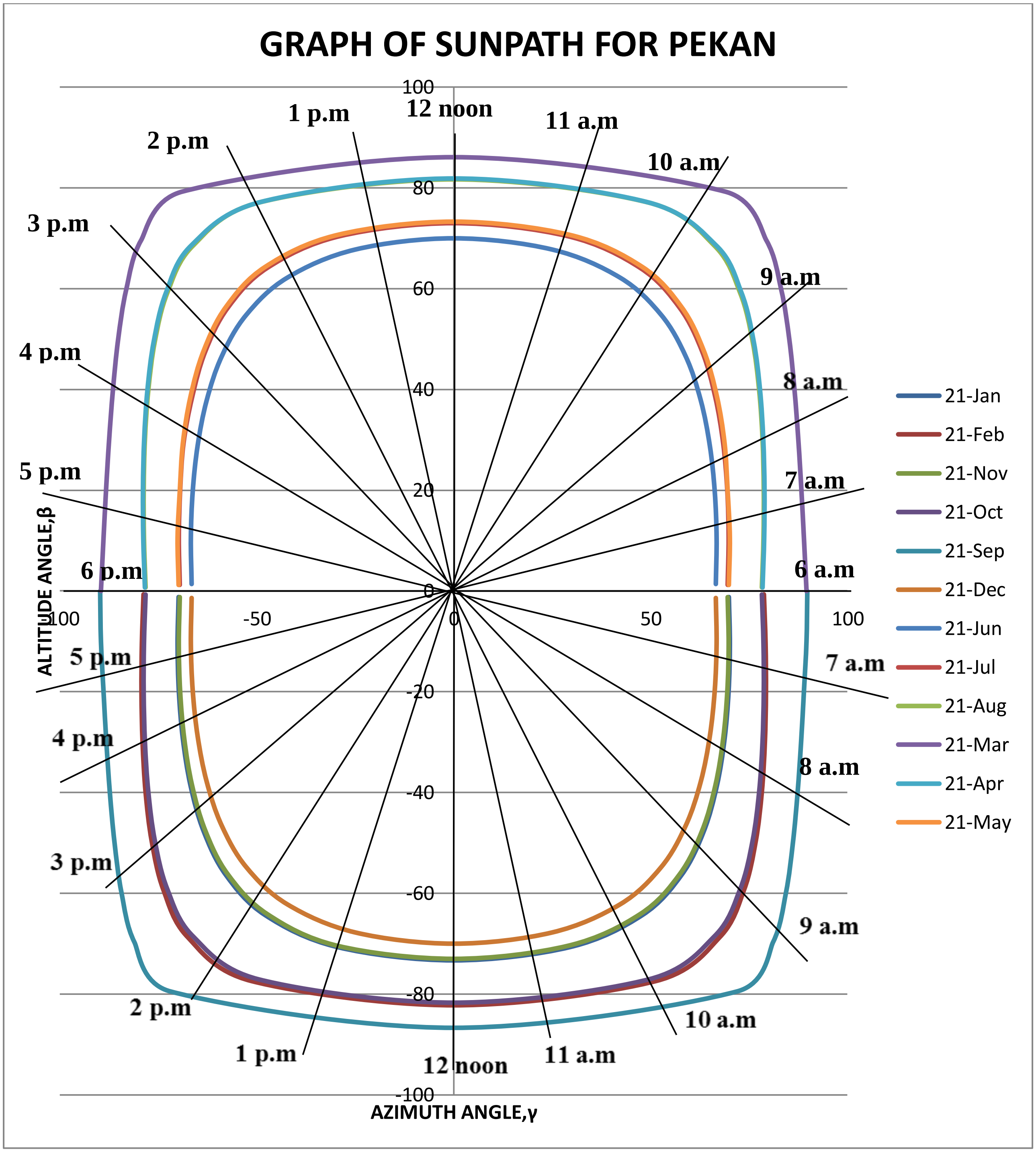


Figure 4.1 Sunpath Diagram for each month of the year.

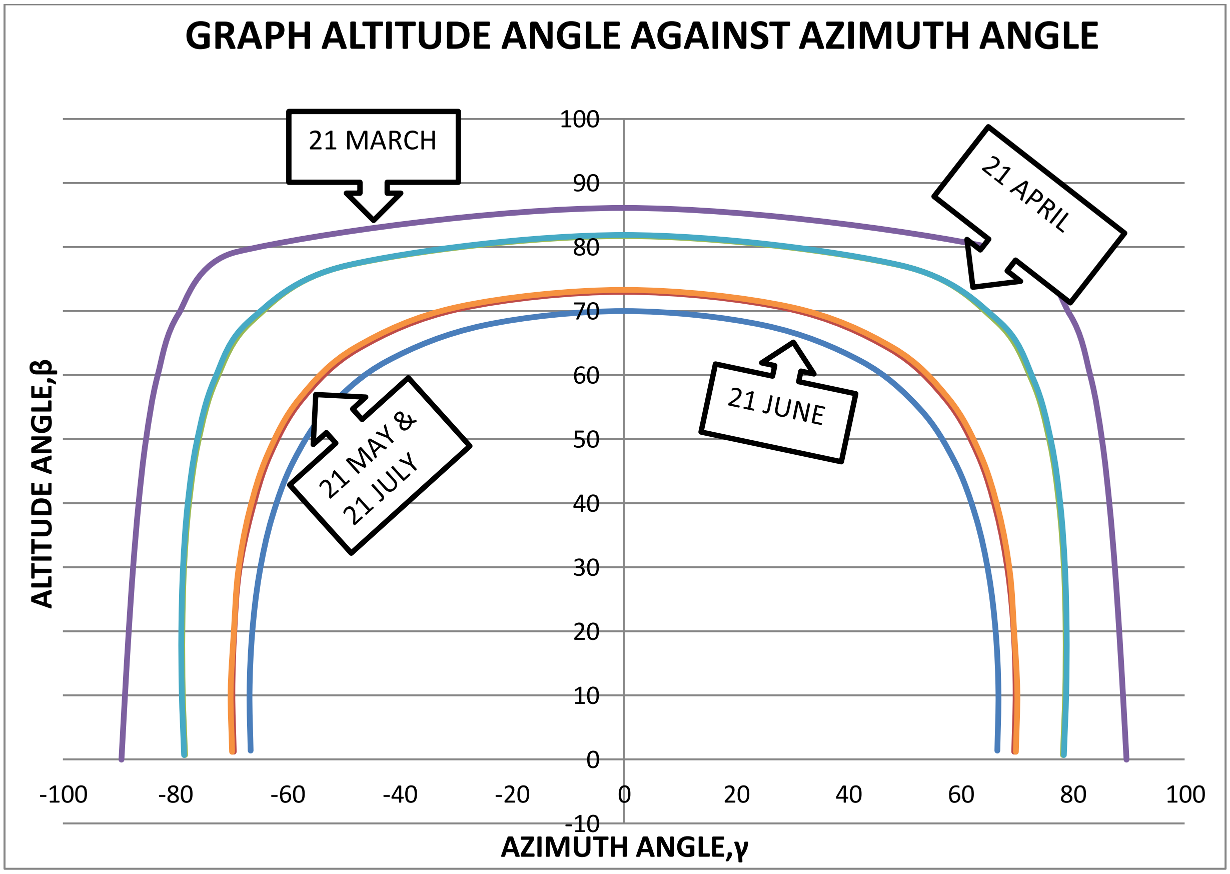


Figure 4.2 At Northern Hemisphere

Figure 4.2 shows the sunpath diagram which basically depicts the latitude angle against azimuth angle or sunpath diagram. Pekan, Pahang is taken as my reference location at a latitude for 3^{o} 29’ North Latitude. In the Northern Hemisphere, it is noted that the sun path a solar azimuth angle range of 0^{o} to 360^{o}. Referring to Table 1.1 , the hour angle took from 0^{o} until 90^{o} due east and 270^{o} to 360^{o} due west. It shows that 21 March gives maximum altitude angle because the declination angle for 21 March is equal to 0^{o} , meanwhile 21 June gives minimum altitude angle due to declination angle is exactly maximum positive 23.47^{o}. On 21 March, the sun is directly overhead the equator, known as equinox (a day of equal nighttime and daytime hours). For 21 April and 21 August, the sun chart is nearly the same for both because of the declination angle for both months is nearly same which is 11.59^{o} and 11.76^{o}. Hence, for both 21 May and 21 July, they also have nearly same the path due to declination angle for both months is the same which is 20.16° and 20.46°

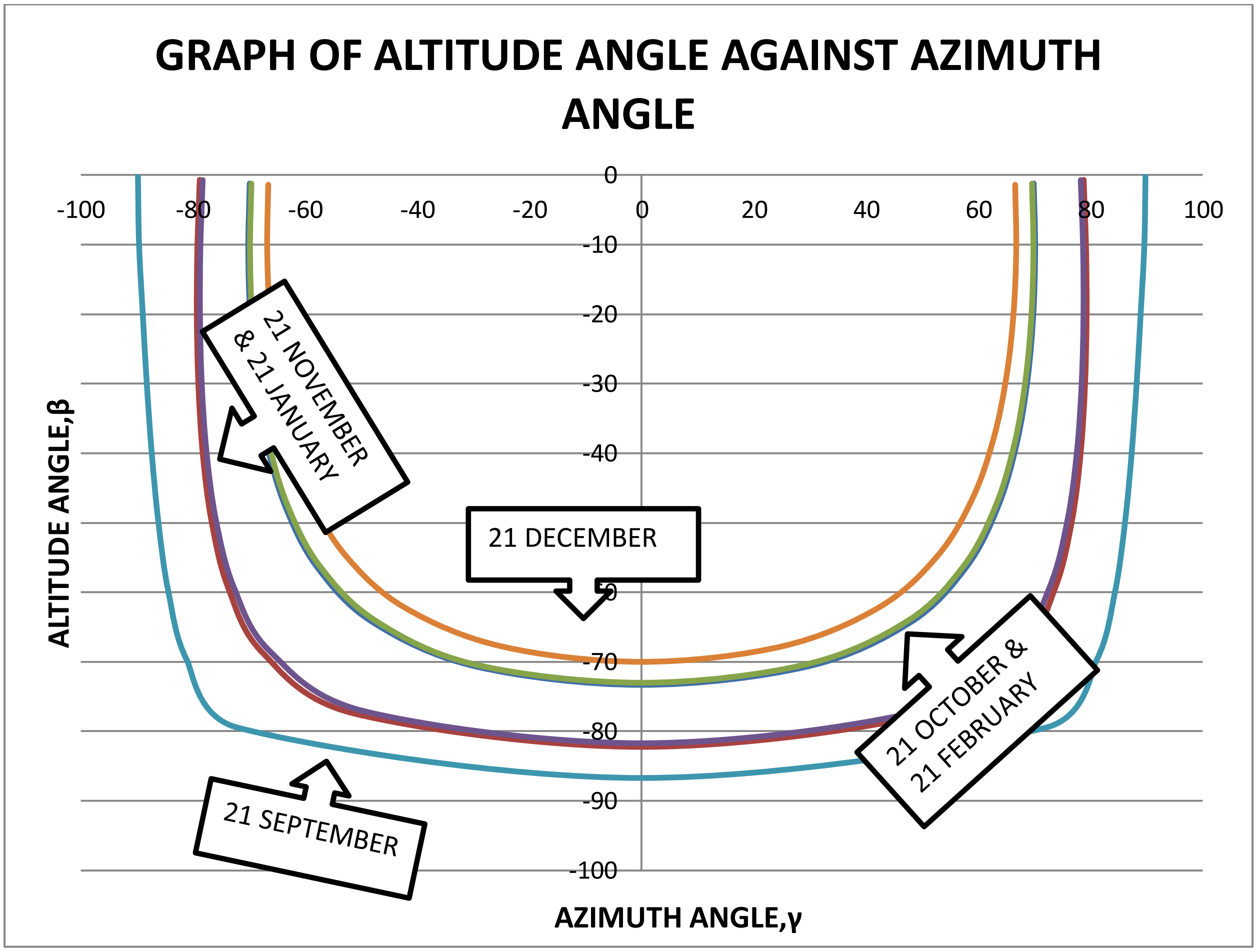


Figure 4.3 At Southern Hemisphere

Figure 4.3 shows the sunpath for Pekan, Pahang which is again taken as the reference location with a latitude of 3° 29' North Latitude. In the Southern Hemisphere, it is noted that the sun chart has a solar azimuth angle range of 0° to 360°. Refer to Table 4.2 in Appendix , where the hour angle is taken from 90° until 270° due east and due west. It shows that 21 September results in a maximum altitude angle due to declination angle for 21 September which is equal to 0°. Meanwhile 21 December results in a minimum altitude angle due to declination angle of exactly maximum negative 23.47°. On 21 September, the sun is directly overhead at the equator, known as equinox (a day of equal nighttime and daytime hours). For 21 October and 21 February, the sun chart is nearly the same for both because of the declination angle for both months is almost equal which is -11.24^{o} and -11.76^{o}. Hence, for 21 November and 21 January, the sun chart is almost equal because the declination for both months is -20.46^{o} and -20.16^{o}.

4.2.2 SUNPATH DIFFERENCE FOR DIFFERENT LATITUDES

Different latitude and different day of the year, will the result in different path of the motion of the sun, different times of sunrise and sunset, and the duration of the sun above the horizon. As shown in Figure 4.2, the sun is not necessarily rising due east or due west, nor exactly in equator plane.

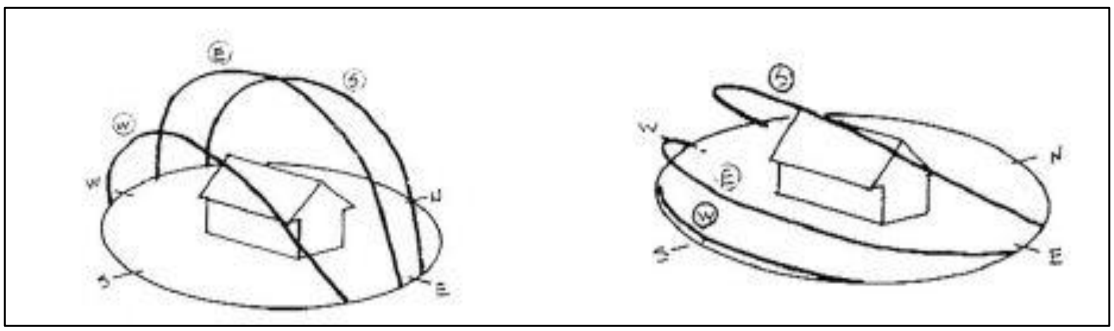


Figure 4.4 Sunpath Diagram

Source: GEK 1506 Heavenly Mathematics - *Sun and Architure* (2006)

Figure 4.4 shows the position of the sun depending on the day of the year and the latitude of the observer. It determines where the sun rises and sets or how long the sun is above the horizon.

Location	Latitude
Johor Bharu	$1^{o}28'$
Pekan	$3^{o}29'$
Kuala Perlis	$6^{o}25'$

Table 4.1 Locations and latitudes

The latitude can be described as the angular difference away from the equator. As a reference, the latitude of the equator is 0 degrees. To show the difference of latitude with the respect to sun path diagrams three cities which is Johor Bharu, Pekan and Kuala Perlis are chosen. There are three cities are chosen because Johor Bharu is located at the lowest latitude in Peninsular Malaysia, whereas Kuala Perlis is located at the highest latitude at the Peninsular Malaysia. Pekan is of course earlier taken as the main study of this project, and located almost in the middle of the two latitudes.

The altitude of sunpath for Kuala Perlis is a minimum angle rather than the altitude angle for Pekan and Johor Bharu. For the sunpath for Johor Bharu and Kuala Perlis, please refer to the Appendix. The latitude of Johor Bharu is near to 0 degrees which is near to the equator, so the altitude is maximum angle is 88.128^{o}. For the equator, altitude angle is exactly 90^{o}. So, it shows that the difference in angles between Johor Bharu and the equator is small.

4.3 APPLICATION OF THE SUNPATH DIAGRAM

Malaysia is a South- East Asian country which is situated in a tropical region and near to the equator. Geographically, it consists of two distinct regions embracing Peninsular Malaysia to the west and East Malaysia to the east, which is separated by the South China Sea. The country lies between 1^{o} and 7^{o} North Latitude, with hot and humid climate and heavy tropical rains. As place of the subject, Pekan is 3^{o} 29' N , longitude 103^{o} 22' 04'' E with 33^{o} C of temperature. Pekan experiences constant high temperature and relative humidity, light and variable wind conditions, long hours of sunshine with heavy rainfall and overcast cloud through the year.

Countries in the tropics do not want excessive heating from the sun while in higher latitude countries welcome the sun's warmth during the winter months. Hence, the amount of heating required depends largely on the latitude and the function of the building. The orientation of the building used in the design plays an important role in controlling the sun's heat.

4.3.1 SOLAR RADIATION EFFECT TO A BUILDING

In designing the buildings and structures, architects and engineers have constantly focused their attention towards the sun. The sun produces the energy that can be used to complement to light in the interior facades and rooms, on the other hand incorporated properly into the design of the building. Hence, designing the building is not only to collect energy from the sun which is providing heat and light as in the case for countries experiencing winter,in the case of countries located near the equator but also to reject the solar energy when is can lead to overheating of the building.

Applying the sun path diagram can reduce the energy efficiency toward the building and can control solar radiation that radiates to the building. At the same time, this will reduce the fossil fuel consumptions of buildings as well as results in building that acts in conjunction with natural forces and not against it. Knowing the knowledge of the sun and the sun's path, the building can be designed to fully utilize the available solar energy.

The calculate below shows an example equation used for solar radiation calculations from various solar energy applications.

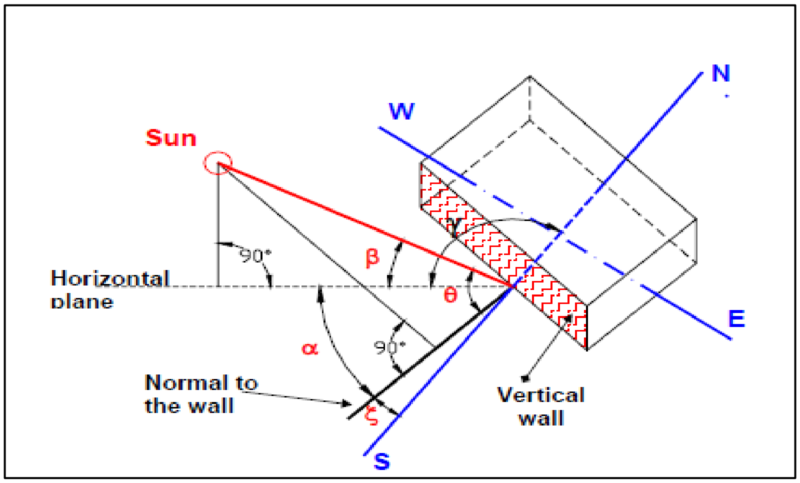


Figure 4.5 Calculation of incident solar angle for vertical surfaces

Source : Kharagpur, IIT. *Cooling and Heating Load Calculations –Estimation of Solar Radiation* (2010)

The surface azimuth angle, is the angle between the normal to the wall and south. When the wall facing south, the surface azimuth angle is zero and when it faces west, then surface azimuth angle is 90 ^{o}.

The wall solar azimuth angle, α is the angle between normal to the wall and the projection of sun's rays on to a horizontal plane.

The arbitrarily oriented surfaces, ɵ is for any surface that is tilted at an angle Σ from the horizontal as shown in Figure 4.8. For example, for horizontal surface, Σ is 0 ^{o}, hence ɵ is equal to (90- β) .Similarly for vertical surface, Σ is 90 ^{o}, hence ɵ is equal to $\cos^{-1}(cos\beta . \cos\alpha)$.

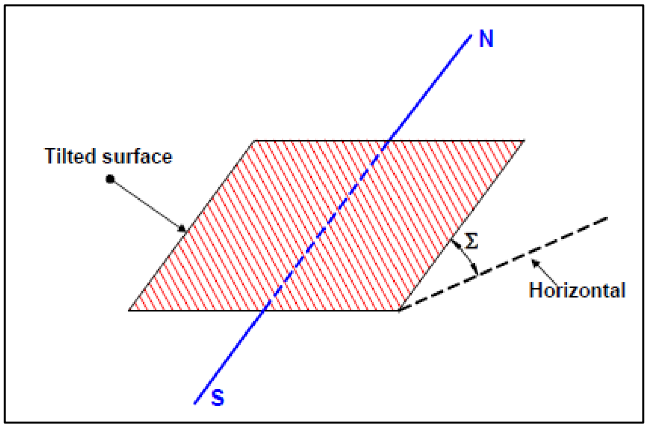


Figure 4.6 An arbitrarily oriented surface with a tilt angle Σ

a) Example: Calculate the angle of incidence at 2 P.M (solar time) of a north- facing roof that is tilted at an angle of 15^o with the respect to the horizontal. Location at Pekan and date is 21st September.

Given: Latitude ,= $3^o29'$

Solar time= 2 P.M= hour angle, h= 30^o

Tilt angle, Σ= 15^o

Date= 21st of September 2013

Declination angle, δ=(-0.20°)

Since the roof is north facing, the surface azimuth angle, is equal to 180^o Refer to the Figure 4.3 and Table at appendix,the altitude angle at 21st September is -59.841°. The azimuth angle at 21st September is 84.392°.

The wall solar azimuth angle, $\alpha = 180 - (\gamma + \xi) = 180 - (84.392^o + 180^o)$

$$= 275.61^o.$$

Hence, the angle of incidence is

$\theta = \cos^{-1}(\sin\beta . \cos\Sigma + \cos\beta . \cos\alpha . \sin\Sigma)$

$=\cos^{-1}(\sin 59.841° . \cos 15° - \cos 59.841° . \cos 275.61° . \sin 15°)$

$=34.66°$.

This equation si general equation and can be used for any arbitrarily oriented surface.

b) To find the direct normal radiation on June 21st at Pekan at solar noon.From the table at appendix, on June 21st at solar noon, the altitude angle for Pekan is 70.013°.

$I_{DN} = A . \exp(-B/\sin\beta\ )$

$=1080.\exp(-0.21/\sin 70.013)$

$=863.73\ W/m^2$

where A is the apparent solar irradiation which is taken as 1230 W/m^2 for the months of December and January and 1080 W/m^2 for mid summer. Constant B is called as atmospheric extinction coefficient, which takes a value of 0.14 in winter and 0.21 in summer.

c) To find the diffuse and total solar radiation incident on a horizontal surface located at Pekan on June 21st at solar noon.

From the previous example, on June 21st the direct solar radiation is equal to 863.73 W/m^2. Since the surface is horizontal, the view factor for diffuse radiation, F_{ws} is equal to 1, whereas it is for reflected radiation. Hence, the diffuse solar radiation is given by:

$I_d = C.\, I_{DN} \,.\, F_{ws}$

$=(0.135 \times 863.73\times 1)$

$=117.6\ W/m^2$

The value of C is assumed to be constant for a cluodness sky for an average monthly values. The value of C is 0135 for mid summer and 0.058 for winter. Meanwhile, F_{ws} is called as view factor or configuration factor and is eequal to the fraction of the diffuse radiation that is incident on the surface. Since, the surface is horizontal, the reflected solar radiation is zero. The angle of incidence is given:

$\theta = (90- \beta)$

$= (90- 70.013)$

$= 19.987^{o}$.

Hence, the total incident solar radiation:

$I_t= I_{DN} \,.\, cos\, \theta + I_d$

$=(863.73 \times \cos 19.987 + 117.6)$

$=929.31\ W/m^2$.

4.3.2 PHOTOVOLTAIC CELL OR SOLAR COLLECTOR

Solar energy can be utilized directly through a variety of devices such as photovoltaic (PV) cell or solar collector. Photovoltaic Solar Panel are means of converting sunlight directly into electricity via the usage of solar cells. into a flow of electrons. Solar photovoltaics are a sustainable energy source. After hydro and wind power, solar photovoltaics are a third most important renewable energy source in terms of global installed capacity. Solar cells produce direct current electricity from sunlight which can be used to power equipment to recharge a battery. This heat that has been created using these solar thermal collectors is then deployed for use in warm up fluids. In turn, these warming up produce the steam that is used to running turbine in order to generate electricity.

Installing the proper solar collector need to consider the amount of radiation flux incident upon the collector. Actually, the amount of radiation flux upon a solar collector is mainly affected by installation angle, *β*. The proper design of the installation of the collector can increase the irradiation received as shown in Figure 4.12 below.

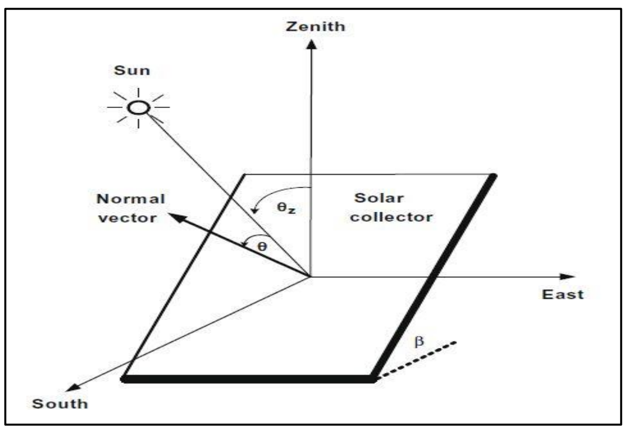


Figure 4.7 Geometry of south-facing solar collector

Source: Chang (2009)

The tilt angle angle varies with factors such as the geographic latitude, climate condition, and utilization period of time.

From the journals reviewed earlier, Chang (2009) has stated that, the optimal orientation is due to the south in the northern hemisphere. The performances of a solar collector are highly influenced by its orientation and its angle of tilt with the horizontal. The optimum tilt angle varies according to the latitude and the days of the year. As can seen from Figure 4.4, sunpath diagram of Pekan Area, on September and March is highest altitude angle and approximately equal to the latitude. Gunerhan and Hepbasli (2005) have stated that a solar collector tilted angle at an angle equal to the latitude will receive solar radiation nearly normal for these months.

The Figures below show a solar panel installed in the UMP Campus Pekan area. This picture was taken in June, 2013 at 10.30 a.m. This solar panel's latitude is 30^{o} east of south. The solar panel was facing toward the south in the northern hemisphere. However, the inclined plane for this solar panel is around 15^{o}.

Figure 4.8 Solar Panel at Pekan Campus

Actually, from the assessment, photovoltaic cell or solar collector's best declination is almost to zero or flat surface by toward the south. This is because Pekan is close to equator, and the ideal position for a solar panel along. The equator is flat or zero inclination (β=0) . However, for pratical reasons, it is good to avoid the solar panel being installed horizontally, as it will collect more dust and dirt during the no rain periods, whereas when it rains the panel will be subjected to vertical impact of the rainwater falling.

4.3.3 BEST INSTALLATION OF SOLAR ENERGY

Solar energy is non-polluting, clean, reliable and renewable energy source of electricity. It does not pollute the air through releasing of harmful gases like carbon dioxide, nitrogen oxide and sulfur oxide. In PV cell, usually it is installed on the ground or on the flat surface. Along the equator the best position for PV cell is horizontally rather than south facing, but to avoid the panel collecting dirt and dust, it must be slightly tilted and the most optimum tilting is a few degrees to the south. For Pekan's latitude, following the same rationale as mentioned in the previous section, it is best to install the panel with few degrees facing south. Installing the solar system would contribute to the green generation of electricity. If the roof of the house is surrounded by trees, it is not suitable enough to install the solar panel or solar water heater to produce solar power. Landscapes or other building may be problematic because the shadows can prevent the solar energy to directly reflect to the panels. Climatic condition also needs to take consider when installing the solar systems. Areas which remain mostly cloudy and foggy or rainy season will still produce electricity but in little rate and may require more panels to generate enough electricity. For example, if the sky is cloudy for two days, the solar water heater still produces warm water as the water get heated due to diffused radiation

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 INTRODUCTION

The sunpath diagram of Pekan town is successfully being plotted by using the results provided by the equations introduced in earlier chapters using the Microsoft Excel subsequently the result of the twelve months in a year were obtained. The sunpath diagram is a way representing annual changes in the path of the sun through the sky on a single 2D diagram.

5.2 CONCLUSION

The sunpath can be determined by the knowledge about solar geometry and solar angle. The altitude angle is highest at the 21st of March in the northern hemisphere, it is also same for September, 21st at southern hemisphere. It is because the sun is directly in line with the equator, it is called as the equinox, where the declination angle for equinox is equal to zero. The equinox occurs when the sun crosses the equator in which day and night are of the same length. Different for in June, 21st and December 21st is a minimum altitude angle at northern and southern hemisphere. The declination angle for both months is the maximum and minimum 23.45^{o} . Summer solstice occurs when northern hemisphere gets more daylight longer than a night, meanwhile winter solstice occurs when southern hemisphere gets more night time rather than daytime

By constructing the sunpath diagram, many applications can be used by engineers and architects. Therefore, the building can be created and designed optimising solar energy as a source of renewable energy, at the same time helps reducing environmental problems of both globally and locally.

5.3 RECOMMENDATION

This project has focused particularly on the Pekan latitude, which is 3^{o} 29' North. Different latitudes will be characterized by different sunpath diagrams. For other cities and towns in Malaysia , therefore their own sunpath diagrams need to be constructed to conduct the above exercise with accuracy. The sunpath diagram can be applied:

1. To determine the best position and angle of inclination for Photovoltaic panels, solar hot water systems, solar panel system and also for window shading.

2. To analyze the thermal behavior of a building and can b used to design the Green Building which will reduced the pollution and save our environment.

3. To calculate the radiation directly entering into a building and determine the energy efficiency in the building.
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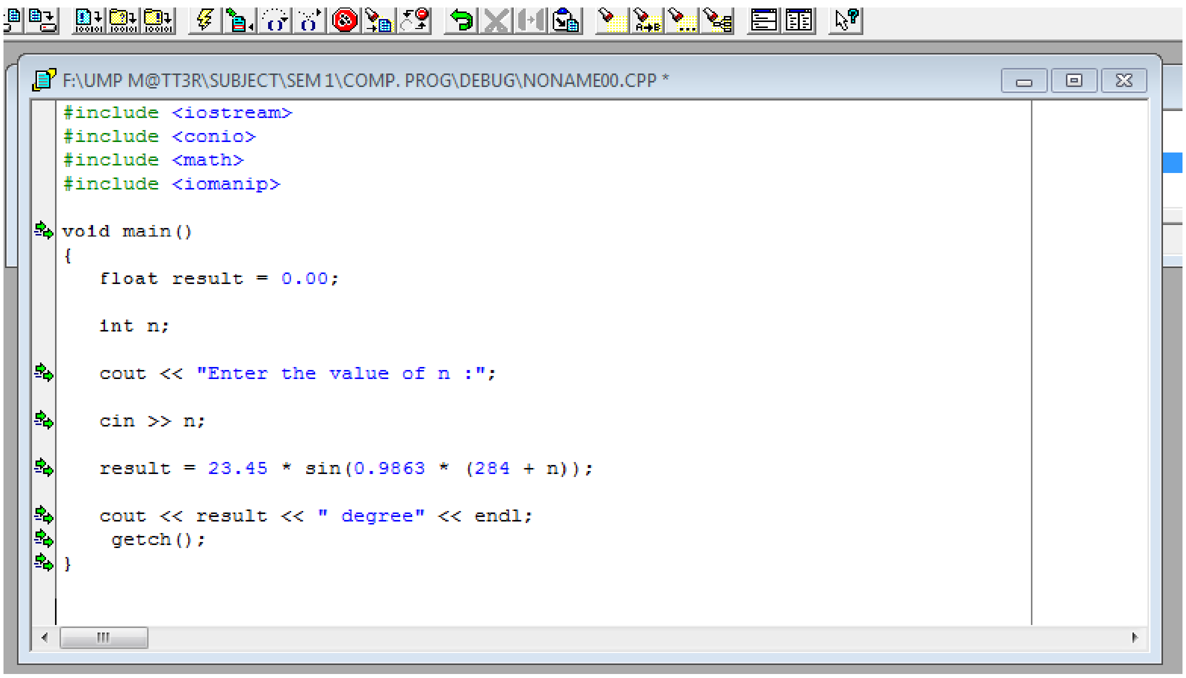
APPENDIX A

C++ PROGRAMMING FOR DECLINATION ANGLE

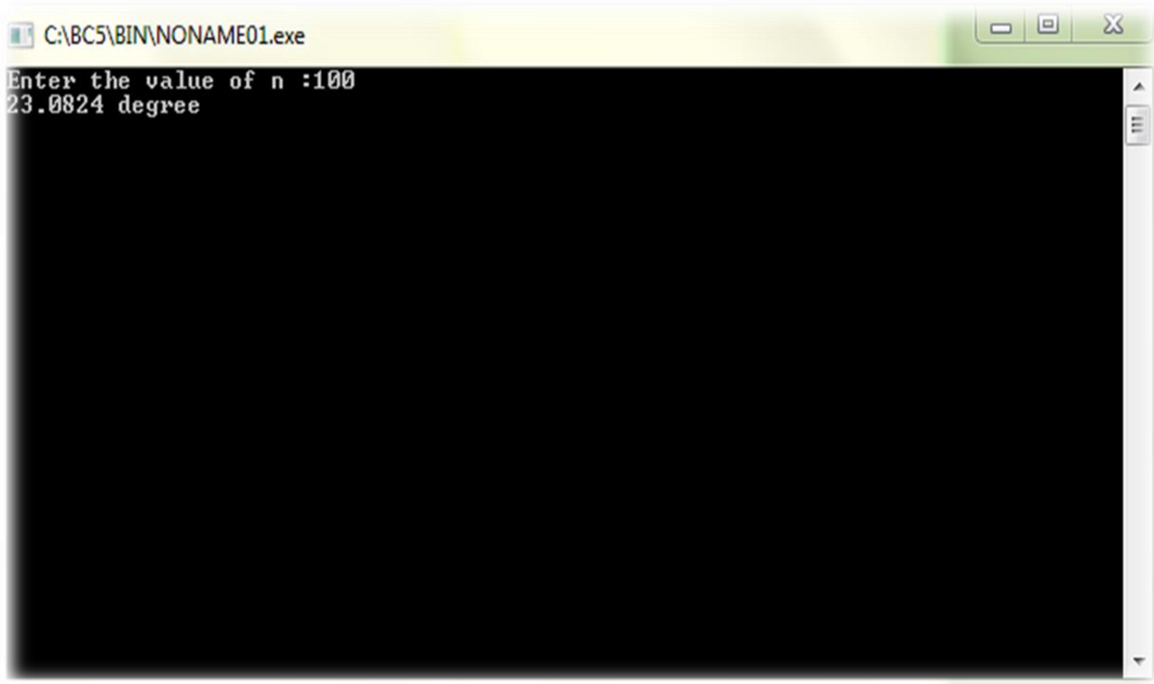
For example,

For April 8, 2013,
$n = 31 + 29 + 31 + 8$
$= 100$

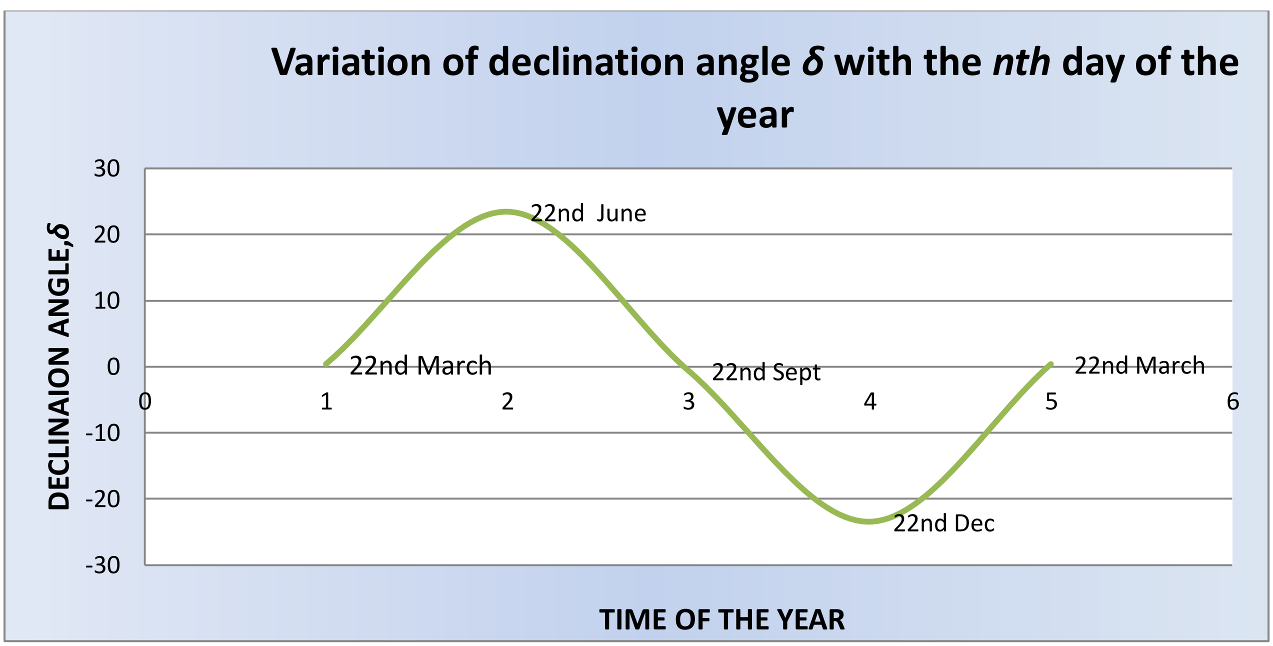
The coding:



Run:



The graph of declination angle :



APPENDIX B

DATE: 21 JANUARY 2013

N= (-20.16°) L= 3° 29' (PEKAN)

HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β	HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β
90	69.874	-1.2	180	0	-73.323
100	70.13	-10.582	190	-29.524	-70.683
110	69.803	-19.963	200	-47.87	-64.347
120	68.791	-29.304	210	-57.885	-56.347
130	66.859	-38.553	220	-63.541	-47.623
140	63.541	-47.623	230	-66.859	-38.553
150	57.885	-56.347	240	-68.791	-29.304
160	47.87	-64.347	250	-69.803	-19.963
170	29.524	-70.683	260	-70.13	-10.582
180	0	-73.323	270	-69.874	-1.2

DATE: 21 FEBRUARY 2013

N= (-11.24°)

L= 3° 29' (PEKAN)

HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β	HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β
90	78.78	-0.679	180	0	-82.243
100	79.202	-10.477	190	-51.42	-77.416
110	79.299	-20.285	200	-67.56	-68.719
120	79.022	-30.089	210	-73.751	-59.282
130	78.254	-39.877	220	-76.712	-49.624
140	76.712	-49.624	230	-78.254	-39.977
150	73.751	-59.282	240	-79.022	-30.089
160	67.56	-68.719	250	-79.299	-20.285
170	51.42	-77.416	260	-79.202	-10.477
180	0	-82.243	270	-78.78	-0.679

DATE: 21 MARCH 2013

N= (-0.40°)

L= 3° 29' (PEKAN)

HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β	HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β
270	-89.601	-0.024	360	0	86.117
280	-88.977	9.956	10	68.963	79.278
290	-88.307	19.935	20	79.385	69.637
300	-87.53	29.91	30	83.197	59.766
310	-86.556	39.878	40	85.246	49.835
320	-85.246	49.835	50	86.556	39.878
330	-83.197	59.766	60	87.53	29.91
340	-79.385	69.637	70	88.307	19.935
350	-68.963	79.278	80	88.977	9.956
360	0	86.117	90	89.601	-0.024

DATE: 21 APRIL 2013

N= (11.59°)

L= 3° 29' (PEKAN)

HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β	HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β
270	-78.431	0.699	360	0	81.893
280	-78.847	10.486	10	49.135	77.201
290	-78.926	20.282	20	66.653	68.597
300	-78.62	30.073	30	73.08	59.205
310	-77.798	39.846	40	76.176	49.574
320	-76.176	49.574	50	77.798	39.846
330	-73.08	59.205	60	78.62	30.073
340	-66.653	68.597	70	78.926	20.282
350	-49.135	77.201	80	78.847	10.486
360	0	81.893	90	78.431	0.699

DATE: 21 MAY 2013

N= (20.16°)

L= 3° 29' (PEKAN)

HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β	HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β
270	-69.874	1.2	360	0	73.323
280	-70.13	10.582	10	29.524	70.683
290	-69.562	19.963	20	47.87	64.347
300	-68.791	29.304	30	57.885	56.347
310	-66.859	38.552	40	63.541	47.623
320	-63.541	47.623	50	66.859	38.552
330	-57.885	56.347	60	68.791	29.304
340	-47.87	64.347	70	69.562	19.963
350	-29.524	70.683	80	70.13	10.582
360	0	73.323	90	69.874	1.2

DATE: 21 JUNE 2013

N= (23.45°)

L= 3° 29' (PEKAN)

HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β	HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β
270	-78.431	0.699	360	0	81.893
280	-78.847	10.486	10	49.135	77.201
290	-78.926	20.282	20	66.653	68.597
300	-78.62	30.073	30	73.08	59.205
310	-77.798	39.846	40	76.176	49.574
320	-76.176	49.574	50	77.798	39.846
330	-73.08	59.205	60	78.62	30.073
340	-66.653	68.597	70	78.926	20.282
350	-49.135	77.201	80	78.847	10.486
360	0	81.893	90	78.431	0.699

DATE: 21 JULY 2013

N= (20.46°)

L= 3° 29' (PEKAN)

HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β	HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β
270	-69.575	1.217	360	0	73.023
280	-69.824	10.581	10	29.055	70.427
290	-69.485	19.943	20	47.326	64.161
300	-68.64	29.264	30	57.398	56.215
310	-66.44	38.489	40	63.117	47.53
320	-63.117	47.53	50	66.44	38.489
330	-57.398	56.215	60	68.45	29.264
340	-47.326	64.161	70	69.485	19.943
350	-29.055	70.427	80	69.824	10.581
360	0	73.023	90	69.575	1.217

DATE: 21 AUGUST 2013

N= (11.76°)

L= 3° 29' (PEKAN)

HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β	HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β
270	-78.261	0.71	360	0	81.723
280	-78.675	10.491	10	49.565	77.094
290	-78.74	20.28	20	66.222	68.537
300	-78.436	30.065	30	72.758	59.167
310	-77.576	39.83	40	75.921	49.549
320	-75.921	49.549	50	77.576	39.83
330	-72.758	59.167	60	78.436	30.065
340	-66.222	68.537	70	78.74	20.28
350	-49.565	77.094	80	78.675	10.491
360	0	81.723	90	0	81.723

DATE: 21 SEPTEMBER 2013

N= (-0.20°)

L= 3° 29’ (PEKAN)

HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β	HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β
90	89.8	-0.012	180	0	-86.717
100	89.599	-9.994	190	-72.021	-79.481
110	88.94	-19.974	200	-81.087	-69.745
120	88.226	-29.953	210	-84.392	-59.841
130	87.345	-39.927	220	-86.159	-49.892
140	86.159	-49.892	230	-87.345	-39.927
150	84.392	-59.841	240	-88.226	-29.953
160	81.087	-69.745	250	-88.94	-19.974
170	72.021	-79.481	260	-89.599	-9.994
180	0	-86.717	270	-89.8	-0.012

DATE: 21 OCTOBER 2013

N= (11.76°)

L= 3° 29’ (PEKAN)

HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β	HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β
90	78.261	-0.71	180	0	-81.723
100	78.675	-10.491	190	-49.565	-77.094
110	78.744	-20.28	200	-66.222	-68.537
120	78.422	-30.065	210	-72.758	-59.167
130	77.576	-39.83	220	-75.916	-49.549
140	75.916	-49.549	230	-77.576	-39.83
150	72.758	-59.167	240	-78.422	-30.065
160	66.222	-68.537	250	-78.744	-20.28
170	49.565	-77.094	260	-78.675	-10.491
180	0	-81.723	270	-78.261	-0.71

DATE: 21 NOVEMBER 2013

N= (-20.46°)

L= 3° 29' (PEKAN)

HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β	HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β
90	69.575	-1.217	180	0	-73.023
100	69.825	-10.581	190	-29.555	-70.427
110	69.485	-19.943	200	-47.326	-64.161
120	68.45	-29.264	210	-57.398	-56.215
130	66.484	-38.489	220	-63.117	-47.53
140	63.117	-47.53	230	-66.484	-38.489
150	57.398	-56.215	240	-68.45	-29.264
160	47.326	-64.161	250	-69.485	-19.943
170	29.055	-70.427	260	-69.825	-10.581
180	0	-73.023	270	-69.575	-1.217

DATE: 21 DECEMBER 2013

N= (-23.45°)

L= 3° 29' (PEKAN)

HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β	HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β
90	66.569	-1.387	180	0	-70.013
100	66.761	-10.555	190	-24.932	-67.799
110	66.294	-19.715	200	-42.268	-62.197
120	65.045	-28.815	210	-52.709	-54.796
130	62.762	-37.786	220	-58.959	-46.516
140	58.959	-46.516	230	-62.762	-37.786
150	52.709	-54.796	240	-65.045	-28.815
160	42.268	-62.197	250	-66.294	-19.715
170	24.932	-67.799	260	-66.761	-10.555
180	0	-70.013	270	-66.569	-1.387

DATE: 21 JANUARY 2013

N= (-20.16°)

L= 1° 28' (JOHOR BHARU)

HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β	HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β
90	69.846	-0.505	180	0	-71.307
100	69.788	-9.891	190	-26.932	-68.906
110	69.131	-19.256	200	-44.92	-62.955
120	67.755	-28.557	210	-55.405	-55.237
130	65.409	-37.736	220	-61.611	-46.694
140	61.611	-46.694	230	-65.409	-37.736
150	55.405	-55.237	240	-67.755	-28.557
160	44.92	-62.955	250	-69.131	-19.256
170	26.932	-68.906	260	-69.788	-9.891
180	0	-71.307	270	-69.846	-0.505

DATE: 21 FEBRUARY 2013

N= (-11.24°)

L= 1° 28' (JOHOR BHARU)

HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β	HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β
90	78.78	-0.679	180	0	-82.243
100	79.202	-10.477	190	-51.42	-77.416
110	79.299	-20.285	200	-67.56	-68.719
120	79.022	-30.089	210	-73.751	-59.282
130	78.254	-39.877	220	-76.712	-49.624
140	76.712	-49.624	230	-78.254	-39.977
150	73.751	-59.282	240	-79.022	-30.089
160	67.56	-68.719	250	-79.299	-20.285
170	51.42	-77.416	260	-79.202	-10.477
180	0	-82.243	270	-78.78	-0.679

DATE: 21 MARCH 2013

N= (-0.40°)

L= 1° 28' (JOHOR BHARU)

HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β	HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β
270	-89.6	-0.01	360	0	88.128
280	-89.335	9.986	10	79.465	79.827
290	-89.046	19.982	20	84.791	69.914
300	-88.678	29.976	30	86.645	59.944
310	-88.256	39.97	40	87.63	49.96
320	-87.63	49.96	50	88.256	39.97
330	-86.645	59.944	60	88.678	29.976
340	-84.791	69.914	70	89.046	19.982
350	-79.465	79.827	80	89.335	9.986
360	0	88.128	90	89.6	-0.01

DATE: 21 APRIL 2013

N= (11.59°)

L= 1° 28' (JOHOR BHARU)

HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β	HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β
270	-78.414	0.295	360	0	79.878
280	-78.488	10.09	10	44.003	75.826
290	-78.203	19.882	20	62.117	67.725
300	-77.486	29.656	30	69.912	58.565
310	-76.172	39.392	40	73.912	49.054
320	-73.912	49.054	50	76.172	39.392
330	-69.912	58.565	60	77.486	29.656
340	-62.117	67.725	70	78.203	19.882
350	-44.003	75.826	80	78.488	10.09
360	0	79.878	90	78.414	0.295

DATE: 21 MAY 2013

N= (20.16°)

L= 1° 28’ (JOHOR BHARU)

HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β	HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β
270	-69.846	0.506	360	0	71.307
280	-69.788	9.891	10	26.932	68.906
290	-69.131	19.256	20	44.922	62.956
300	-67.755	28.557	30	55.407	55.238
310	-65.411	37.737	40	61.611	46.694
320	-61.611	46.694	50	65.411	37.737
330	-55.407	55.238	60	67.755	28.557
340	-44.922	62.956	70	69.131	19.256
350	-26.932	68.906	80	69.788	9.891
360	0	71.307	90	69.846	0.506

DATE: 21 JUNE 2013

N= (23.45°)

L= 1° 28’ (JOHOR BHARU)

HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β	HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β
270	-66.537	0.584	360	0	67.997
280	-66.432	9.754	10	23.014	65.957
290	-65.649	18.894	20	39.835	60.676
300	-64.06	27.948	30	50.52	53.544
310	-61.404	36.842	40	57.187	45.449
320	-57.187	45.449	50	61.404	36.842
330	-50.52	53.544	60	64.06	27.948
340	-39.835	60.676	70	65.649	18.894
350	-23.014	65.957	80	66.432	9.754
360	0	67.997	90	66.537	0.584

DATE: 21 JULY 2013

N= (20.46°)

L= 1° 28’ (JOHOR BHARU)

HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β	HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β
270	-69.546	0.513	360	0	71.007
280	-69.484	9.88	10	26.535	68.643
290	-68.814	19.225	20	44.429	62.757
300	-67.418	28.506	30	54.946	55.092
310	-65.043	37.661	40	61.201	46.588
320	-61.201	46.588	50	65.043	37.661
330	-54.946	55.092	60	67.418	28.506
340	-44.429	62.757	70	68.814	19.225
350	-26.535	68.643	80	69.484	9.88
360	0	71.007	90	69.546	0.513

DATE: 21 AUGUST 2013

N= (11.76°)

L= 1° 28’ (JOHOR BHARU)

HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β	HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β
270	-78.244	0.299	360	0	79.707
280	-78.315	10.088	10	43.512	75.705
290	-78.023	19.874	20	61.713	67.651
300	-77.291	29.641	30	69.6	58.516
310	-75.955	39.369	40	73.656	49.02
320	-73.656	49.02	50	75.955	39.369
330	-69.6	58.516	60	77.291	29.641
340	-61.713	67.651	70	78	19.874
350	-43.512	75.705	80	78.315	10.088
360	0	79.707	90	78.244	0.299

DATE: 21 SEPTEMBER 2013

N= (-0.20°)

L= 1° 28’ (JOHOR BHARU)

HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β	HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β
90	89.8	-0.005	180	0	-88.742
100	89.529	-9.991	190	-82.901	-79.922
110	89.714	-19.999	200	-86.584	-69.963
120	89.391	-29.995	210	-87.855	-59.977
130	89.049	-39.991	220	-88.603	-49.986
140	88.603	-49.986	230	-89.049	-39.991
150	87.855	-59.977	240	-89.391	-29.995
160	86.584	-69.963	250	-89.714	-19.999
170	82.901	-79.922	260	-89.529	-9.991
180	0	-88.742	270	-89.8	-0.005

DATE: 21 OCTOBER 2013

N= (11.76°)

L= 1° 28’ (JOHOR BHARU)

HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β	HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β
90	78.244	-0.299	180	0	-79.707
100	78.315	-10.088	190	-43.512	-75.705
110	78.023	-19.874	200	-61.713	-67.651
120	77.291	-29.641	210	-69.6	-58.516
130	75.957	-39.369	220	-73.656	-49.02
140	73.656	-49.02	230	-75.957	-39.369
150	69.6	-58.516	240	-77.291	-29.641
160	61.713	-67.651	250	-78.023	-19.874
170	43.512	-75.705	260	-78.315	-10.088
180	0	-79.707	270	-78.244	-0.299

DATE: 21 NOVEMBER 2013

N= (-20.46°)

L= 1° 28’ (JOHOR BHARU)

HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β	HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β
90	69.546	-0.513	180	0	-71.007
100	69.484	-9.88	190	-26.535	-68.643
110	68.814	-19.225	200	-44.429	-62.757
120	67.418	-28.506	210	-54.946	-55.092
130	65.043	-37.661	220	-61.201	-46.588
140	61.201	-46.588	230	-65.043	-37.661
150	54.946	-55.092	240	-67.418	-28.506
160	44.429	-62.757	250	-68.814	-19.225
170	26.535	-68.643	260	-69.484	-9.88
180	0	-71.007	270	-69.546	-0.513

DATE: 21 DECEMBER 2013

N= (-23.45°)

L= 1° 28’ (JOHOR BHARU)

HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β	HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β
90	66.537	-0.584	180	0	-67.997
100	66.432	-9.754	190	-23.013	-65.956
110	65.649	-18.894	200	-39.835	-60.676
120	64.061	-27.949	210	-50.52	-53.544
130	61.404	-36.842	220	-57.187	-45.449
140	57.187	-45.449	230	-61.404	-36.842
150	50.52	-53.544	240	-64.061	-27.949
160	39.835	-60.676	250	-65.649	-18.894
170	23.013	-65.956	260	-66.432	-9.754
180	0	-67.997	270	-66.537	-0.584

DATE: 21 JANUARY 2013

N= (-20.16°)

L= 6° 25' (KUALA PERLIS)

HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β	HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β
90	69.956	-2.207	180	0	-76.257
100	70.672	-11.567	190	-34.278	-73.176
110	70.834	-20.951	200	-52.779	-66.222
120	70.367	-30.328	210	-61.803	-57.821
130	69.07	-39.654	220	-66.521	-48.862
140	66.521	-48.862	230	-69.07	-39.654
150	61.803	-57.821	240	-70.367	-30.328
160	52.779	-66.222	250	-70.834	-20.951
170	34.278	-73.176	260	-70.672	-11.567
180	0	-76.257	270	-69.956	-2.207

DATE: 21 FEBRUARY 2013

N= (-11.24°)

L= 6° 25' (KUALA PERLIS)

HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β	HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β
90	78.829	-1.248	180	0	-85.177
100	79.75	-11.013	190	-63.274	-79.007
110	80.38	-20.802	200	-74.868	-69.665
120	80.712	-30.605	210	-78.613	-59.983
130	80.685	-40.413	220	-80.127	-50.213
140	80.127	-50.213	230	-80.685	-40.413
150	78.613	-59.983	240	-80.712	-30.605
160	74.868	-69.665	250	-80.38	-20.802
170	63.274	-79.007	260	-79.75	-11.013
180	0	-85.177	270	-78.829	-1.248

DATE: 21 MARCH 2013

N= (-0.40°)

L= 6° 25’ (KUALA PERLIS)

HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β	HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β
270	-89.603	-0.046	360	0	83.177
280	-88.461	9.89	10	56.002	77.91
290	-87.246	19.821	20	71.86	68.906
300	-85.846	29.74	30	78.272	59.293
310	-84.119	39.639	40	81.794	49.502
320	-81.794	49.502	50	84.119	39.639
330	-78.272	59.293	60	85.846	29.74
340	-71.86	68.906	70	87.246	19.821
350	-56.002	77.91	80	88.461	9.89
360	0	83.177	90	89.603	-0.046

DATE: 21 APRIL 2013

N= (11.59°)

L= 6° 25’ (KUALA PERLIS)

HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β	HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β
270	-78.481	1.287	360	0	84.835
280	-79.396	11.041	10	61.677	78.858
290	-80.009	20.819	20	73.912	69.592
300	-80.311	30.611	30	77.931	59.942
310	-80.229	40.406	40	79.591	50.192
320	-79.591	50.192	50	80.229	40.406
330	-77.931	59.942	60	80.311	30.611
340	-73.912	69.592	70	80.009	20.819
350	-61.677	78.858	80	79.396	11.041
360	0	84.835	90	78.481	1.287

DATE: 21 MAY 2013

N= (20.16°)

L= 6° 25' (KUALA PERLIS)

HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β	HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β
270	-69.956	2.208	360	0	76.26
280	-70.672	11.567	10	34.282	73.178
290	-70.835	20.952	20	52.782	66.223
300	-70.367	30.328	30	61.809	57.823
310	-69.07	39.654	40	66.524	48.863
320	-66.524	48.863	50	69.07	39.654
330	-61.809	57.823	60	70.367	30.328
340	-52.782	66.223	70	70.835	20.952
350	-34.282	73.178	80	70.672	11.567
360	0	76.26	90	69.956	2.208

DATE: 21 JUNE 2013

N= (23.45°)

L= 6° 25' (KUALA PERLIS)

HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β	HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β
270	-66.661	2.551	360	0	72.947
280	-67.294	11.7	10	28.382	70.422
290	-67.291	20.871	20	46.335	64.298
300	-66.554	30.018	30	56.204	56.503
310	-64.852	39.082	40	61.718	47.969
320	-61.718	47.969	50	64.852	39.082
330	-56.204	56.503	60	66.554	30.018
340	-46.335	64.298	70	67.291	20.871
350	-28.382	70.422	80	67.294	11.7
360	0	72.947	90	66.661	2.551

DATE: 21 JULY 2013

N= (20.46°)

L= 6° 25' (KUALA PERLIS)

HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β	HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β
270	-69.658	2.239	360	0	75.957
280	-70.365	11.58	10	33.668	72.934
290	-70.513	20.947	20	52.155	66.059
300	-70.019	30.304	30	61.28	57.712
310	-68.684	39.608	40	66.078	48.789
320	-66.078	48.789	50	68.684	39.608
330	-61.28	57.712	60	70.019	30.304
340	-52.155	66.059	70	70.513	20.947
350	-33.668	72.934	80	70.365	11.58
360	0	75.957	90	69.658	2.239

DATE: 21 AUGUST 2013

N= (11.76°)

L= 6° 25' (KUALA PERLIS)

HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β	HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β
270	-78.312	1.305	360	0	84.657
280	-79.222	11.053	10	60.856	78.776
290	-79.824	20.825	20	73.416	69.551
300	-80.111	30.612	30	77.586	59.919
310	-80.003	40.401	40	79.319	50.179
320	-79.319	50.179	50	80.003	40.401
330	-77.586	59.919	60	80.111	30.612
340	-73.416	69.551	70	79.824	20.825
350	-60.856	78.776	80	79.222	11.053
360	0	84.657	90	78.312	1.305

DATE: 21 SEPTEMBER 2013

N= (-0.20°)

L= 6° 25' (KUALA PERLIS)

HOUR ANGLE, *h*	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β	HOUR ANGLE, *h*	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β
90	89.801	-0.023	180	0	-83.791
100	89.08	-9.96	190	-58.484	-78.247
110	87.891	-19.894	200	-73.483	-69.1
120	86.541	-29.819	210	-79.443	-59.429
130	84.907	-39.729	220	-82.725	-49.609
140	82.725	-49.609	230	-84.907	-39.729
150	79.443	-59.429	240	-86.541	-29.819
160	73.483	-69.1	250	-87.891	-19.894
170	58.484	-78.247	260	-89.08	-9.96
180	0	-83.791	270	-89.801	-0.023

DATE: 21 OCTOBER 2013

N= (11.76°)

L= 6° 25' (KUALA PERLIS)

HOUR ANGLE, *h*	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β	HOUR ANGLE, *h*	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β
90	78.312	-1.305	180	0	-84.657
100	79.222	-11.053	190	-60.856	-78.776
110	79.824	-20.825	200	-73.416	-69.551
120	80.111	-30.612	210	-77.586	-59.919
130	80.003	-40.401	220	-79.319	-50.179
140	79.319	-50.179	230	-80.003	-40.401
150	77.586	-59.919	240	-80.111	-30.612
160	73.416	-69.551	250	-79.824	-20.825
170	60.856	-78.776	260	-79.222	-11.053
180	0	-84.657	270	-78.312	-1.305

DATE: 21 NOVEMBER 2013

N= (-20.46°)

L= 6° 25’ (KUALA PERLIS)

HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β	HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β
90	69.658	-2.239	180	0	-75.957
100	70.365	-11.58	190	-33.668	-72.934
110	70.513	-20.947	200	-52.155	-66.059
120	70.019	-30.304	210	-61.28	-57.712
130	68.684	-39.608	220	-66.078	-48.789
140	66.078	-48.789	230	-68.684	-39.608
150	61.28	-57.712	240	-70.019	-30.304
160	52.155	-66.059	250	-70.513	-20.947
170	33.668	-72.934	260	-70.365	-11.58
180	0	-75.957	270	-69.658	-2.239

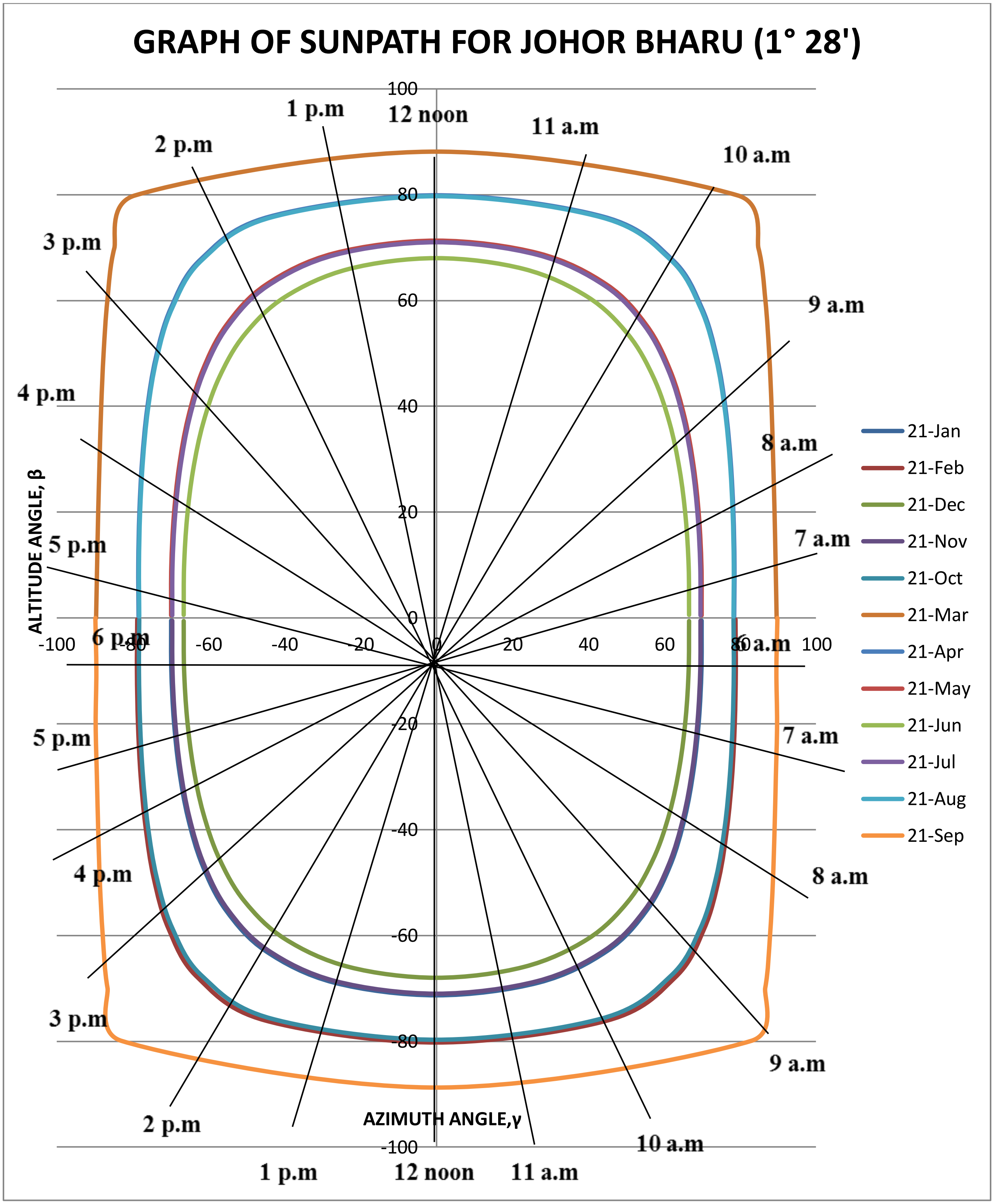
DATE: 21 DECEMBER 2013

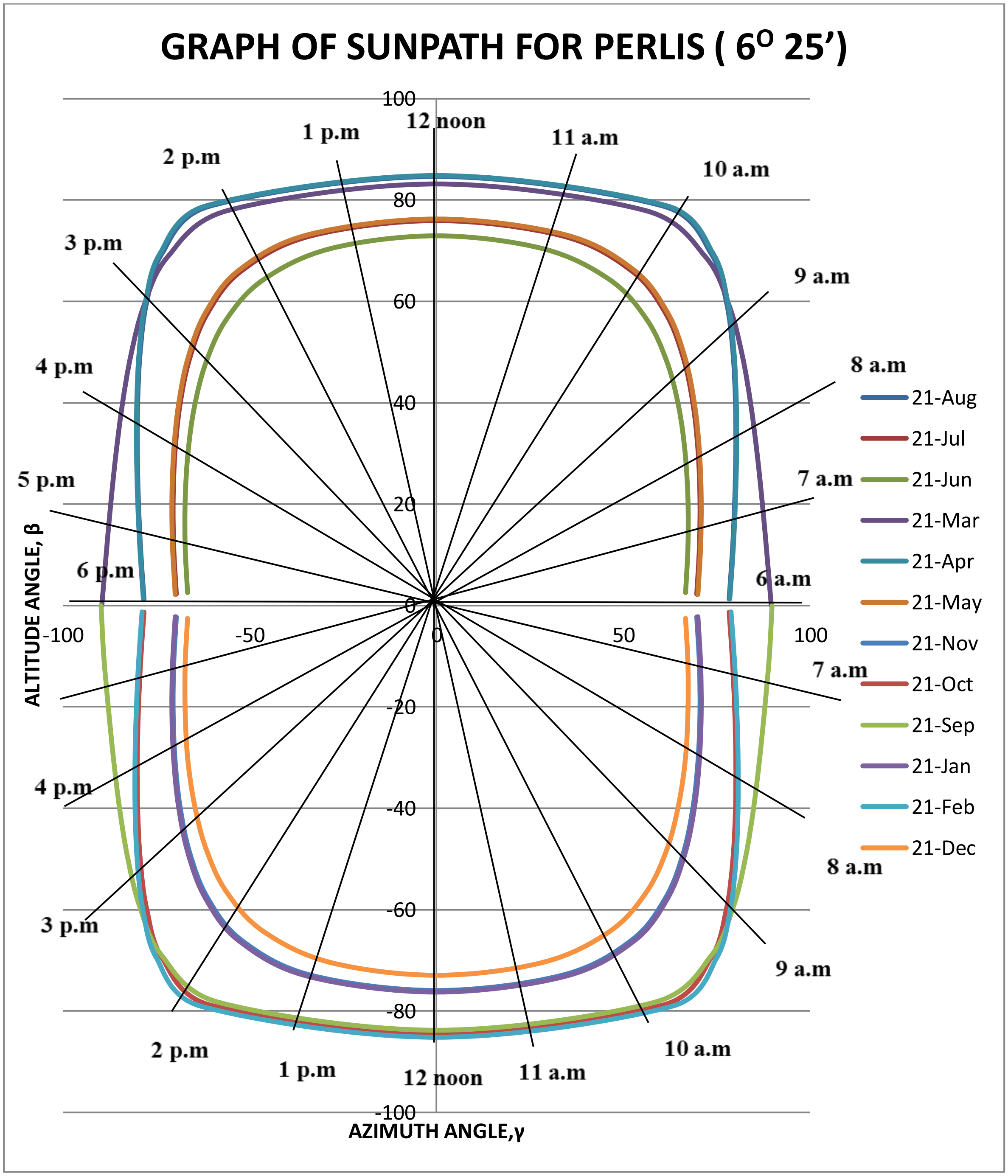
N= (-23.45°)

L= 6° 25’ (KUALA PERLIS)

HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β	HOUR ANGLE, h	AZIMUTH ANGLE, γ	ALTITUDE ANGLE, β
90	66.661	-2.551	180	0	-72.947
100	67.294	-11.7	190	-28.382	-70.422
110	67.291	-20.871	200	-46.335	-64.298
120	66.64	-30.018	210	-56.204	-56.503
130	64.852	-39.082	220	-61.718	-47.969
140	61.718	-47.969	230	-64.852	-39.082
150	56.204	-56.503	240	-66.64	-30.018
160	46.335	-64.298	250	-67.291	-20.871
170	28.382	-70.422	260	-67.294	-11.7
180	0	-72.947	270	-66.661	-2.551

APPENDIX C


GRAPH OF SUNPATH FOR JOHOR BHARU (1° 28')
ALTITUDE ANGLE, β
AZIMUTH ANGLE,γ
12 noon
1 p.m
2 p.m
3 p.m
4 p.m
5 p.m
6 p.m
11 a.m
10 a.m
9 a.m
8 a.m
7 a.m
6 a.m
100
80
60
40
20
0
-20
-40
-60
-80
-100
21-Jan
21-Feb
21-Dec
21-Nov
21-Oct
21-Mar
21-Apr
21-May
21-Jun
21-Jul
21-Aug
21-Sep


GRAPH OF SUNPATH FOR PERLIS (6O 25')
ALTITUDE ANGLE, β
AZIMUTH ANGLE,γ
100
80
60
40
20
0
-20
-40
-60
-80
-100
-100
-50
0
50
100
12 noon
1 p.m
2 p.m
3 p.m
4 p.m
5 p.m
6 p.m
11 a.m
10 a.m
9 a.m
8 a.m
7 a.m
6 a.m
7 a.m
8 a.m
9 a.m
10 a.m
11 a.m
12 noon
1 p.m
2 p.m
3 p.m
4 p.m
21-Aug
21-Jul
21-Jun
21-Mar
21-Apr
21-May
21-Nov
21-Oct
21-Sep
21-Jan
21-Feb
21-Dec