THERMAL COMFORT AND DUST CONCENTRATION LEVEL ANALYSIS OF AIR-CONDITIONED LECTURE ROOMS

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Final Report

Projek Sarjana Muda

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MAY 2017

DECLARATION

I declare that this project report entitled "Thermal Comfort and Dust Concentration Level Analysis of Air-Conditioned Lecture Rooms" is the result of my own work except as cited in the references.

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APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Thermal Fluids).

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ABSTRACT

The main purpose of this study is to evaluate the current thermal conditions and dust concentration level of selected air-conditioned lecture rooms. The selected lecture rooms were lecture room of BK10, BK12, BK13 and BK17. These lecture rooms are located at Technology Campus, University Teknikal Malaysia Melaka (UTeM), Faculty of Mechanical Engineering. The main physical parameters involved in this project are air temperature (Ta), relative humidity (RH), air velocity (Va) and particulate matter of 10µm and 2.5µm. The measurement is taken by using Thermal Micro Climate and Dust Trak II. The thermal comfort analysis of this study is conducted through DeltaLog10 software. These include the analysis of Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied (PPD) index of measurements. A form of survey had been created and been separated to the occupant involved during the measurement for with occupant condition. According to the obtained results, almost 72% of air temperature measurement data is within the standard. Compared to relative humidity and air velocity, almost 67% of relative humidity and 86% air velocity readings were not satisfied the current standard. For the measurement of dust concentration, there were 100% readings of all particulate matter of 10µm measurement were satisfied the standard. On other hand, almost 90% of particulate matter readings of 2.5µm measurement were not satisfied the standard.

ABSTRAK

Tujuan utama kajian ini adalah untuk menilai keadaan terma semasa dan tahap kepekatan habuk bilik kuliah berhawa dingin yang dipilih. Bilik-bilik kuliah yang terpilih adalah bilik kuliah BK10, BK12, BK13 dan BK17. Bilik-bilik kuliah terletak di Kampus Teknologi Univeristi Teknikal Malaysia Melaka (UTeM), Fakulti Kejuruteraan Mekanikal. Parameter fizikal utama yang terlibat dalam projek ini adalah suhu udara (Ta), kelembapan relatif (RH), halaju udara (Va) dan bahan zarahan daripada 10μm dan 2.5μm. Ukuran ini diambil dengan menggunakan TermoMicro Climate dan Dust Trak II. Analisis keselesaan haba kajian ini dijalankan melalui perisian DeltaLog10. Ini termasuk analisis ramalan purata undian (PMV) dan indeks peratus ramalan ketidakpuashatian (PPD) ukuran. Satu bentuk kajian telah diwujudkan dengan mengambil kira kehadiran penghuni dan ketiadaan penghuni. Berdasarkan keputusan yang diperolehi, hampir 72% pengukuran suhu udara mengikut piawaian. Tetapi berbeza dengan kelembapan relatif dan halaju udara, hampir 67% daripada kelembapan dan 86% bacaan halaju udara tidak mengikut piawaian semasa. Untuk mengukur kepekatan habuk, terdapat 100% bacaan semua zarah pengukuran 10μm menepati piawaian. Disamping itu, hampir 90% daripada bacaan zarah pengukuran 2.5μm tidak menepati piawaian.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Malaysia is a tropical country that possesses a hot and humidity climate in every year. The average annual temperature in is in the range of 26-27^{o}C and the relative humidity (RH) of 70-90% (Yau, Chew, & Saifullah, 2011). In order to achieve comfort or good health to the occupants, the Air conditioning (AC) and ventilation systems are installed in the building and the temperature can be controlled. The improper control of relative humidity can cause the occupants to suffer from headaches, nausea, irritations of eyes, fatigue, rash and others, that is called Sick Building Syndrome (SBS). Indoor Air Quality (IAQ) is the important factor to produce the comfortable surroundings for the occupant's attention, concentration, learning, hearing and performance. When talking about indoor air quality, the main important factor is thermal comfort (Yau et al., 2011).

The improper thermal comfort will cause the negative impact on occupant's health and the improper functioning of sensitive electronic equipment like computers, or certain equipment in manufacturing process that had minimum and maximum temperature of operation (Bradshaw, 2006). Also the indoor air quality problems are basically due to the ventilation of the halls that is not functioned well. Occupants in the university spend 90% of their time in the campus for indoor activity. The pollutants in the halls surroundings can be 100 times greater of the outside pollutants (Yau et al., 2011). Lecture halls is usually overcrowded during the peak hours compare to during term break.

Thermal comfort is a parameter that determine the comfort zone or temperature range to ensure the occupants feel comfortable. In order to determine the comfort zone of the occupants, the measurement of the current thermal comfort level should be compare with the relevant standards. ASHRAE Standard 55 is a standard that defines the thermal comfort according to the surrounding situation. Usually the common parameters to be measured for the thermal comfort are air temperature, average radiant temperature, relative humidity and air speed and the personal factor like indoor activity and clothing.(Nasir et al., 2011)

The health of the occupants can be affected by the dissatisfaction indoor air contains particles. The size, kind, and concentration of the particles that are contain in air need to be determine in order to ensure the health risk of occupants in a room.(Vilhelm & Kvols, 2000). The pollutants whether primary or secondary are definitely divided into two classifications according to the chemical composition of organic and non-organic. Organic materials contain of carbon, oxygen, hydrogen, nitrogen, phosphorus and sulphur. There are only carbon and oxygen in organic substances like hydrocarbons. For the organic material, the component involved in these materials of contaminated air are carboxylic acids, alcohols, esters and other organic sulphur. In- organic material found in the contaminated air is carbon monoxide (CO), carbon dioxide (CO2), carbonates, sulphur oxides (SOx), nitrogen oxides (NOx), ozone (O3), hydrogen fluoride (HF) and hydrogen chloride (HCC)(Nasir et al., 2011).

1.2 PROBLEM STATEMENT

Mechanical Engineering Faculty building is a one of the faculty's building in University Teknikal Malaysia Melaka. It is located at UTeM Technology Campus. It is surrounding with industrial factory like Konica Minolta, Allan D'lious Marketing and one of building construction behind the Mars building. The building contains lecture room, lecturer room, library, lab, café and others. The common factor that affected the air indoor quality is commercial or manufacturing like dry cleaning, restaurant, photo-processing, automotive shop, gas station, paint shop, electronics manufacture and various industrial operations. When it surrounding with industrial factory, it means that it will be disturb the air environment of the building (US EPA,

n.d.). The occupants are always experiencing the uncomfortable thermal environment that disturbed the occupant's performance like attention, focus, learning, hearing and seeing in their lecture room. The high occupant's density and the negative influence which is unsatisfactory thermal environment is disturbed the thermal comfort of the lecture rooms. It is suspected that the air conditioning of the lecture room is not functioning at optimum level. The occupants also always experiencing the Sick Building Syndrome (SBS) like headache, irritation of eyes and fatigue during their lecture slot. The factor of this SBS is suspected coming from the high dust concentration in the class.

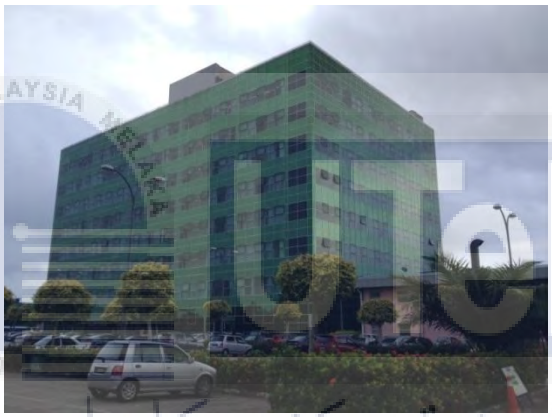


Figure 1.1 Mars building in Technology Campus, UTeM.

1.3 OBJECTIVE

The objectives of this project are as follows:

1. To evaluate the current thermal conditions of air-conditioned lecture rooms
2. To compare measured physical conditions to the comfort zone specifications by the existing standard.
3. To investigate whether the current thermal conditions and dust concentration level may have significant effects on occupants' health in the selected lecture rooms.

1.4 SCOPES OF PROJECT

The scopes of this project are:

1. The report in only present the analysis of the thermal comfort and dust concentration measurement. The measurement of analysis will be measured using the equipment obtained at thermal lab.
2. The analysis is focus on the lecture room of BK4, BK9 and BK11 With occupants and without occupants.
3. The result is compared to ASHRAE-55, MS1525 and Malaysian Air Quality Guideline standard and several suggestions is proposed.

CHAPTER 2

LITERATURE REVIEW

2.0 BACKGROUND

2.1 THERMAL COMFORT

The definition of thermal comfort defined by ASHRAE Standard 55-1992 is a state of mind that satisfied with terms of environment. There are several factors of thermal comfort which are air temperature, average radiant temperature, relative humidity and air speed and the side factor obtained activity and clothing. Several factors that involving to rise the temperature in a building are emission of heat from the lights and electrical appliances, the admission of heat from outside to the walls, windows and roofs of building and heat convection of hot air from outside the building. The standard thermal comfort in Malaysia when the relative humidity (RH) between 45% - 80.6% and the temperature is between 25.5^{o}C – 28.5^{o}C in dry bulb temperature. (Nasir et al., 2011)

There are several parameters involved in thermal comfort such as temperature, humidity, air motion and side factor like dress and occupant's activity level. To maintained the thermal comfort, human metabolism and the equipment that generate heat should be dissipate. Then the thermal equilibrium will maintain with the surroundings. ASHRAE Standard 55 (2004) stated that operating temperature and humidity is accepted in summer when the temperature is in the range of 24^{o}C-28^{o}C with 30% relative humidity and 23^{o}C - 25.5^{o}C with 60% relative humidity and air speed of below that 0.25 m/s for 0.5 clo light clothing.

The value of humidity below 50% is contribute to the spreading of influenza virus and will cause tissue weakness. The discomfort situation will happen by drying out the mucous membrane and can cause skin rashes. Office worker will feel comfort when the relative humidity is at 50%. The massive humidity will affect the office feel stuffy. Then bacterial and fungal can growth easily in sealed buildings (Yau et al., 2011).

2.1.1 Air Velocity

Air velocity also called as air movement. Air velocity is much related to heat lost by human body. If the rate of the air velocity is at low level, the heat loss produced by human body by evaporation will be rise. This is because the ability of air to absorb the moisture is much related to evaporation process. The air moisture will be change with a lower moisture content when the air passed through over the body and it will absorb the moisture from skin. The quantity of moisture will be lower if the rate of air velocity is at lower value (Bradshaw, 2006).

If the air velocity is at static condition, the air nearest the skin will absorb the moisture only until it is saturated. If the saturation point is reached the heat lost by evaporation will be decrease. The heat lost through convection is also effected by air velocity. The constant warm air next to the skin is being replaced with cooler air that will suck more heat. The air velocity also able to increase the amount of heat lost by radiation as it removes heat from the surrounding (Bradshaw, 2006).

2.1.2 Relative Humidity

The determination of moisture content in air and the value of the ability of moisture to be absorbed by air is called relative humidity. To determine the quantity of air conditioning needed in the building, the relative humidity of indoor is as the indicator. It has a tremendous effect on the amount of heat rejected through the radiation process by the body. The relative humidity can be determined by dividing the value of water vapour that contained in air by the quantity of the

air could hold when saturated at the same temperature. Human body will reject more heat through evaporation process when the relative humidity of air surroundings at low level. Also, the human body will reject less heat through evaporation process when the relative humidity of air surroundings at high level. Generally, almost person will satisfy the comfortable when air is at condition of 26.7^{o}C temperature and 50% relative humidity (Bradshaw, 2006).

2.1.3 Radiant Temperature

The warm object that transfer heat and radiates are called thermal radiation. According to the Handbook of Air Conditioning and Refrigeration second edition, mean radiant temperature can be defined as the temperature of a uniform black enclosure in which an occupant would have the same amount of radiative heat exchange as in an actual indoor environment. The radiation normally come from the sunlight, light bulb and others specially for building. The sense of radiant temperature by human usually stronger than air temperature. This is because the human skin has massive emissivity and absorptive. Therefore, the skin is very sensitive to the radiant heat loss and gain (Bradshaw, 2006).

The mean radiant temperature can be measure by using globe thermometer or also called as globe temperature. This equipment contains of a 152 mm copper hollow sphere diameter. It is coated with black paint on the outer space. Inside the globe there was a component called thermometer or thermocouple with the sensing bulb or the thermo junction located at the middle of the sphere (Bradshaw, 2006).

2.2 PREDICTED MEAN VOTE (PMV) AND PREDICTED PERCENTAGE OF DISSATISFIED

Predicted mean vote (PMV) is the thermal index value corresponding with a mean vote of neutral on the thermal sensation scale according to ASHRAE Standard. The predicted percentage of dissatisfied (PPD) an index establishes a quantitative prediction of the percentage of thermally dissatisfied people determined from PMV.

The PMV model uses heat balance principles to relate the six key factors for thermal comfort parameters listed. The PPD is related to the PMV and based on the assumption that people voting +2, +3, -2, -3 on the thermal sensation scale are dissatisfied and on simplification that PPD is symmetric around a neutral PMV. According to ASHRAE Standard, they recommended the PPD below 10 and the PMV in the range of -0.5 to +0.5.

2.3 METABOLIC RATE

Basically the metabolic rate is depending on the activity level of human and proportional to weight. Body surface area, health, sex, age, clothing, the thermal of surrounding and atmospheric pressure is related to the metabolic rate. The maximum production of metabolism is at the age's range of 10 years and minimum at old age. It can be higher when fever, continuous activity or cold environmental conditions happen.

The heat production by human body increases proportional to exercise's level. It is important to ensure the metabolic rate of human physical activities in other to ascertain the comfort and health of optimum environmental conditions. The metabolic rate can be analysed from sleeping to high level of work as shown the Table 2.1 below (Bradshaw, 2006)

Table 2.1 The Activities Metabolic Rate from ASHRAE 1989

Activity	Metabolic Rate in Met Units	Activity	Metabolic Rate in Met Units
Resting		Miscellaneous Work	
Sleeping	0.7	Watch-repairing, seated	1.1
Reclining	0.8	Lifting/packing	1.2 to 2.4
Seated, reading	0.9	Garage work	2.2 to 3.0
Office Work		Vehicle Driving	
Seated, writing	1.0	Car	1.5
Seated, typing or talking	1.2 to 1.4	Motorcycle	2.0
Seated, filling	1.2	Heavy vehicle	3.2
Standing, talking	1.2	Aircraft flying, routine	1.4
Drafting	1.1 to 1.3	Instrument landing	1.8
Miscellaneous office work	1.1 to 1.3	Combat flying	2.4
Standing, filling	1.4		
Walking (on level ground)		Leisure Activities	
2 mph (0.89 m/s)	2.0	Stream Activities	1.2 to 2.0
3 mph (2.34 m/s)	2.6	Golf, swinging and walking	1.4 to 2.6
4 mph (1.79 m/s)	3.8	Golf, swinging and with golf cart	1.4 to 1.8
Domestic Work		Dancing	2.4 to 4.4
Shopping	1.4 to 1.8	Calisthenics exercise	3.0 to 4.0
Cooking	1.6 to 2.0	Tennis, singles	3.6 to 4.6
House cleaning	2.0 to 3.4	Squash, singles	5.0 to 7.2
Washing by hand and iron	2.0 to 3.6	Basketball, half court	5.0 to 7.6
Carpentry		Wrestling, competitive or intensive	7.0 to 8.7
Machine sawing, table	1.8 to 2.2		
Sawing by hand	4.0 to 4.8		
Planing by hand	5.6 to 6.4		

2.3.1 Thermal Sensation

When the occupants doing several activity or under several environmental situations, the metabolism rate can be change. The various and type of clothing wearing by occupants also contribute to the satisfaction of thermal. ASHRAE Standard 55 (2004) outlines the guidelines the studies of thermal comfort to using the ASHRAE thermal sensation scale. (Yau et al., 2011) The scales are shown as (+3hot), (+2 warm), (+1 slightly warm), (0 neutral), (-1 slightly cool), (-2 cool) and (-3 cold).

2.4 CLOTHING

Clothing is one of parameter to determine the thermal comfort. The clothing insulation properties is the main thing modifier of body heat loss and comfort. It is can be describe in term of clo value. 1 clo is equal to 0.155 m^2.C/W. Clothing insulation and room temperature has their own relationship. It presented in Figure 2.1 for sedentary occupants, and specified air speed and humidity.

No combination's condition would satisfy all occupant at all time. The middle line of the Figure 2.1 Is the operative temperature that satisfies most of the people with given amount of clothing and activity level specifications. The lower and upper line are the thermal acceptability show that an environment of a room at least 80 percent of the occupants would find thermally acceptable.

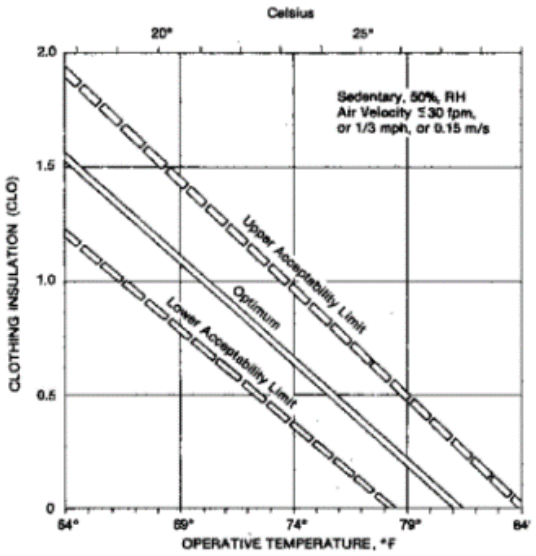


Figure 2.2 Clothing Level Necessary for Comfort at Different Operative Temperature

2.5 DUST

It can be particulate or gaseous on defining the air contaminants. Also organic or inorganic, visible or invisible, toxic or harmless. The classification can be divided into three. The first one is dust, fumes and smoke that are chiefly solid particulates. However most of smoke often obtains liquid particles. The second one is mist and fog like liquid particulates. And the third is vapour and gases which are non-particulates. The containing of dust is solid particles moved into air that forced by natural forces like wind, volcanic eruption or earth quakes and also by human activities. The 100 times smaller than dust particles which is solid airborne particles is called fumes. It is formed by consideration of vapour of normally solid materials. It is tended to agglomerate into larger cluster if it permitted to age. Smoke if formed from solid or liquid particles same size of fume commonly produced by combustion of organic substances like tobacco, wood, coal and oil. It is also allowed the living organism which range in size from submicroscopic viruses to the larger pollen grains included bacteria and fungus spore but not the smallest insects.

2.6 STANDARD

Standard is a guideline that every analysis experiment should be compared. It is also to determine either the result of the experiment satisfy the standard or not. On more detail, the standard is an outline guideline that the occupants achieve the comfortable condition. Also for particulate matter, the result must be compared to the standard to ensure the quality of air and not to be dangerous for occupants. There are several standards that will put into consideration. The standard can be classified as international standard and Malaysian standard.

2.6.1 ASHRAE Standard 55

ASHRAE's Standard 55 the short form of American Society of Heating, Refrigerating and Air Conditioning Engineers guides to provide comfort of the indoor space conditions and personal factor. It outlined a guidelines or standard of the interactions between temperature, thermal radiation, humidity, air speed, personal activity level and clothing.

The standard had suggested that the condition needed to be consider in experiment should be 80 percent of the occupants within a space. The operative temperature ranges for building occupants is about 20^{o}C to 23.5^{o}C with winter clothing (0.8 clo to 1.2 clo). For the summer clothing (0.35 clo to 0.6 clo), the range temperature recommended is 22.5^{o}C to 26^{o}C.

These value are referring to the 60 percent relative humidity and 1.2 met of activity level and the air velocity is about 0.15m/s to 0.5m/s. The standard obtained a chart that showed the allowable air velocity to room air temperature and the turbulence of air. Each 0.1 clo rise, the temperature is decreased by 0.6^{o}C. Comfort are referring on maintaining a uniform distribution of clothing insulation over entire body as the temperature decrease like hands and feet.

2.6.2 ASHRAE Standard 2010 - Ventilation for Acceptable Indoor Air Quality

ASHRAE Standard 2010 for Ventilation for Acceptable Indoor Air Quality had been outlined the guideline of the safe indoor particulate matter concentration for building design, diagnostic and ventilation system design by using the indoor air quality procedure. Basically the particles diameter of 2.5 micron and below are coming from combustion product, cooking, candles, incense, resuspension and outdoor air and the particles diameter of 10 microns and below usually from dust, smoke, deteriorating materials and also outdoor air. Particulates matter concentration if not control can cause the haze that reduces visibility. For the concern of health effects, it can cause nose and throat irritation, lung damage, bronchitis and early death. Generally, the particulates matter source are coming from wood burning, diesel, industrial plants, agriculture and unpaved roads. The standard of particulates matter that had been outlined by ASHRAE are shown below:

Particulates matter diameter of 2.5 micron, $PM_{2.5}$: $< 15\ \mu g/m^3$
Particulates matter diameter of 10 micron, PM_{10} : $< 50\ \mu g/m^3$

2.6.3 Malaysian Standard (MS 1525: 2014)

Malaysian Standard of energy efficiency and use of renewable energy for non-residential buildings (MS 1525:2014) list the parameters of room comfort condition as shown below:

a) Dry bulb temperature
b) Relative humidity
c) Air movement or air velocity

A person will satisfy comfortable when metabolic rate is dissipated at the rate at which it is produced. Temperature that needs to be constant at human body is at the range of $37 \pm 0.5^{o}C$ without counting the current condition of ambient. The amount of heat by human body will be less transfer if the space of humidity is high. The human body will feel unsatisfied if the

temperature of indoor air and the relative humidity is high. Relative humidity of indoor comfort condition should be not exceeding 70 %.

Air velocity is important for the human body comfort as it increase heat exchange between the air and the human body and accelerates the cooling of human body. The feeling of freshness will produce by air movement in a space by lowering the temperature of skin. The low temperature of the air movement will produce a drought. A comfort room temperature that was outlined is at the range of 24^{o}C to 26^{o}C and the acceptable air velocity is at 0.15 m/s to 0.5 m/s. Below are the parameter that had outlined by Malaysian Standard to achieve thermal comfort of indoor condition.

a) recommended design dry bulb temperature	24^{o}C - 26^{o}C
b) minimum dry bulb temperature	23^{o}C
c) recommended design relative humidity	50 % - 70 %
d) recommended air movement	0.15 m/s – 0.50 m/s
e) maximum air movement	0.70 m/s

2.6.4 Malaysian Air Quality Guideline

The Department of Environment (DOE) outlined a guidelines of air quality in 1989. Recommended Malaysian Air Quality Guidelines (RMG) for air pollutants come out the concentration limits of the selected air pollutants which could be affect the human health. The common factors that had put in the considerations to Malaysian Air Pollutants Index (API) are ozone (O3), carbon monoxide (CO), nitrogen dioxide (NO2), Sulphur dioxide (SO2) and suspended particulate matter (PM_{10}).

Table 1.2 is presented the basis calculating API by the Recommended Malaysian Air Quality (RMG). These listed guidelines are derived from available scientific and human health data and generally guarantee safe level below which there is no negative effect of health. The

RMG also compare to the corresponding air quality standards recommended by the World Health Organization and other countries.

Table 1.2 Recommended Malaysia Air Quality adopted in Air Pollutant Index Calculation

Pollutant	Average Time	Malaysian Guidelines	
		(ppm)	($\mu g/m^3$)
Ozone	1 hour	0.10	200
Carbon Monoxide	8 hour	9	10
Nitrogen Dioxide	1 hour	0.17	320
Sulphur Dioxide	24 hour	0.04	105
PM_{10}	24 hour		150

2.7 PREVIOUS STUDY OF THERMAL COMFORT AND DUST CONCENTRATION LEVEL

2.7.1 Effective Ventilation Parameters and Thermal Comfort Study of Air-conditioned Offices (Daghigh & Sopian, 2009)

The studied conducted by Roonak Daghigh and Kamaruzzaman Sopian at University Putra Malaysia which is held at the office of Department of Electrical and Electronic Engineering. The studied was analysed the thermal comfort of two different offices which is classified as office 1 and office 2. The result of office 1 showed that the average temperature was 21.5^{o}c with relative humidity of 53%. The result of the office 2 found that the temperature was 22.6^{o}c with relative humidity of 59%. However, the result found were not fall in the comfort range when comparing to the ASHRAE Standard. The results of PMV and PPD showed that the value is not achieve with the standard of ISO 7730. ISO 7730 recommended that the comfort range is achieved when the PMV has the values between -1 to +1. The range of PMV obtained were between -1.7 to -1.5 for office 1 and -1.2 to -1.4 and the PPD was in range of 50 % to 60 %

for office 1 and 35 % to 45 % for office 2. Almost half of the occupants feel unsatisfied the thermal comfort for both offices.

The measurement is using measuring physical quantities instrument such as air velocity, relative humidity, dry bulb temperature and mean radiant temperature. All the measurement is taken at 1.1 meter of height above the floor. Every one minutes interval the sample are recorded. The metabolic rate is set 1.2 met represent the sedentary office (office, dwelling, school) and the clo value of 0.5 which the males were wearing underpants, shirt with short sleeves, light trousers, light socks and shoes and the females were wearing cotton or silk with light cotton undergarments and lightweight scarf.

2.7.2 Thermal Comfort in Lecture Halls In The Tropics (Yau et al., 2011)

Yat Huang Yau and others had conducted a field study about Thermal Comfort in Lecture Halls in the Tropics. The scope of the study is at the lecture halls which is conducted 6 lecture halls DK1-DK6 at Faculty of Engineering at University of Malaya, Kuala Lumpur. The data that had been measured are air temperature, mean radiant temperature, relative humidity, air velocity and personal variables. There were several points that had been selected in the lecture halls which is most crowded zones and possibility to place the equipment. The measurements were taken at the range of time of 10.00 am to 5.00 pm and mostly on the sunny days.

The result of the study showed that only one of the six lecture halls satisfy the thermal comfort of ASHRAE Standard 55 (2004). The TSV analysis of the thesis showed most of the occupants felt ‘slightly cool’ and ‘cool’ in the lecture halls. At the end of the thesis, the authors recommended the operation of temperature should be 25.3^{o}C as a solution to satisfy the comfortable of the occupants. The air conditioning design should be increase the air speed better than lowering the value of temperature and humidity to achieve comfort. For the great energy saving for the air conditioning, the operative temperature should be 27.5^{o}C and 60 % of relative humidity, the air speed being 0.36 m/s with ≤1.2 activity level for sedentary working environment and clothing insulation of 0.5 clo. The overall results are shown below:

Table 2.3 The Measurement Result of Thermal Comfort Parameters in Lecture Halls (Yau et al., 2011)

Location	Input Parameters						Outputs	
	Clothing (clo)	Air temp. (°C)	Mean radiant temp. (°C)	Activity (met)	Air speed (m/s)	Relative humidity (%)	PMV	PPD
DK1	0.64	20.84	23.4	1.12	0.20	47.67	-1.10	30.50
DK2	0.61	21.1	22.56	1.03	0.10	62.6	-1.20	35.20
DK3	0.57	22.16	22.65	1.08	0.12	69.31	-0.70	15.30
DK4	0.59	22.27	22.13	1.02	0.12	48.2	-1.30	40.30
DK5	0.64	21.38	22.32	1.05	0.14	48.96	-1.00	26.10
DK6	0.60	24.86	25.38	1.10	0.08	62.4	0.20	5.80

2.7.3 Carbon Dioxide Concentrations Analysis Inside Lecture Rooms (Dadan, Tuan, Kim, & Leman, 2006)

One study that had been conducted at Universiti Teknikal Malaysia Melaka to determine the carbon dioxide CO_2 concentration relationship and also the relationship between the concentration of carbon dioxide and the temperature of indoor inside lecture room. The study conducted by Norlidawati Dadan, Tee Boon Tuan, Gan Chin Kim and Abdul Mutalib Leman. The lecture room that using the mechanical ventilation had been selected to measure the physical measurement in this study. The parameter that had been put into consideration are indoor temperature and relative humidity. The equipment that had been selected to measure the parameters are Air Velocity Meter and Thermal Comfort Meter (Thermal Microclimate). The thesis was measured at three different lecture rooms which is can be classified as BK1, BK2 and BK3. The measurement was conducted with fully occupancy condition.

The results of the thesis showed that the indoor temperature obtained at the first 2-hour period almost constant which is in the range of 21.9°C to 23.5°C. for the values of relative humidity, the values were in the range of 54.4 % to 65.6 %. The average indoor temperature obtained in this study was 22.33°C. The standard recommended by ASHRAE Standard suggested that the indoor temperature to be in the range of 22.5°C to 26°C. It can be say that almost indoor

temperature was fall in the values suggested by ASHRAE Standard. For relative humidity, the higher value was 65.7 % and the average value was 61.09 %. ASHRAE Standard recommended that the value must fall in the range of 40 % to 60 %. Compared to the result obtained, the value of relative humidity was achieved ASHRAE Standard. Table 2.4 showed the results obtained with comparison with ASHRAE Standard.

Table 2.2 Results Comparison to ASHRAE Standard 62-2004

Parameters	Current study	ASHRAE Standard (summer)
Indoor temperature (^{o}C)	21.9 – 23.5 (average: 22.33)	22.5^{o}C – 26^{o}C
Relative Humidity (%)	54.4 – 65.7 (average: 61.09)	40 % - 60 %

2.7.4 Identification of Indoor Environmental Quality (IEQ) Parameter in Creating Conducive Learning Environment for Architecture Studio (Nasir et al., 2011)

There was a study conducted at Universiti Kebangsaan Malaysia to identify the indoor environmental quality (IEQ) parameter in creating conducive learning environment for architecture studio.(Nasir et al., 2011). There were several parameters is taken into account that's are thermal comfort, ventilation, noise, suspended material in the air and the chemical content composition. Also the others parameter like air quality, disturbances, control, appearance, general atmosphere and lighting was put into consideration. A selective studio had been chosen to take the parameters measurement. The studio-based learning is a student facility to share information and facilitated lecturers to monitor student's activities.

The result obtained to be focused are the parameters of thermal comfort and relative humidity. At the end of the study, the results showed that the temperature reading is fall in the range of 25.5^{o}C to 28.5^{o}C. for the relative humidity, the reading measurement was at 45 % to 80.6 %. The authors classified the temperature reading into several conditions. The classification was divided into four categories which are very low, low, average and good. Same goes to the relative humidity, it is divided into the same categories as reading temperature. The value of each categories is shown in the Table 2.5.

Table 2.3 The Reading of Temperature and Relative Humidity Parameters (Nasir et al., 2011)

No	Parameter	Reading	Notes
1	Thermal comfort		
	a. Temperature	25.5°C – 28.5°C	1= Very low (less than 25.5°C or more than 28.5°C 2= Low (25.6°C – 26°C) 3= Average (26.1°C – 27°C) 4= Good (27.1°C – 28.5°C)
	b. Relative humidity	45% - 80.6%	1= Very low (less than 45% or more than 80.6% 2=Low (45.1% - 60%) 3=average (60.1% - 70%) 4=Good (70.1% - 80.6%)

2.7.5 Development and application of an indoor air quality audit to an air-conditioned tertiary institutional building in the tropics (Cheong & Lau, 2003)

A study is about the development and application of an indoor air quality audit to an air conditioned tertiary institutional building in the tropics had measured the thermal comfort institutional building. The study was located in Singapore. There were two locations were selected to measure the parameters that's are the staff room and lecture theatre in the institution. The parameters that were put into considerations were air temperature (dry bulb), relative humidity and mean air velocity. Others parameters also included in this study but not be focused in this section. the measurements of the parameters were conducted at four different locations in staff room and lecture theatre. These is to ensure a good representation of the status of human exposure to thermal comfort and air quality. The measurement was using an Indoor Climate Analyser, Type 1213. This equipment a portable type that sense environmental conditions via separate transducers. The result of the study was shown in the Table 2.6 for staff room and Table 2.7 for lecture theatre.

Table 2.4 The Thermal Comfort Results of Staff Room (Cheong & Lau, 2003)

Location	Air temp. (dry bulb) (°C)	Relative humidity (%)	Mean air velocity (m/s)
A	24.3	62.5	0.13
B	24.9	60.5	0.12
C	25.9	63.0	0.14
D	23.5	61.3	0.17
Outside air	27.8	70.0	—

Table 2.5 The Thermal Comfort Results of Lecture Theatre (Cheong & Lau, 2003)

Location	Air temp. (dry bulb) (°C)	Relative humidity (%)	Mean air velocity (m/s)
A	22.9	75.6	0.04
B	23.1	74.7	0.15
C	23.4	76.0	0.19
D	23.6	78.3	0.09
Outside air	30.9	84.7	—

For the staff room, the temperature obtained was in the range of 22.9^{o}C to 23.6^{o}C. This value is satisfied the IAQ guideline which is recommended the temperature of 22.5^{o}C to 25.5^{o}C. For the value of air velocity, all the points got the value less than 0.25 m/s (recommended by IAQ) which is the higher value is 0.09 m/s and the lower is 0.04 m/s. But for the relative humidity, the reading obtain at all locations were above the IAQ recommended value (≤ 70%). For the result of lecture theatre, the air temperature was also within the recommended range of 22.5^{o}C to 25.5^{o}C except the location C, which is the value of the reading is 23.5^{o}C to 25.9^{o}C.

Same goes to the relative humidity and the air velocity, all the values are within the local IAQ guideline. Unfortunately, the measure obtained of relative humidity marginally exceeded the ASHRAE Standard 60%.

The objective of this study also to measure the dust particles or particulate matter. This study was measured the suspended particulate (PM10). The equipment used in this study was an environmental laser aerosol spectrometer, Grim Portable Dust Monitor Series 1.105. This equipment is able to measure the dust particle of diameter 0.1 to 10 µm with an accuracy of ±5 %. The unit measurement was µg m^{-3}. Same goes to other parameters measurement, the measurement of dust particle was also run in both location, staff room and lecture theatre. The result obtained from this study was compared to Singapore Guidelines for good air quality. The standard used recommended the suspended particulate matter for particulate less than 10 µm is 150 μgm^{-3}.

Table 2.6 showed that the average concentration of particulates matters in indoor staff room. Seems that all the value obtained was less than the requirement which is in the range of 2 to 10 μgm^{-3}. For the measurement of dust particles in lecture theatre, seem that the value obtained as overall are relatively higher that the level in the staff room. The value of the measurement was in the range of 42 to 127 μgm^{-3}. This result can be seen in the Table 2.7. However, although the result of lecture theatre of dust particles was higher than the results obtained in staff room, the result still within the threshold level and there is no cause for concern.

Table 2.6 The Particulate Concentration (PM10) Results of Staff Room (Cheong & Lau, 2003)

Location	Particulate concentration ($\mu g\ m^{-3}$)
A	2
B	4
C	7
D	10
Outside air	50

Table 2.7 The Particulate Concentration (PM10) Results of Lecture Theatre (Cheong & Lau, 2003)

Location	Particulate concentration (μg m^{-3})
A	60
B	127
C	81
D	42
Outside air	42

2.7.6 Indoor air quality evaluation of two museums in a subtropical climate conditions (Zorpas & Skouroupatis, 2016)

A study conducted by Zorpas and others is a study about indoor air quality evaluation of two museums in a subtropical climate conditions. This study is aims to characterize, analyse and determine indoor air pollutants in Archeological and Byzantine museum. The parameters concerned in this study was particulate matters of PM1, PM2.5, PM7 and PM10. There were several parameters also put into considerations but in this section will be focused on the parameters of particulate matters. The measurements were run in different periods in four seasons that's are summer (June), autumn (November), winter (December) and spring (March-April). The measurements were run during morning 8.00am to 11.00am and during afternoon 4.00pm to 7.00pm. The equipment used in this study were Mass particle Counter of PM1, PM2.5, PM7 and PM10.

The result obtained by this study can be seen in Table 2.10 and Table 2.11 for the results at Cypriot Archeological Museum, seems that the value got for PM1 and PM2.5 was zero value. For PM7, the result got was in the range 0.01 mg/m^3 ± 0.01 mg/m^3 to 0.02 mg/m^3 ± 0.01 mg/m^3. For the results of PM10, the value got was only 0.02 mg/m^3 ± 0.01 mg/m^3 in all conditions.

Seems that the measurement gained in this study for particulate matters of PM1 and PM2 is zero value at Byzantine Museum. For the PM7 and PM10 at Byzantine Museum, the results gained showed that the value got was 0.01 mg/m^3 ± 0.01 mg/m^3 for PM7 and 0.01 mg/m^3 ± 0.01 mg/m^3 to 0.02 mg/m^3 ± 0.01 mg/m^3.

Table 2.8 The Results Study at Archeological Museum (Zorpas & Skouroupatis, 2016)

Measurements Eastern Halls measurements	Average morning	Average afternoon	Measurements of Western Halls	Average morning	Average afternoon
T °C	22.04 ± 1.84	23.84 ± 2.16	T °C	20.75 ± 2.31	22.45 ± 1.39
RH%	42.71 ± 7.12	32.82 ± 8.21	RH %	47.25 ± 5.76	41.33 ± 7.02
CO_2 ppm	631.55 ± 48.47	693.71 ± 125.37	CO_2 ppm	676.18 ± 100.53	698.77 ± 116.88
SO_2 ppb	5.82 ± 0.57	4.76 ± 1.31	SO_2 ppb	5.45 ± 0.99	4.46 ± 1.08
NO ppb	0.00 ± 0.00	0.00 ± 0.00	NO ppb	0.55 ± 1.72	0.00 ± 0.00
NO_2 ppb	32.36 ± 25.38	17.35 ± 23.42	NO_2 ppb	30.82 ± 24.77	11.08 ± 13.91
O_3 ppb	88.09 ± 12.71	79.41 ± 17.06	O_3 ppb	77.82 ± 12.35	68.23 ± 14.46
BEN ppb	4.00 ± 3.30	2.59 ± 3.03	BEN ppb	3.64 ± 2.87	2.15 ± 2.03
TOL ppb	10.45 ± 2.15	8.00 ± 2.52	TOL ppb	10.00 ± 2.30	8.77 ± 2.36
ETH ppb	0.09 ± 0.29	1.06 ± 1.30	ETH ppb	0.09 ± 0.29	0.85 ± 1.29
XYL ppb	0.00 ± 0.00	0.00 ± 0.00	XYL ppb	0.00 ± 0.00	0.00 ± 0.00
NH_3 ppb	33.18 ± 5.86	39.71 ± 10.53	NH_3 ppb	29.18 ± 6.58	37.46 ± 8.40
H_2S ppb	0.09 ± 0.29	1.06 ± 1.21	H_2S ppb	0.27 ± 0.45	0.85 ± 1.17
PM1 mg/m^3	0.00 ± 0.00	0.00 ± 0.00	PM1 mg/m^3	0.00 ± 0.00	0.00 ± 0.00
PM2.5 mg/m^3	0.00 ± 0.00	0.00 ± 0.00	PM2.5 mg/m^3	0.00 ± 0.00	0.00 ± 0.00
PM7 mg/m^3	0.02 ± 0.01	0.01 ± 0.01	PM7 mg/m^3	0.02 ± 0.01	0.02 ± 0.01
PM10 mg/m^3	0.02 ± 0.01	0.02 ± 0.01	PM10 mg/m^3	0.02 ± 0.01	0.02 ± 0.01
TSS mg/m^3	0.03 ± 0.01	0.02 ± 0.01	TSP mg/m^3	0.03 ± 0.01	0.03 ± 0.01

Table 2.9 The Results Study at Byzantine Museum (Zorpas & Skouroupatis, 2016)

Measurements	Average for the Morning Hall I	Average for the Afternoon Hall I	Average for the Morning Hall II	Average for the Afternoon Hall II
T, °C	20.57 ± 2.87	21.44 ± 2.81	19.86 ± 2.04	20.68 ± 1.87
RH%	45.49 ± 10.37	42.80 ± 10.10	47.43 ± 7.45	44.81 ± 6.24
CO_2, ppm	617.67 ± 68.41	748.22 ± 153.38	596.89 ± 37.94	712.89 ± 101.2
SO_2, ppb	5.78 ± 0.97	4.89 ± 0.78	5.67 ± 0.87	4.56 ± 0.53
NO, ppb	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
NO_2, ppb	29.44 ± 24.05	3.33 ± 10.00	21.22 ± 18.28	4.00 ± 12.00
O_3, ppb	91.67 ± 16.91	70.78 ± 20.81	76.33 ± 13.58	59.44 ± 18.09
BEN, ppb	4.89 ± 3.33	1.00 ± 1.73	4.67 ± 2.60	1.33 ± 2.06
TOL, ppb	11.56 ± 2.13	8.67 ± 4.03	11.56 ± 1.67	9.22 ± 2.39
ETH, ppb	0.11 ± 0.33	2.22 ± 2.64	0.11 ± 0.33	2.33 ± 2.50
XYL, ppb	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
NH_3, ppb	30.11 ± 8.19	36.67 ± 12.44	29.44 ± 7.02	36.44 ± 9.82
H_2S, ppb	0.11 ± 0.33	1.67 ± 1.58	0.44 ± 0.73	2.11 ± 1.76
PM1, mg/m^3	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
PM2.5, mg/m^3	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
PM7, mg/m^3	0.01 ± 0.01	0.01 ± 0.01	0.01 ± 0.01	0.01 ± 0.01
PM10, mg/m^3	0.01 ± 0.01	0.02 ± 0.01	0.01 ± 0.01	0.01 ± 0.01
TSS, mg/m^3	0.02 ± 0.01	0.02 ± 0.01	0.01 ± 0.01	0.02 ± 0.01

2.7.7 Concentration of particulate matter, CO and CO_2 in selected schools in Malaysia (Yang Razali et al., 2015)

Yang Razali and the team had conducted a case study about the concentration of particulate matter, CO and CO2 in selected schools in Malaysia. The study had been conducted at Bandar Baru Bangi and Putrajaya. The school that had been chosen were Precint 14 Secondary School (S1), Jalan Reko Secondary School (S2) and Section 4 Secondary Schol Bandar Baru Bangi (S3). The study was aim to determine the influence of the total local surroundings on the IAQ in the school classrooms. There were numerous parameters that had put into considerations that's was the concentration of gas pollutants (CO, CO2) and particulate matter (PM1, PM2.5, PM10). The parameters had been determined by using automatic portable indoor air spectrometers. The study was conducted at one chosen classroom from 14th June to 1st July 2011. The period of experiment running was 8 hours from 7:30 to 15:30 for two days

For indoor measurements, the equipment was placed at the middle of the classroom, 1m from the floor. The equipment's name to measure the PM was portable aerosol spectrometer model 1.108 with a flow rate of 1.2 L/min (Grimm Technologies, Germany). The result of this study can be seen at Table 2.12. the highest concentration of PM10 were recorded at S1 which is 35 ± 11 μgm^{-3}. The average particulate matter concentration for S2 and S3 was 28 ± 11 μgm^{-3} and 30 ± 8 μgm^{-3}. For the particulate matter measuring using PM2.5 and PM1, the school of S1 (with concentration of 22 ± 6 μgm^{-3} and 20 ± 5 μgm^{-3}) and S3 (with concentration of 22 ± 5 μgm^{-3} and 20 ± 5 μgm^{-3}) got the similar value. For the S2, the concentration of particulate matter for PM2.5 and PM1 was 11 ± 1 μgm^{-3} and 9 ± 5 μgm^{-3} which was the lowest concentration recorded.

Table 2.10 The Results of each Parameter at All School

Station	Statistics	Indoor air						
		PM_{10}	$PM_{2.5}$	PM_1	CO_2	CO	T	RH
		($\mu g\ m^{-3}$)			(ppm)		(°C)	(%)
Precinct 14	Min	16	13	12	462	0.0	26	54
Secondary	Max	69	36	32	645	1.3	35	89
School,	Avg	35	22	20	502	0.2	32	67
Putrajaya (S1)	SD	11	6	5	36	0.2	2	8
Jalan Reko	Min	14	8	6	462	0.0	26	51
Secondary	Max	72	16	11	684	4.3	35	90
School (S2)	Avg	28	11	9	507	0.3	32	64
	SD	11	1	1	35	0.6	3	11
Section Four	Min	16	14	13	439	0.0	25	59
Secondary	Max	62	34	30	684	3.8	34	90
School (S3)	Avg	30	22	20	498	0.5	30	72
	SD	8	5	5	53	0.5	2	7
Average (Overall)		31	18	16	502	0.3	31	68
DOSH Malaysia [35].		150	N/A	N/A	1000	10.0	23–26	40–70
NEA Singapore [36].		150	N/A	N/A	1000	9.0	22.5–25.5	≤70

CHAPTER 3

METHODOLOGY

3.1 BACKGROUND

This section is the explanation about the method used to run the study. Furthermore, it explains the research design, sampling techniques and analysis method used and explained on how the data was collected from the research and analysis. Two systems of evaluation of field study which are literature review and field measurement was used. The literature reviewed like journals, articles or any materials related to the field study had been reviewed.

Generally, the methodology flows were beginning with literature reviewed of related field study as mentioned before. Then several locations (lecture rooms) had been chosen and some questionnaire will be separated to the occupants to identify the several issues about the field study chosen. The analysis of the thermal comfort and dust concentration measurement is focusing on the thermal comfort and dust concentration level analysis. Several parameters are measured in this field study like operating temperature, relative humidity, air velocity, mean radiant temperature, dust concentration (PM2.5 and PM10). The general flow chart of methodology is shown in Figure 3.1.

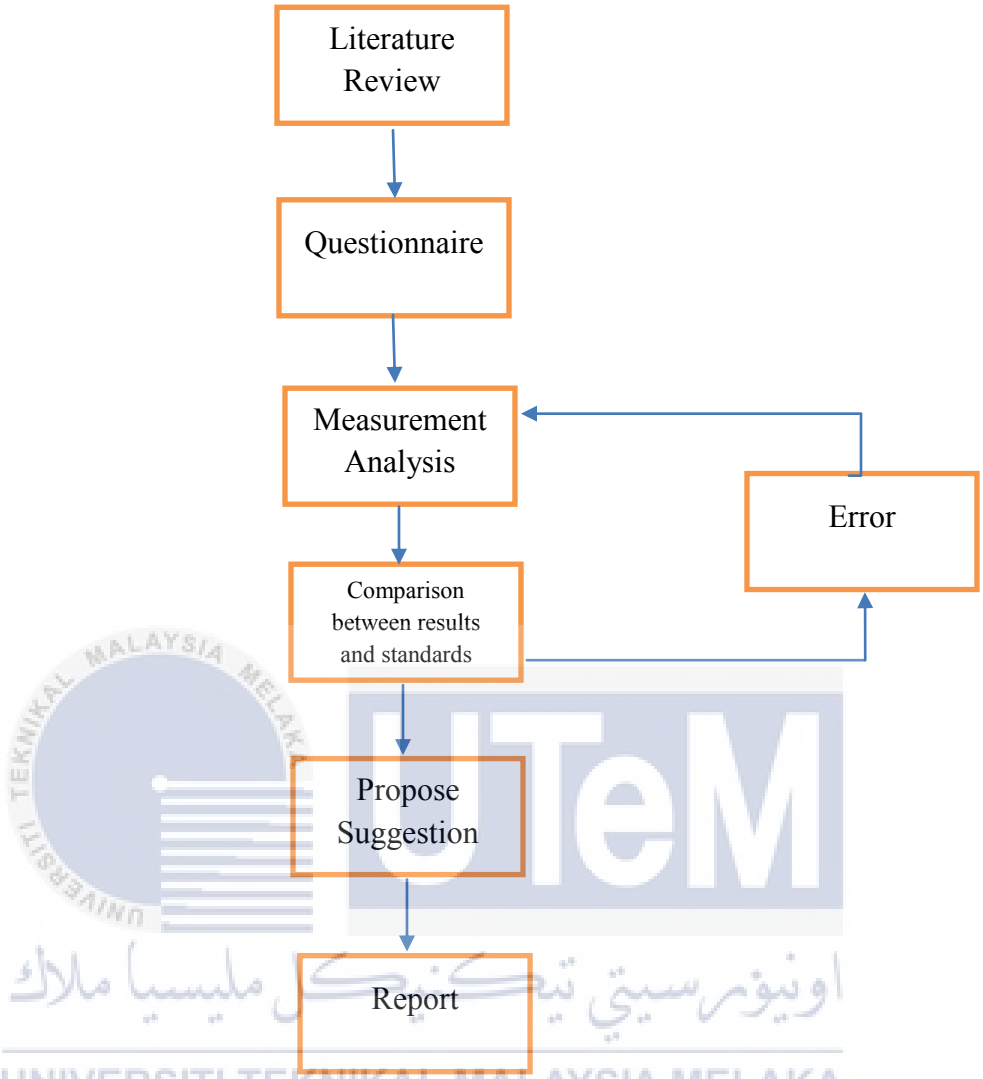


Figure 3.1 The Flow Chart of Methodology

3.2 AREA SELECTION

The selected lecture rooms at Mechanical Engineering building had been chose to run this field study. The lecture rooms that had been chosen was BK4, BK12 and BK6. Several criteria were put in consideration to choose the lecture rooms. The first one is the lecture rooms should not have the partition behind the class. Several lecture rooms at Mechanical Engineering building had a partition which can open up and combine the classes. The lecture rooms that had partition part must be avoid because the air conditioning behind the class will disturb the data collection especially for the parameter of air velocity and thermal comfort.

All the lecture rooms that had been chosen was different in area of space. The third criteria to choose the lecture rooms are the different in size which is can be classified as small, medium and large. The lecture rooms of BK10 is the smallest room, the BK13 is the medium room and the BK17 is the largest room. The additional lecture room is BK12 is suggested by second examiner which is to study the condition of BK12 because of BK12 had large window. Figure 3.2, Figure 3.3, Figure 3.4 and Figure 3.5 are the several figured of the lecture rooms. However, the lecture rooms obtained the sliding door that connected behind lecture rooms. It is different with the partition part of the classroom because the sliding door can close without allowing the air movement behind the lecture room come to the lecture room selected.

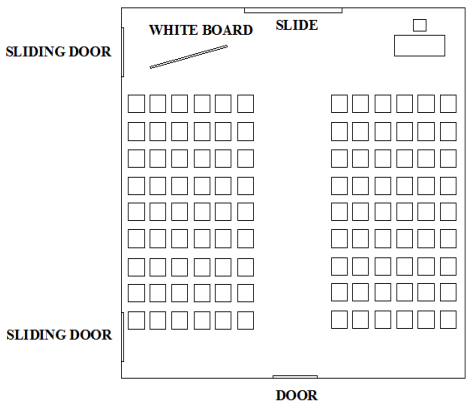


Figure 3.2 The BK10 Lecture Room

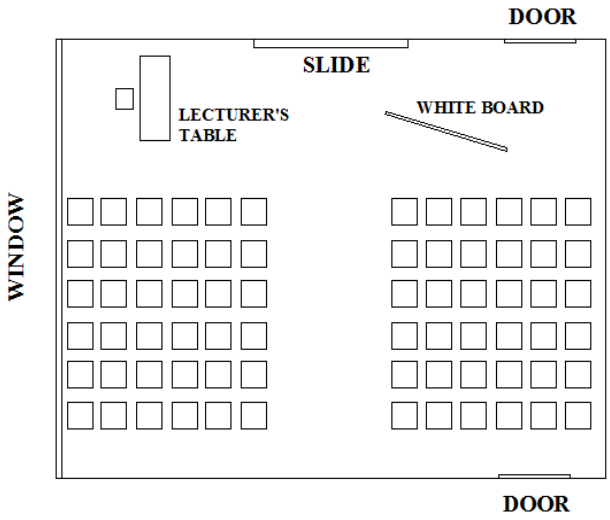


Figure 3.3 The BK12 Lecture Room

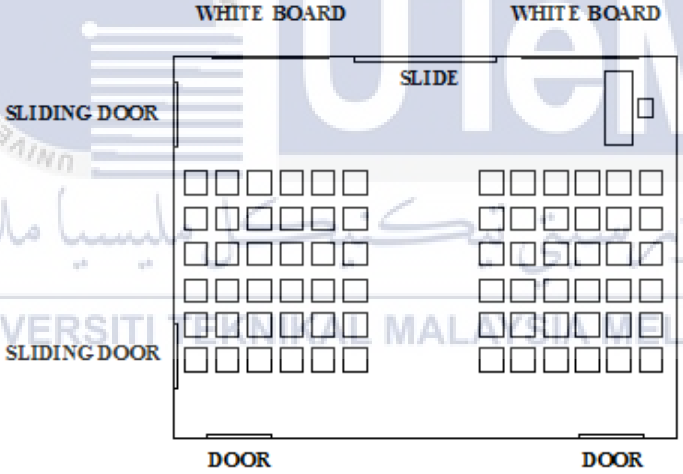


Figure 3.4 The BK13 Lecture Room

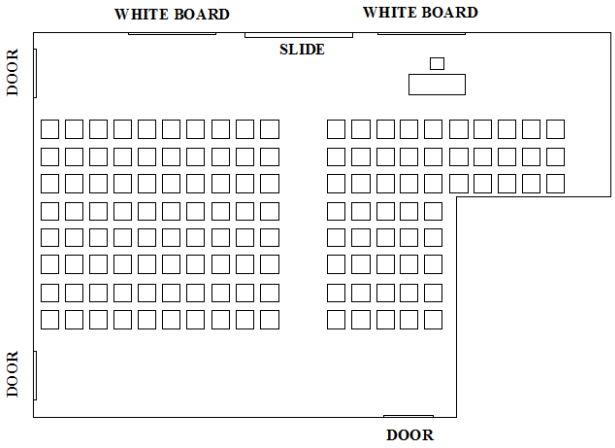


Figure 3.5 The BK17 Lecture Room

3.3 EQUIPMENT

The equipment used to this study are Thermal Microclimate and Dust Trak monitor. The Thermal Microclimate is an equipment with the ability to measure the thermal comfort of the indoor space. Thermal Microclimate is able to measure operating temperature, air velocity, relative humidity, mean radiant temperature predicted mean vote (PPV) and predicted percentage dissatisfied (PPD). There are four probes is used to measure the parameter as mentioned before that's are wet bulb and dry bulb temperature (HP3217DM), relative humidity (HP3217), globe temperature (TP3275) and air velocity (AP3203).

Table 3.1, 3.2 and Figure 3.6, 3.7 are shown the list of equipment used, the probes in thermal comfort. The second equipment used in this study is Dust Trak Monitor. The Dust Trak Monitor is able to measure particulate matter contain in the indoor space. There are several particulate sizes of diameter can be classified that's are PM1, PM2.5, PM7 and PM10. Only PM2.5 and PM10 will put into consideration in this study. The PM2.5 probe represent the size of particulate matter of 2.5 microns and PM10 represent the size of particulate matter of 10 microns.

Table 3.1 The List of Equipment

Type of equipment	Parameter
Thermal Microclimate	• Operating Temperature • Relative Humidity • Air Velocity • Mean Radiant Temperature
Dust Trak Monitor	• Dust Concentration Level (PM2.5 and PM10)

Table 3.2 The Probes in Thermal Microclimate Meter

Physical Parameters	Probes
Wet bulb and dry bulb	HP3217DM
Relative humidity	HP3217
Globe temperature	TP3275
Air velocity	AP3203

Figure 3.6 The Thermal Micro Climate Equipment

Figure 3.7 The Dust Trak Monitor Equipment

3.4 PHYSICAL MEASUREMENT

As mentioned before, there are several parameters collected in this study in all lecture rooms to determine the thermal comfort and dust concentration level analysis. The parameters involved in this study are shown in Table 3.3.

Table 3.3 Measurement Parameter and unit

Physical Measurement	Unit
Indoor Air Temperature	^{o}C
Relative Humidity	%
Air Velocity	m/s
Mean Radiant Temperature	^{o}C
Predicted Mean Vote	-
Predicted Mean Dissatisfied	%
Dust Level (PM2.5 and PM10)	mg/m^3

Several standards are used in this study to do comparison in order to ensure the lecture rooms is in the comfort or safe condition of dust concentration level. The standard used are ASHRAE Standard 55, MS 1525 2014, ASHRAE Standard 2010 and Malaysian Air Quality Guideline. The thermal comfort parameters are compared to ASHRAE Standard 55 and MS 1525 2014 while the dust concentration level (particulate matter) are compares to the ASHRAE Standard 2010 and Malaysian Air Quality Guideline. Below are shown the standard of thermal comfort and dust parameters limits guideline.

Table 3.4 The Standard Range of ASHRAE 55 and MS12525 2014 for Thermal Comfort

Parameter	Limit	
	ASHRAE 55	MS1525 2014
Air Temperature	22.5^{o}C to 26^{o}C	23^{o}C to 26^{o}C
Relative Humidity	60%	50% to 70%
Air Velocity	0.15 m/s to 0.50 m/s	0.15 m/s to 0.50 m/s

Table 3.5 The Standard Range of ASHRAE 55 and Malaysian Air Quality Guideline for Dust Concentration Level Analysis

Parameter	Limit	
	ASHRAE 55	Malaysian Air Quality
PM2.5	< 15 μg/m^3	-
PM10	< 50 μg/m^3	< 150 μg/m^3

CHAPTER 4

RESULTS AND ANALYSIS

4.1 EXPERIMENTAL RESULTS

The experimental results consist of two conditions which is with and without occupants. The parameter taken in the experimental results is thermal comfort parameter and dust concentration parameter which are include wet temperature (Tw), globe temperature (Tg), air Temperature (Ta), air velocity (Va), relative humidity (RH), radiant temperature (Tr), predicted mean voted (PMV), predicted percentage of dissatisfied (PPD) and dust concentration (mg/m^3) of 10µm and 2.5µm. The data is taken in three phase which are in the morning (9.00am-10.00am), afternoon (12.00pm-1.00pm) and evening (3.00pm-4.00pm) which is one hour in each phases. But with occupant condition, the data was taken in two phase which is before afternoon and after afternoon. The point position of the measurement is different at each phase. For the morning session, the measurement is taken at back of the class. For the afternoon session, the measurement is taken at front of the class and for the evening session the measurement is taken at middle of the class. But for measurement with occupant, the position of measurement is chosen based on the lecturer rooms condition during the lecture. Mostly the measurement position for with occupants is chosen at the back of the class seems that that is the suitable point that did not disturb the lecture sessions. The data is taken one minute each in one hour which is can be set in Delta Log 10. The data are shown in the form of maximum value, minimum value and average value of each parameter.

Table 4.1 The Physical Parameter Measurements in BK10 Without Occupants

Sessions	Physical Parameter	Tw (°C)	Tg (°C)	Ta (°C)	Pr (hPA)	RH (%)	Va (m/s)	Tr (°C)
Morning	Maximum Value	22.2	25.6	24.9	1006.6	71.4	0.1	25.8
	Minimum Value	20.7	24.6	23.7	1005.9	68.9	0	25.0
	Average Value	21.23	24.98	24.1	1006.24	69.71	0	25.29
Afternoon	Maximum Value	19.7	23.8	22.9	1006.4	71.6	0.29	24.5
	Minimum Value	19.3	23.5	22.6	1005.3	69.9	0	23.7
	Average Value	19.43	23.53	22.74	1005.93	70.26	0.08	23.95
Evening	Maximum Value	19	22.9	22.7	1004.1	68.8	0.53	23.7
	Minimum Value	18.4	22.7	22.3	1002.8	65.7	0.05	22.9
	Average Value	18.69	22.84	22.46	1003.54	66.47	0.31	23.29

Table 4.2 The Physical Parameter Measurements in BK12 Without Occupants

Sessions	Physical Parameter	Tw (°C)	Tg (°C)	Ta (°C)	Pr (hPA)	RH (%)	Va (m/s)	Tr (°C)
Morning	MaximumValue	21.8	24.5	23.7	1007.5	83.4	0.19	25
	Minimum Value	20	23.1	22.3	1006.5	78.3	0	23.4
	Average Value	20.84	23.71	22.99	1007.05	80.64	0.02	23.98
Afternoon	Maximum Value	21	25.6	24.6	1003.1	74	0.2	26.2
	Minimum Value	20.3	23.3	23.3	1002.1	69.4	0	24.9
	Average Value	20.59	23.8	23.8	1002.5	71.92	0.004	25.38
Evening	Maximum Value	20.5	24.5	23.9	1007.4	71.4	0.21	25
	Minimum Value	20.0	24.2	23.5	1005.9	69.4	0	24.4
	Average Value	20.27	24.36	23.69	1006.7	70.48	0.03	24.62

Table 4.3 The Physical Parameter Measurements in BK13 Without Occupants

Sessions	Physical Parameter	Tw (°C)	Tg (°C)	Ta (°C)	Pr (hPA)	RH (%)	Va (m/s)	Tr (°C)
Morning	Maximum Value	24.2	25.7	25.6	1006.2	87.5	0.19	26
	Minimum Value	20.2	23.2	22.6	1005.8	76.8	0	23.3
	Average Value	21.76	24.31	23.85	1006.04	79.2	0.03	24.48
Afternoon	Maximum Value	18	21.9	21	1005.6	73.1	0.13	22.2
	Minimum Value	17.4	20.8	20.1	1004.2	71.5	0	21
	Average Value	17.59	21.13	20.43	1004.85	72.23	0.01	21.38
Evening	Maximum Value	17.1	20.6	19.9	1003.4	72	0.1	21
	Minimum Value	16.9	20.5	19.8	1002.6	71.3	0	20.7
	Average Value	17.02	20.51	19.84	1002.92	71.6	0.01	20.76

Table 4.4 The Physical Parameter Measurements in BK17 Without Occupants

Sessions	Physical Parameter	Tw (°C)	Tg (°C)	Ta (°C)	Pr (hPA)	RH (%)	Va (m/s)	Tr (°C)
Morning	Maximum Value	23	25.9	24.8	1007.4	82.2	0.28	26.5
	Minimum Value	20.5	22.8	22.8	1006.5	76.8	0	23.8
	Average Value	21.26	24.33	23.4	1006.88	78.14	0.04	24.73
Afternoon	Maximum Value	22.1	23.4	22.7	1006.6	74.7	0.39	24.6
	Minimum Value	21.6	23	21.8	1005.8	71.3	0.01	23.3
	Average Value	21.8	23.16	22.2	1006.27	72.33	0.16	23.92
Evening	Maximum Value	17.9	20.6	19.9	1004.3	75.5	0.39	21.8
	Minimum Value	16.8	19.7	18.7	1003.4	72.7	0	19.9
	Average Value	17.18	20	19.08	1003.84	73.6	0.12	20.61

Table 4.5 The Physical Parameter Measurements in BK10 With Occupants

Sessions	Physical Parameter	Tw (°C)	Tg (°C)	Ta (°C)	Pr (hPA)	RH (%)	Va (m/s)	Tr (°C)
Morning	Maximum Value	24.6	28	27.6	1008.2	74.5	0.12	28.2
	Minimum Value	21.5	26.1	24.9	1006.8	66.4	0	26.5
	Average Value	22.59	26.83	25.95	1007.49	69.81	0.01	27.15
Evening	MaximumValue	21.1	25.4	24.8	1006.1	74.2	0.14	26.1
	Minimum Value	19.8	24.6	23.8	1004.3	65	0	24.8
	Average Value	20.39	25.17	24.44	1005.62	67.13	0.04	25.44

Table 4.6 The Physical Parameter Measurements in BK12 With Occupants

Sessions	Physical Parameter	Tw (°C)	Tg (°C)	Ta (°C)	Pr (hPA)	RH (%)	Va (m/s)	Tr (°C)
Morning	Maximum Value	21	24.4	24.2	1005.8	78.2	0.41	24.9
	Minimum Value	20.3	23.2	23	1005.4	72.6	0	23.2
	Average Value	20.68	24.11	23.66	1005.64	74.6	0.07	24.33
Evening	Maximum Value	20.5	24.2	23.9	1004.1	73.1	0.39	24.9
	Minimum Value	19.6	23.7	23.1	1003.5	71.7	0	23.8
	Average Value	20.05	23.97	23.5	1003.68	72.7	0.09	24.24

Table 4.7 The Physical Parameter Measurements in BK13 Without Occupants

Sessions	Physical Parameter	Tw (°C)	Tg (°C)	Ta (°C)	Pr (hPA)	RH (%)	Va (m/s)	Tr (°C)
Afternoon	Maximum Value	20.7	24.8	24.1	1007.9	70.3	0.17	25.2
	Minimum Value	20.2	24.6	23.7	1007.6	68	0	24.7
	Average Value	20.51	24.63	23.99	1007.75	68.96	0.01	24.86
Evening	Maximum Value	22.6	24.6	24.2	1006.1	71.7	0.24	25
	Minimum Value	20.5	23.9	23.4	1005.1	67.5	0	24
	Average Value	21.52	24.4	23.96	1005.61	69.02	0.04	24.57

Table 4.8 The Physical Parameter Measurements in BK17 Without Occupants

Sessions	Physical Parameter	Tw (°C)	Tg (°C)	Ta (°C)	Pr (hPA)	RH (%)	Va (m/s)	Tr (°C)
Morning	Maximum Value	20.8	24.6	23.9	1007.7	78.4	0.3	25.4
	Minimum Value	20.3	23.8	23	1007.4	71.3	0	24
	Average Value	20.58	24.36	23.68	1007.52	73.65	0.08	24.71
Afternoon	Maximum Value	19.6	23.8	23.2	1008.8	74.6	0.4	25.4
	Minimum Value	18.9	23	21.7	1007.8	67.7	0	23.4
	Average Value	19.31	23.57	22.73	1008.31	68.94	0.07	24.02
Evening	Maximum Value	18.7	22.3	21.9	1005.9	74.7	0.58	23.5
	Minimum Value	18.3	22	21.3	1004.4	72.6	0	22.2
	Average Value	18.53	22.16	21.59	1004.15	73.57	0.25	22.75

4.1.1 BK 10 WITHOUT OCCUPANT (MORNING)

The Lecture Room 10 or also known as BK10 can be categorized the smallest size lecture rooms among the other lecture rooms. The maximum value of air temperature (Ta) for BK10 in the morning session is 24.9°C while for the minimum value obtained is 23.7°C. Hence, the average value gained in this session is 24.1°C. The range of the air temperature value against time is shown in Figure 4.1. The other physical parameter is relative humidity which is a measure of the moisture in the air. The maximum value of relative humidity in this measurement is 71.4% and the minimum value obtained is 68.9%. Hence, the average value gained for relative humidity in this measurement is 69.71%. The range of the relative humidity value against time is shown in Figure 4.2. For the physical parameter of air velocity (Va), the maximum value obtained for BK10 in the morning session is 0.1m/s and the minimum value obtained is 0m/s. Hence the average value obtained in this measurement is 0m/s. The range of the air velocity value against time is shown in Figure 4.3.

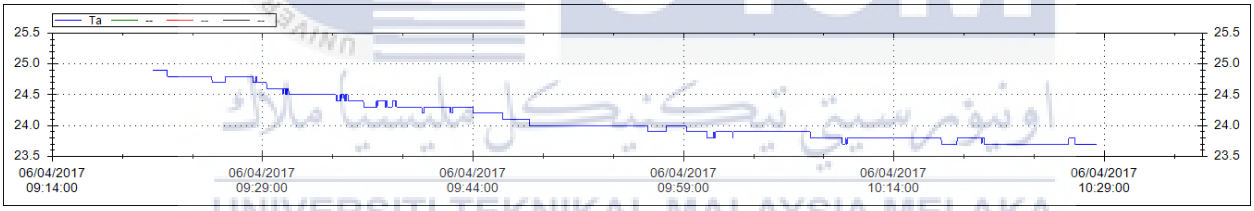


Figure 4.1 The graph of air temperature against time

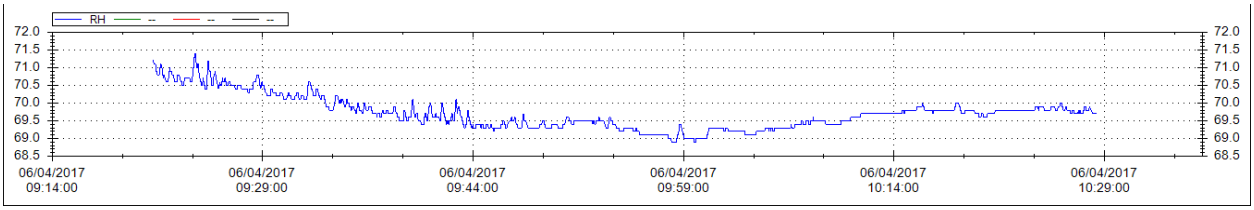


Figure 4.2 The graph of relative humidity against time

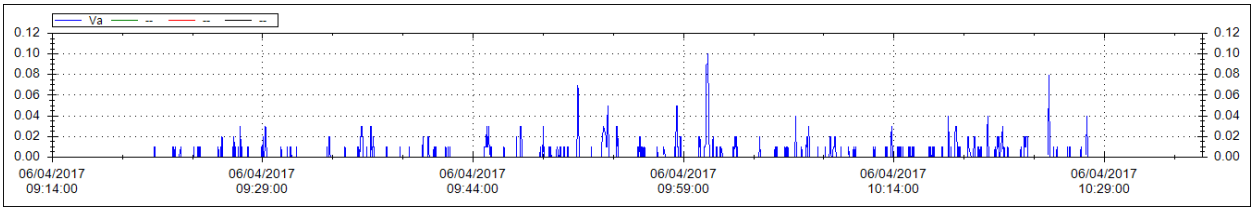


Figure 4.3 The graph of air velocity against time

According to the ASHRAE Standard 55, the general standard for air temperature is between 22.5°C to 26°C for the physical parameter relative humidity of 60%. The standard range for physical parameter of air velocity is between 0.15 m/s to 0.5 m/s. For local standard which is Malaysian Standard MS1525 2014, the standard recommended air temperature is between 23°C to 26°C. For the physical parameter of relative humidity, the standard range suggested is between 50% to 70% in the indoor condition. While for the air velocity, the standard range are between 0.15 m/s to 0.50 m/s.

Based on the average air temperature obtained for the morning session of BK10 without occupant, the average value is satisfied both standard of ASHRAE Standard 55 and Malaysian Standard MS1525 2014, which is the value was 21.4°C fall in the range of 22.5°C to 26°C and 23°C to 26°C. For the physical parameter of relative humidity, the average value obtained was 69.71% is fall in the range of 50% to 70% of the Malaysian Standard MS1525 2014. So the average value obtained satisfied the Malaysian Standard MS1525. For the physical parameter of air velocity, the average value is not satisfied both standard of ASHRAE Standard 55 and Malaysian Standard MS1525 2014. The average value obtained was 0m/s which is out of the range of 0.15m/s to 0.5m/s.

4.1.2 BK 10 WITHOUT OCCUPANT (AFTERNOON)

The second sessions of measurement of without occupant condition is afternoon sessions. The range time to take the measurement of without occupant in afternoon session is between 11.00am to 1.00pm. The maximum value of air temperature (Ta) for BK10 in the afternoon

session is 22.9°C while for the minimum value obtained is 22.6°C. Hence, the average value gained in this session is 22.74°C. The range of the air temperature value against time is shown in Figure 4.4. The next physical parameter is relative humidity which are the maximum value of relative humidity in this measurement is 71.6% and the minimum value obtained is 69.9%. Hence, the average value gained for relative humidity in this measurement is 70.26%. The range of the air velocity value against time can be seen in Figure 4.5. For the physical parameter of air velocity (Va), the maximum value obtained for BK10 in the afternoon session is 0.29m/s and the minimum value obtained is 0m/s. Hence the average value obtained in this measurement is 0.08m/s. The range of the air velocity value against time is shown in Figure 4.6.

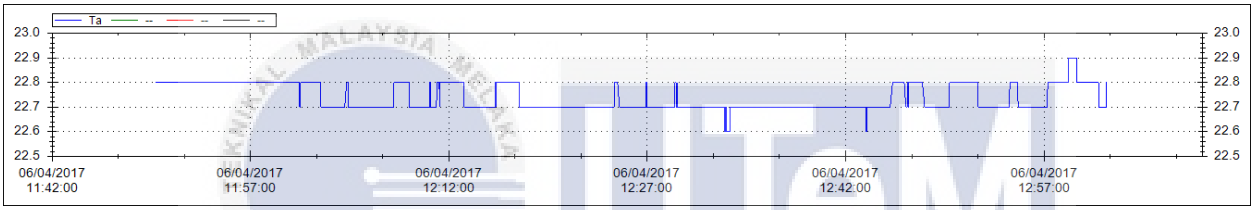


Figure 4.4 The graph of air temperature against time

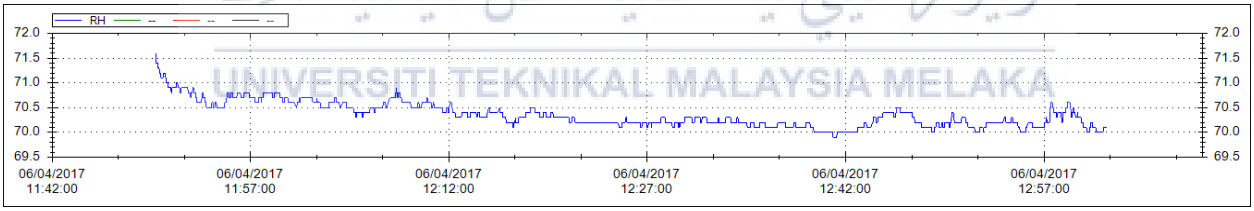


Figure 4.5 The graph of relative humidity against time

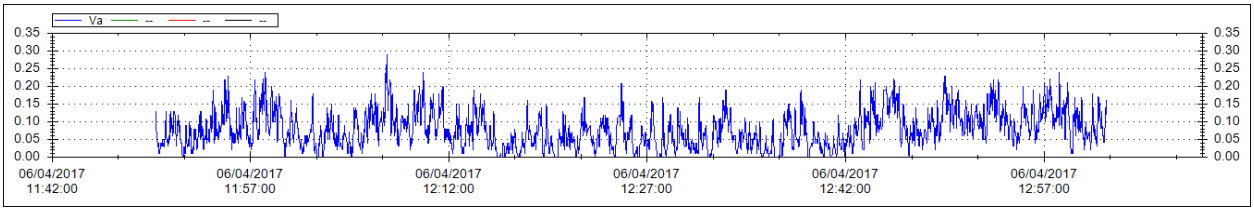


Figure 4.6 The graph of air velocity against time

According to the average air temperature obtained for the afternoon session of BK10 without occupant, the average value is satisfied both standard of ASHRAE Standard 55 and Malaysian Standard MS1525 2014, which is the value was 22.74^{o}C fall in the range of 22.5^{o}C to 26^{o}C. For the physical parameter of relative humidity, the average value obtained was 70.26% is not fall in the range of 50% to 70% of the Malaysian Standard MS1525 2014. So the average value obtained for relative humidity in not satisfied the Malaysian Standard MS1525 seems that the average value is slightly higher to the standard range. For the physical parameter of air velocity, the average value is not satisfied both standard of ASHRAE Standard 55 and Malaysian Standard MS1525 2014. The average value obtained was 0.08m/s which is out of the range of 0.15m/s to 0.5m/s.

4.1.3 BK 10 WITHOUT OCCUPANT (EVENING)

The third session was measurement without occupant condition during evening period. The time range to take the measurement of without occupant in afternoon session is between 2.00am to 5.00pm. The maximum value of air temperature (Ta) for BK10 in the evening session is 22.7^{o}C while for the minimum value obtained is 22.3^{o}C. Hence, the average value gained in this session is 22.84^{o}C. The range of the air temperature value against time is shown in Figure 4.7. The next physical parameter is relative humidity which are the maximum value of relative humidity in this measurement is 68.8% and the minimum value obtained is 65.7%. Hence, the average value gained for relative humidity in this measurement is 66.47%. The range of the air velocity value against time can be seen in Figure 4.8. For the physical parameter of air velocity (Va), the maximum value obtained for BK10 in the afternoon session is 0.53m/s and the minimum value obtained is 0.05m/s. Hence the average value obtained in this measurement is 0.31m/s. The range of the air velocity value against time is shown in Figure 4.9.

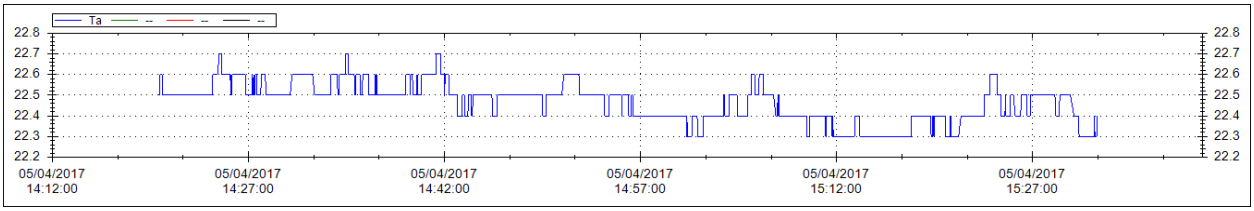


Figure 4.7 The graph of air temperature against time

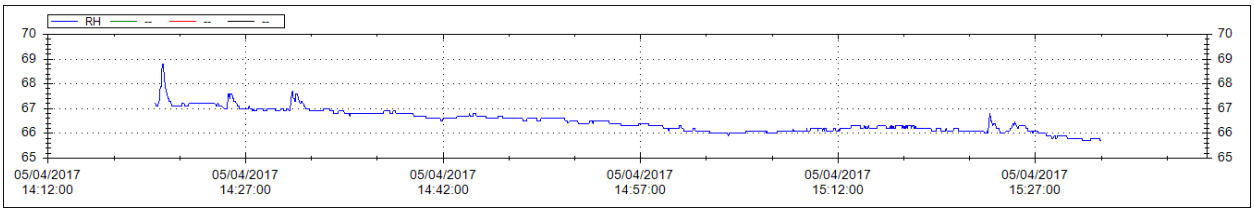


Figure 4.8 The graph of relative humidity against time

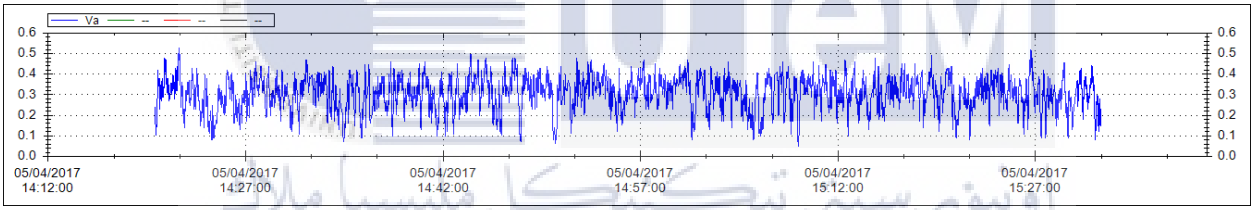


Figure 4.9 The graph of air velocity against time

Based on the average air temperature obtained for the afternoon session of BK10 without occupant, the average value is satisfied both standard of ASHRAE Standard 55 and Malaysian Standard MS1525 2014, which is the value was 22.46^{o}C fall in the range of 22.5^{o}C to 26^{o}C and 23^{o}C to 26^{o}C. For the physical parameter of relative humidity, the average value obtained was 66.47% is fall in the range of 50% to 70% of the Malaysian Standard MS1525 2014. So the average value obtained for relative humidity in satisfied the Malaysian Standard MS1525. For the physical parameter of air velocity, the average value is also satisfied both standard of ASHRAE Standard 55 and Malaysian Standard MS1525 2014. The average value obtained was 0.31m/s which is fall in the range of 0.15 m/s to 0.5 m/s.

4.1.4 BK 12 WITHOUT OCCUPANT (MORNING)

The first set of data of BK12 is shown in the Figure 4.10 for air temperature physical parameter in the morning session for without occupant session. The BK12 lecture room can be classified as the second largest of lecture room among the others. The maximum and minimum value of the air temperature (Ta) are 23.7°C and 22.3°C. For the average value of the air temperature (Ta) is 22.99°C. For the physical parameter of relative humidity (RH), the maximum and minimum value are 83.4% and 78.3%. The average value of relative humidity obtained is 80.64%. For the graph of relative humidity against time can be seen in Figure 4.11. For the value of air velocity, the maximum and minimum value are 0.19m/s and 0m/s. The average value of air velocity is 0.02m/s. For the graph of air velocity against time can be seen in Figure 4.12.

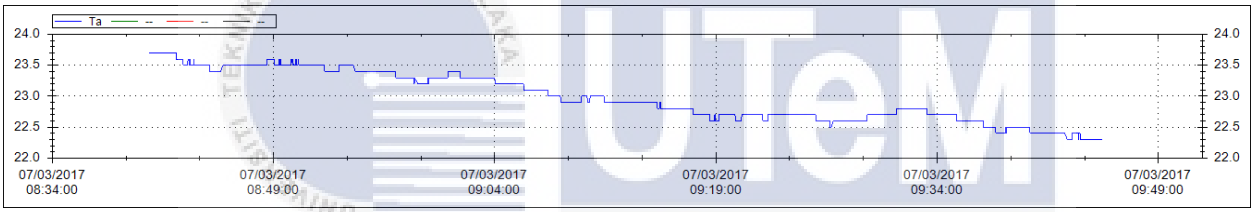


Figure 4.10 The graph of air temperature against time

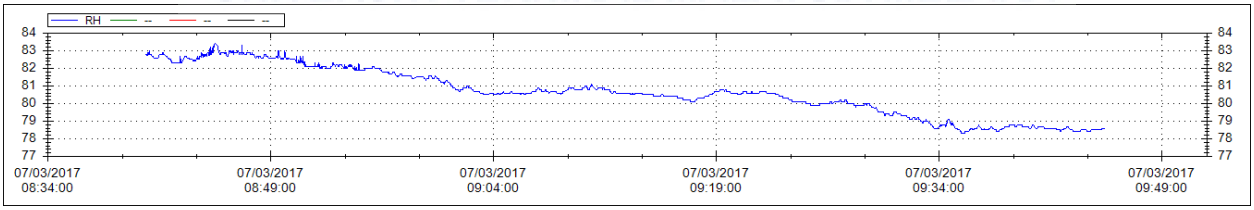


Figure 4.11 The graph of relative humidity against time

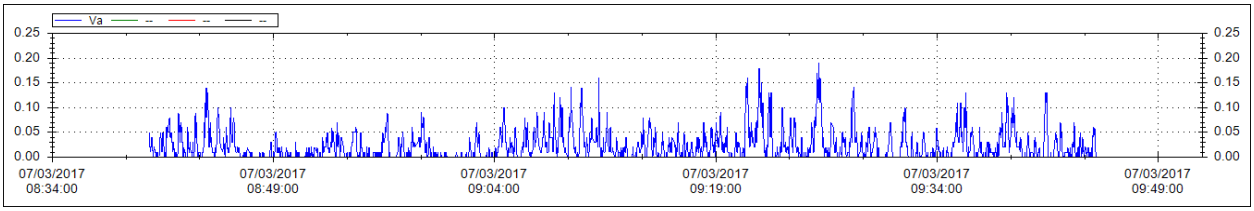


Figure 4.12 The graph of air velocity against time

According to the data obtained, the average air temperature obtained in BK12 lecture room for the morning session without occupant is within both standard of ASHRAE Standard 55 and Malaysian Standard MS1525 2014. The value obtained was 22.99°C fall in the range of 22.5°C to 26°C and 23°C to 26°C. For the relative humidity physical parameter, the average value obtained was 80.64% is not fall in the range of 50% to 70% (Malaysian Standard MS1525 2014). So the average value obtained for relative humidity is not satisfied the Malaysian Standard MS1525. For the physical parameter of air velocity, the average value is not satisfied with both standard of ASHRAE Standard 55 and Malaysian Standard MS1525 2014. The average value gained was 0.02m/s which is not fall in the range of 0.15m/s to 0.5m/s.

4.1.5 BK 12 WITHOUT OCCUPANT (AFTERNOON)

The second session of data measurement is shown in Table 4.2 which is during afternoon session. The range time to take the measurement of without occupant in afternoon session is also between 11.00am to 1.00pm. The maximum and minimum value of the air temperature (Ta) are 24.6°C and 23.3°C. For the average value of the air temperature (Ta) is 23.8°C. The graph of the range of air temperature against time can be seen in Figure 4.13. For the relative humidity physical parameter (RH), the maximum and minimum value are 74% and 69.4%. The average value of relative humidity is 71.92%. The graph of the range of relative humidity against time can be seen in Figure 4.14. For the value of air velocity, the maximum and minimum value are 0.2m/s and 0m/s. The average value obtained for air velocity is 0.004m/s. The graph of the range of air velocity against time can be seen in Figure 4.15.

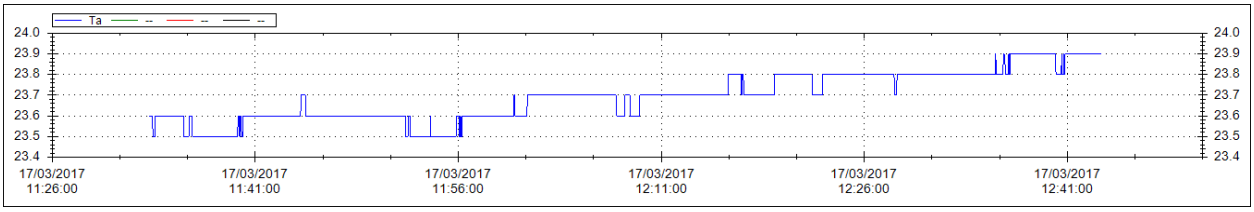


Figure 4.13 The graph of air temperature against time

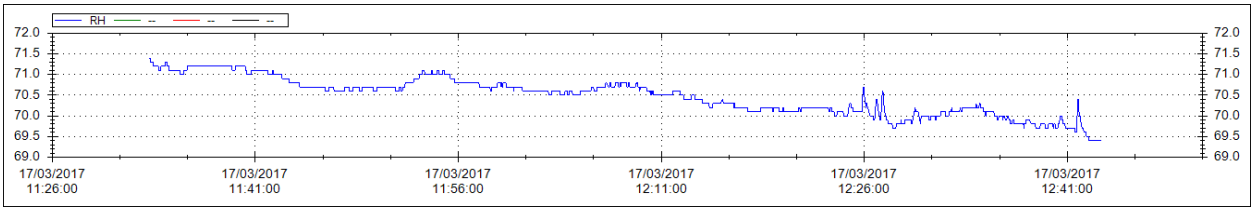


Figure 4.14 The graph of relative humidity against time

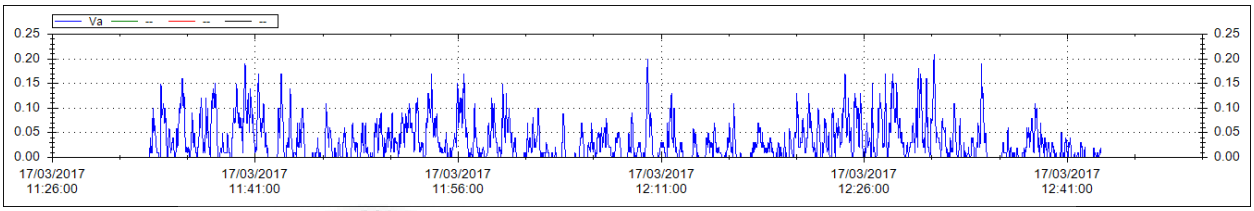


Figure 4.15 The graph of air velocity against time

By referring to the data obtained, the average air temperature obtained in BK12 lecture room for the afternoon session without occupant is satisfied both standard of ASHRAE Standard 55 and Malaysian Standard MS1525 2014. The value obtained was 23.8^{o}C fall in the range of 22.5^{o}C to 26^{o}C (ASHRAE Standard 55) and 23^{o}C to 26^{o}C (Malaysian Standard MS1525 2014). For the relative humidity physical parameter, the average value obtained was 71.92% is not comply in the range of 50% to 70% (Malaysian Standard MS1525 2014). So the average value obtained for relative humidity in not satisfied the Malaysian Standard MS1525 which is the value obtained is slightly higher than the standard. For the physical parameter of air velocity, the average value is not satisfied with both standard of ASHRAE Standard 55 and Malaysian Standard MS1525 2014. The average value gained was 0.004m/s which is out of the range of 0.15m/s to 0.5m/s.

4.1.6 BK 12 WITHOUT OCCUPANT (EVENING)

The third session of data measurement is shown in Table 3 which is in the evening session. Normally the evening session measurement is taken in the range time of 2.00pm to 5.00pm. The maximum value of the air temperature (Ta) is 23.9^{o}C and the minimum value of air temperature (Ta) is 23.5^{o}C. For the average value of the air temperature(Ta) obtained is 23.69^{o}C. The graph of the range of air temperature against time can be seen in Figure 4.16. For the relative humidity physical parameter (RH), the maximum value is 71.4% and the minimum value is 69.4%. For the average value obtained for relative humidity is 70.48%. The graph of the range of relative humidity against time can be seen in Figure 4.17. For the term of air velocity, the maximum is 0.21m/s and the minimum value is 0m/s. The average value of obtained for air velocity in this measurement session is 0.03m/s. The graph of the range of air velocity against time can be seen in Figure 4.18.

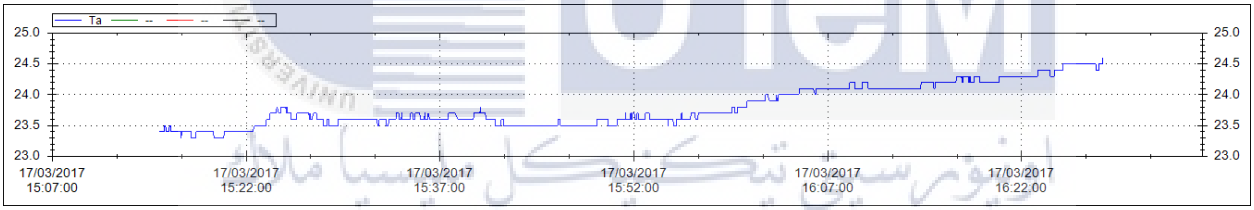


Figure 4.16 The graph of air temperature against time

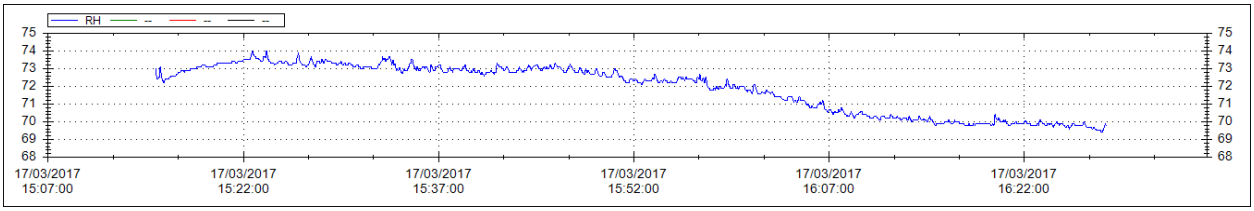


Figure 4.17 The graph of relative humidity against time

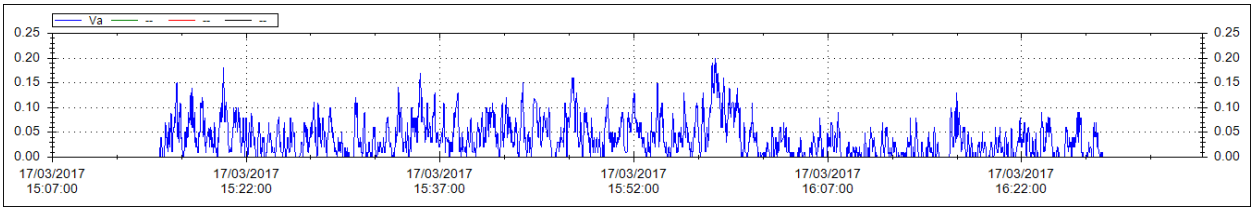


Figure 4.18 The graph of air velocity against time

Based on to the data obtained, the average air temperature obtained in BK12 lecture room for the evening session without occupant is satisfied both standard of ASHRAE Standard 55 and Malaysian Standard MS1525 2014. The average value obtained was 23.69^{o}C fall in the range of 22.5^{o}C to 26^{o}C (ASHRAE Standard 55) and 23^{o}C to 26^{o}C (Malaysian Standard MS1525 2014). For the relative humidity physical parameter, the average value obtained was 70.48% is not comply in the range of 50% to 70% (Malaysian Standard MS1525 2014). So the average value obtained for relative humidity in not satisfied the Malaysian Standard MS1525. For the physical parameter of air velocity, the average value is not satisfied with both standard of ASHRAE Standard 55 and Malaysian Standard MS1525 2014. The average value gained was 0.03m/s which is out of the range of 0.15m/s to 0.5m/s.

4.1.7 BK 13 WITHOUT OCCUPANT (MORNING)

The Lecture Room BK10 or also known as BK13 can be categorized as the medium size lecture rooms among the other lecture rooms. Figure 4.19 showed the graph of the air temperature against time. The highest value of air temperature (Ta) for BK10 achieved in the morning session is 25.6^{o}C while for the minimum value obtained is 22.6^{o}C. So that, the average value gained in this session is 23.85^{o}C. The other physical parameter is relative humidity which is the maximum value of relative humidity in this measurement is 87.5% and the minimum value obtained is 76.8%. Hence, the average value gained for relative humidity in this measurement is 79.2%. The range of the air velocity value against time is shown in Figure 4.20. Figure 4.21 showed the graph of the air velocity against time. For the physical parameter of air velocity (Va),

the maximum value obtained for BK10 in the morning session is 0.19m/s and the minimum value obtained is 0m/s. Hence the average value obtained in this measurement is 0.03m/s.

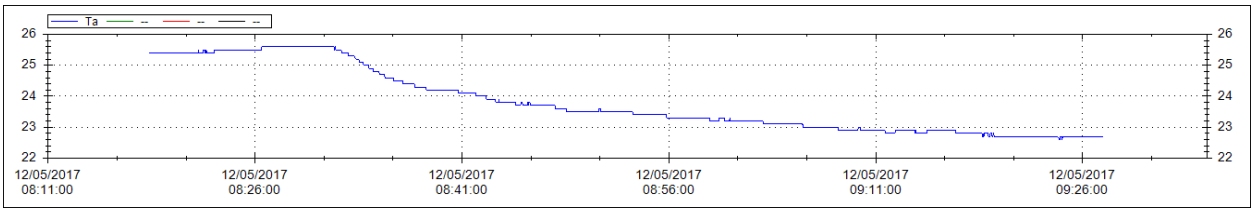


Figure 4.19 The graph of air temperature against time

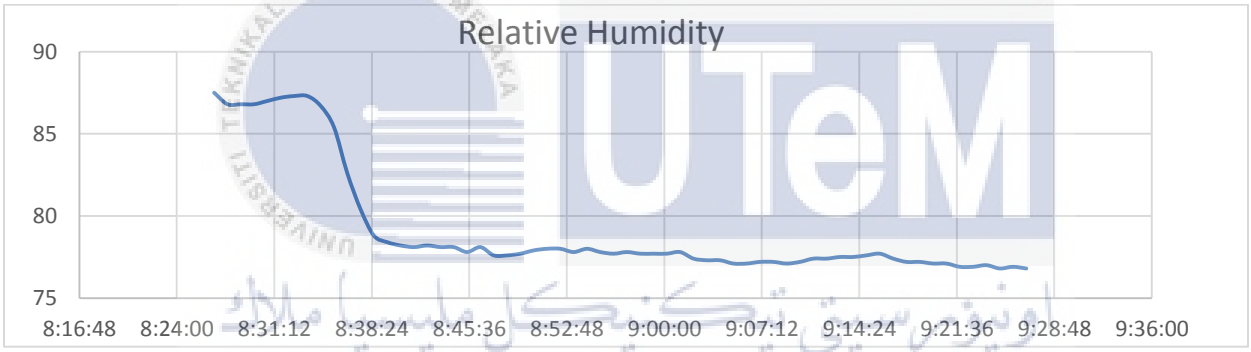


Figure 4.20 The graph of relative humidity against time

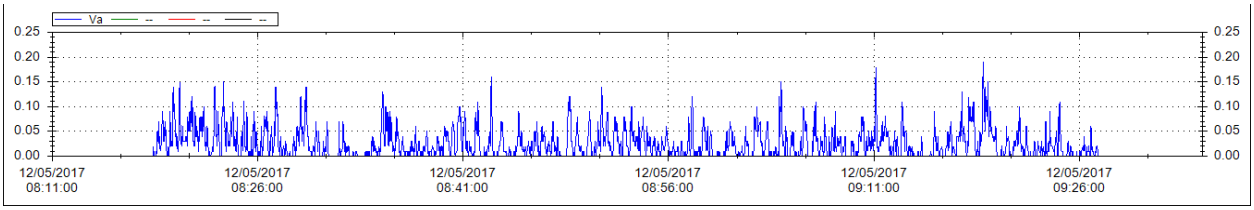


Figure 4.21 The graph of air velocity against time

Based on the average air temperature obtained for the morning session of BK13 without occupant, the average value is satisfied both standard of ASHRAE Standard 55 and Malaysian Standard MS1525 2014, which is the value was 23.8°C fall in the range of 22.5°C to 26°C and 23°C to 26°C. For the physical parameter of relative humidity, the average value obtained was 79.2% is not fall in the range of 50% to 70% of the Malaysian Standard MS1525 2014. So, the average value obtained for relative humidity is not satisfied the Malaysian Standard MS1525. For the physical parameter of air velocity, the average value is not satisfied both standard of ASHRAE Standard 55 and Malaysian Standard MS1525 2014. The average value obtained was 0.03m/s which is out of the range of 0.15m/s to 0.5m/s.

4.1.8 BK 13 WITHOUT OCCUPANT (AFTERNOON)

The first set of data is shown in Figure 4.22, Figure 4.23 and Figure 4.24 which are represent the graph of air temperature, relative humidity and air velocity against time in the afternoon session of BK13. The maximum value of the air temperature (Ta) achieved in this measurement session is 21.0°C while the minimum value gained is 20.1°C. Hence, the average value of the air temperature (Ta) is 20.43°C. For the physical parameter of relative humidity (RH), the maximum and minimum value obtained are 73.1% and 71.5%. Then, the average value of relative humidity is 72.23%. For the value of air velocity, the maximum and minimum value are 0.13m/s and 0m/s. So, the average value of air velocity is 0.01m/s.

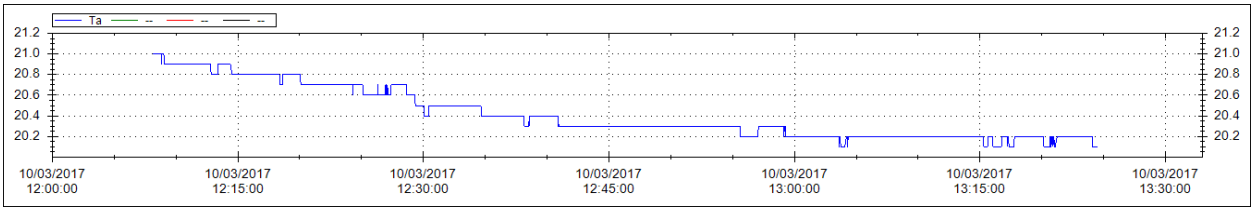


Figure 4.22 The graph of air temperature against time

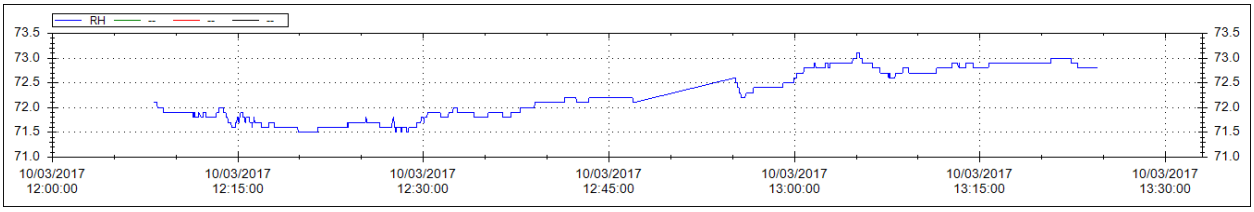


Figure 4.23 The graph of relative humidity against time

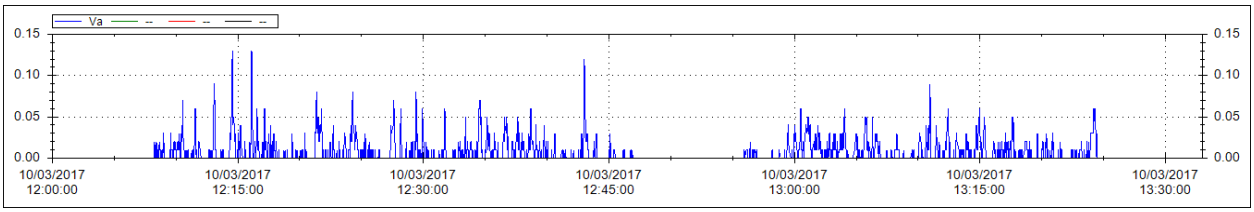


Figure 4.24 The graph of air velocity against time

By refer to the average air temperature achieved for the afternoon session of BK13 without occupant, the average value is failed to satisfied both standard of ASHRAE Standard 55 and Malaysian Standard MS1525 2014, which is the value was 20.43^{o}C not fall in the range of 22.5^{o}C to 26^{o}C and 23^{o}C to 26^{o}C. For the physical parameter of relative humidity, the average value obtained was 79.2% is not fall in the range of 50% to 70% of the Malaysian Standard MS1525 2014. So, the average value obtained for relative humidity is not satisfied the Malaysian Standard MS1525. For the physical parameter of air velocity, the average value is not satisfied both standard of ASHRAE Standard 55 and Malaysian Standard MS1525 2014. The average value obtained was 0.01m/s which is out of the range of 0.15m/s to 0.5m/s.

4.1.9 BK 13 WITHOUT OCCUPANT (EVENING)

The set of data is shown in Figure 4.25, Figure 4.26 and Figure 4.27 represent the graph of air temperature, relative humidity and air velocity against time in the evening session of BK13. The maximum and minimum value of the air temperature (Ta) are 19.9^{o}C and 19.8^{o}C. For the average value of the air temperature (Ta) is 19.84^{o}C. For the physical parameter of relative

humidity (RH), the maximum and minimum value are 72% and 71.3%. The average value of relative humidity is 71.6%. For the value of air velocity, the maximum and minimum value are 0.1m/s and 0m/s. The average value of air velocity is 0.01m/s.

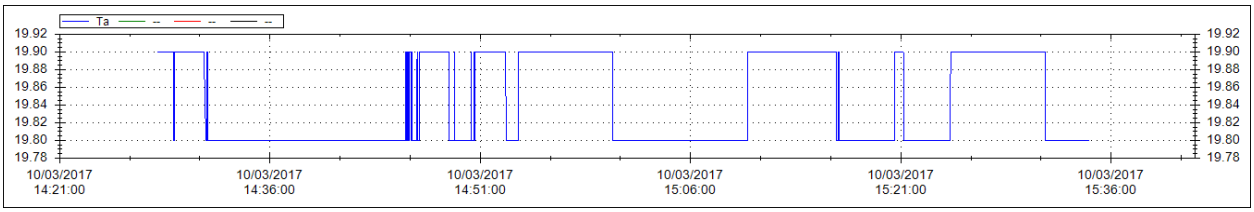


Figure 4.25 The graph of air temperature against time

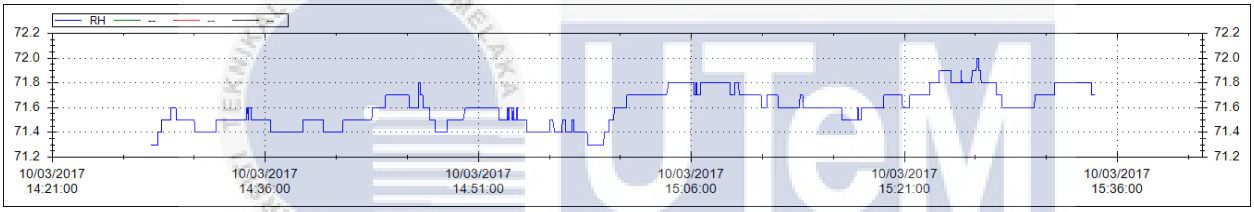


Figure 4.26 The graph of relative humidity against time

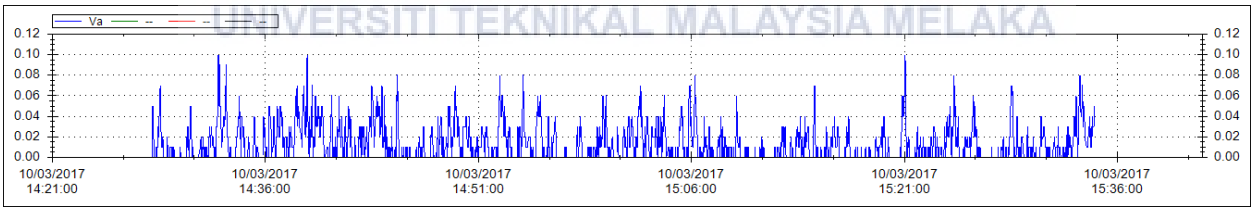


Figure 4.27 The graph of air velocity against time

By referring to ASHRAE Standard 55 and Malaysian Standard MS1525 2014, the average air temperature obtained for this measurement session is not satisfied both of the standards. The value obtained was 19.84^{o}C (air temperature, Ta) failed to comply with the standards which are the suggested air temperature range were 22.5^{o}C to 26^{o}C (ASHRAE Standard 55) and 23^{o}C to 26^{o}C (Malaysian Standard Ms1525 2014). For the physical parameter

of relative humidity (RH), the average value obtained is 71.6% which is also not satisfied the standards. The recommended value by MS1525 2014 is between the range of 50% to 70%. Seems that the average value obtained is slightly over the standard range, the average value of relative humidity is not satisfied the standards. Then, for the physical parameter of air velocity, the average value obtained is 0.01m/s which is also not satisfied the standard. Both of the standards recommended the value of air velocity is between 0.15m/s to 0.5m/s.

4.1.10 BK 17 WITHOUT OCCUPANT (MORNING)

The Lecture Room BK17 can be categorized as the largest lecture rooms among others. The set of data is shown in Figure 4.28, Figure 4.29 and Figure 4.30 represent the graph of air temperature, relative humidity and air velocity against time in the morning session of BK17. The maximum and minimum value of the air temperature (Ta) are 24.8°C and 22.8°C. For the average value of the air temperature (Ta) is 23.4°C. For the physical parameter of relative humidity (RH), the maximum and minimum value are 82.2% and 76.8%. The average value of relative humidity is 78.14%. For the value of air velocity, the maximum and minimum value are 0.28m/s and 0m/s. The average value of air velocity is 0.04m/s.

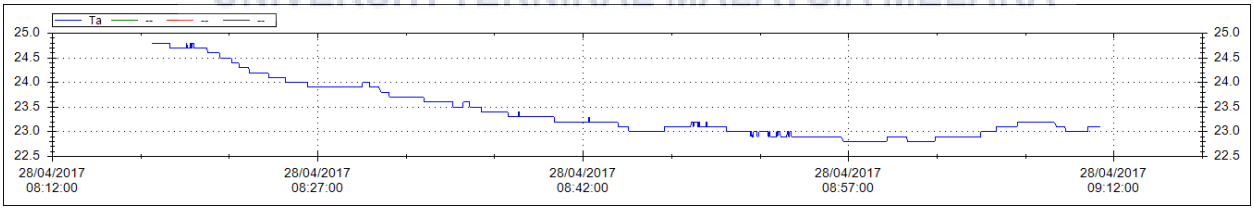


Figure 4.28 The graph of air temperature against time

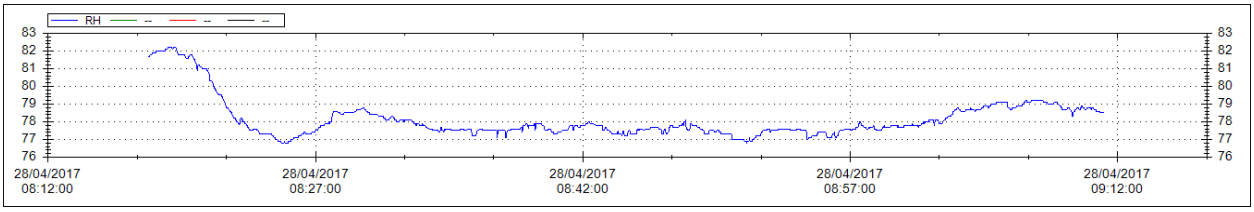


Figure 4.29 The graph of relative humidity against time

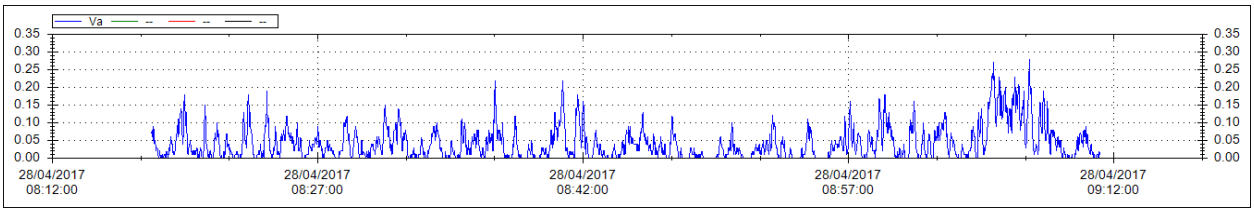


Figure 4.30 The graph of air velocity against time

By referring to the ASHRAE Standard 55 and Malaysian Standard MS1525 2014, the average air temperature obtained for this measurement session is satisfied both of the standards. The average value obtained was 23.4°C (air temperature, Ta) comply with the standards which are the suggested air temperature range were 22.5°C to 26°C (AHSRAE Standard 55) and 23°C to 26°C (Malaysian Standard MS1525 2014). For the physical parameter of relative humidity (RH), the average value obtained is 78.14% which is also not satisfied the standards. The standard recommended for MS1525 2014 is between the range of 50% to 70%. Seems that the average value obtained is slightly over the standard range, the average value of relative humidity is not satisfied the standards. Then, for the physical parameter of air velocity, the average value obtained is 0.04m/s which is also not satisfied the standard. Both of the standards recommended the value of air velocity is between 0.15m/s to 0.5m/s.

4.1.11 BK 17 WITHOUT OCCUPANT (AFTERNOON)

The set of data is shown in Figure 4.31, Figure 4.32 and Figure 4.33 represent the graph of air temperature, relative humidity and air velocity against time in the afternoon session of BK17. The maximum and minimum value of the air temperature (Ta) are 22.7°C and 21.8°C. For the average value of the air temperature (Ta) is 22.2°C. For the physical parameter of relative humidity (RH), the maximum and minimum value are 74.7% and 71.3%. The average value of relative humidity is 72.33%. For the value of air velocity, the maximum value obtained is 0.39 and minimum value obtained is 0.01m/s. Hence, the average value obtained of air velocity in the afternoon session without occupant is 0.16 m/s.

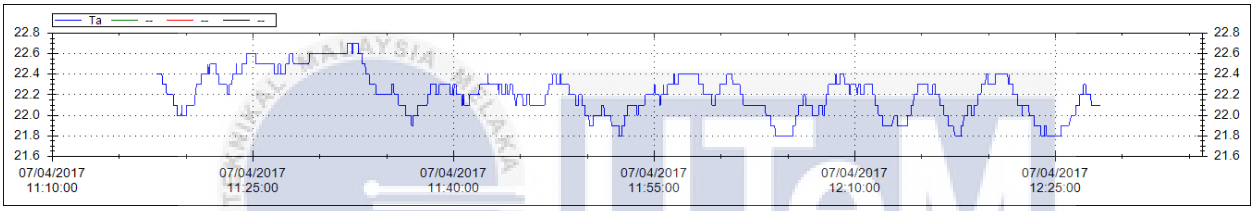


Figure 4.31 The graph of air temperature against time

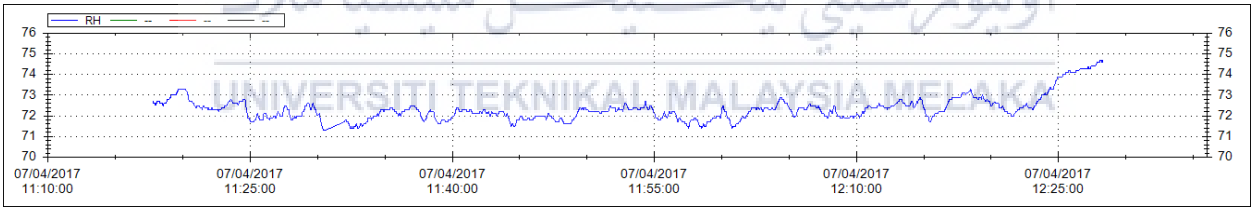


Figure 4.32 The graph of relative humidity against time

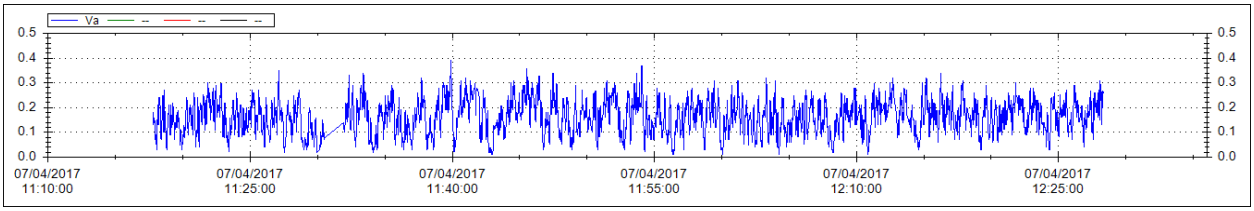


Figure 4.33 The graph of air velocity against time

According to the ASHRAE Standard 55 and Malaysian Standard MS1525 2014, the average air temperature obtained for this measurement session is not fall in both of the standards range. The average value obtained was 22.2°C (air temperature, Ta) is not comply with the standards which are the suggested air temperature range were 22.5°C to 26°C (AHSRAE Standard 55) and 23°C to 26°C (Malaysian Standard MS1525 2014). For the physical parameter of relative humidity (RH), the average value obtained is 72.33% which is also not comply with the standards. The standard recommended for MS1525 2014 is between the range of 50% to 70%. Then, for the physical parameter of air velocity, the average value obtained is 0.16m/s which is also not satisfied the standard. Both of the standards recommended the value of air velocity is between 0.15 m/s to 0.5 m/s.

4.1.12 BK 17 WITHOUT OCCUPANT (EVENING)

The third session of measurement of physical parameter was during evening period. The highest value obtained for the air temperature (Ta) is 19.9°C and the minimum value of air temperature (Ta) is 18.7°C. For the average value of the air temperature(Ta) obtained is 19.08°C. The graph of the range of air temperature against time can be seen in Figure 4.34. For the relative humidity physical parameter (RH), the maximum value is 82.8% and the minimum value is 79.3%. For the average value obtained for relative humidity is 80.2%. The graph of the range of relative humidity against time can be seen in Figure 4.35. For the term of air velocity, the maximum is 0.39m/s and the minimum value is 0m/s. The average value of obtained for air velocity in this measurement session is 0.12m/s. The graph of the range of air velocity against time can be seen in Figure 4.36.

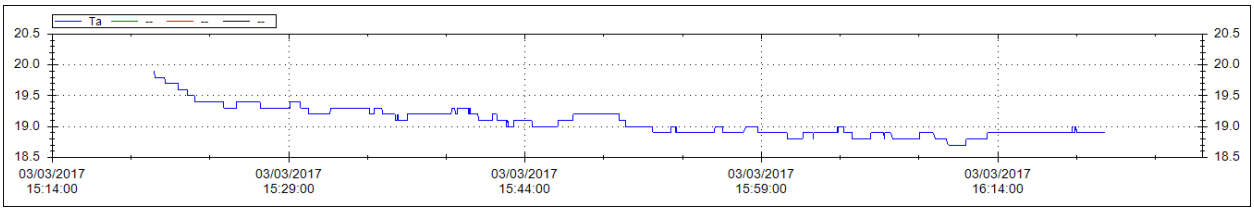


Figure 4.34 The graph of air temperature against time

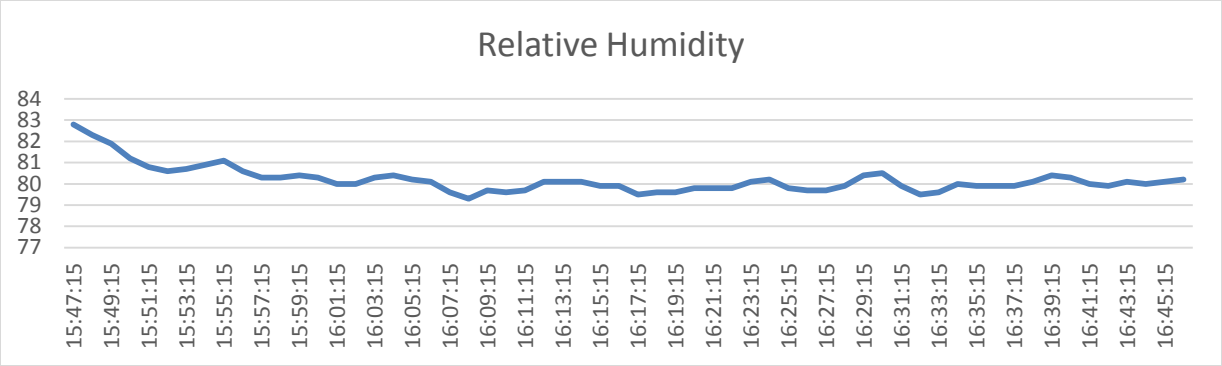


Figure 4.35 The graph of relative humidity against time

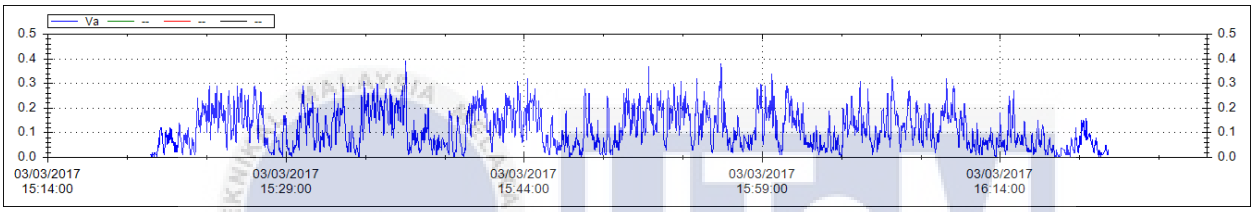


Figure 4.36 The graph of air velocity against time

By referring to the ASHRAE Standard 55 and Malaysian Standard MS1525 2014, the average air temperature obtained for this measurement session is not satisfied both of the standards seems that the values obtained is lower than standard range. The average value obtained was 19.08^{o}C (air temperature, Ta) is not comply with the standards which are the suggested air temperature range were 22.5^{o}C to 26^{o}C (AHSRAE Standard 55) and 23^{o}C to 26^{o}C (Malaysian Standard Ms1525 2014). For the physical parameter of relative humidity (RH), the average value obtained is 82.8% which is also not satisfied the standards. The standard recommended for MS1525 2014 is between the range of 50% to 70%. Seems that the average value obtained is quite higher over the standard range, the average value of relative humidity is not satisfied the standards. Then, for the physical parameter of air velocity, the average value obtained is 0.12m/s which is also not satisfied the standard. Both of the standards recommended the value of air velocity is between 0.15m/s to 0.5m/s.

4.1.13 BK10 WITH OCCUPANT (MORNING)

The physical parameter for the lecture rooms with occupant measurement is one of the condition that had put into considerations in this thesis. For the morning session, the measurement was taken is starting from 8.30am to 9.30am. There were 30 persons during the lecturer sessions. Seems that the lecture room is quite small, the suitable position for measurement was taken at the back of the class. Figure 4.37 show the graph of the air temperature against time. The highest value of the air temperature is 27.6^{o}C and the lowest value of the air temperature is 24.9^{o}C. Hence, the average value obtained for this measurement session is 25.95^{o}C.

The next physical parameter is relative humidity which is Figure 4.38 show the graph of relative humidity against time. The maximum value of relative humidity in this measurement is 74.5% and the minimum value obtained is 66.4%. Hence, the average value gained for relative humidity in this measurement is 69.81%. For the physical parameter of air velocity (Va), the maximum value obtained for BK10 in the morning session with occupant is 0.12m/s and the minimum value obtained is 0m/s. Hence the average value obtained in this measurement is 0.01m/s. The range of the air velocity value against time is shown in Figure 4.39.

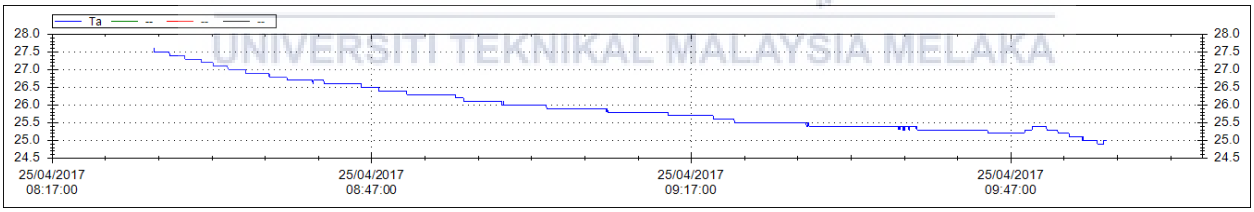


Figure 4.37 The graph of air temperature against time

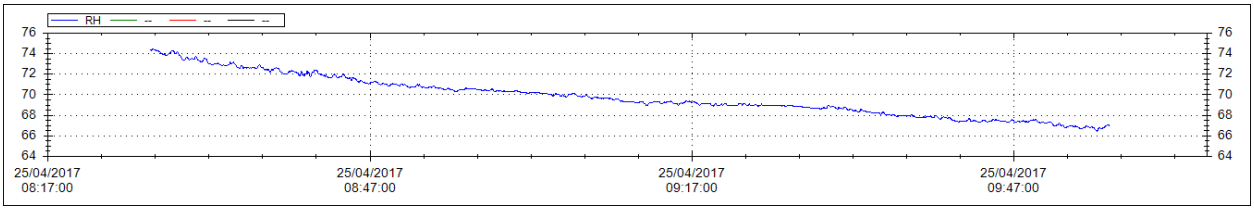


Figure 4.38 The graph of relative humidity against time

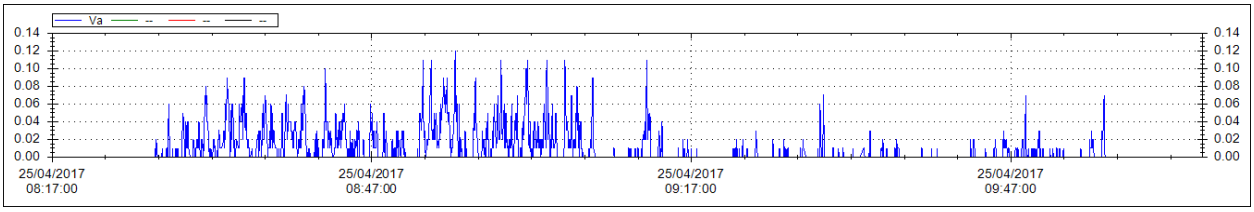


Figure 4.39 The graph of air velocity against time

According to the data obtained, the average value of the air temperature (25.95°C) is satisfied the standard of ASHRAE Standard 55 and Malaysian Standard MS1525 2014. The ASHRAE Standard 55 and Malaysian Standard MS1525 2014 recommended that the suitable range of air velocity is between 22.5°C to 26°C and 23°C to 26°C. For the physical parameter of relative humidity, Malaysian Standard MS1525 2014 recommended the suitable relative humidity is between 50% to 70%. When comparing to the data obtained, the average relative humidity obtained (69.81%) is satisfied the standard. For the last physical parameter, the average value air velocity obtained (0.01m/s) is not satisfied the standard seems that both of the standard recommended the range of air velocity between 0.15m/s to 0.5m/s.

4.1.14 BK10 WITH OCCUPANT (EVENING)

There were 30 persons attended the class during the lecturer sessions. The position of the measurement is also at the back of the class seems that the classroom is quite small. Figure 4.40 show the graph of the air temperature against time for the evening session with occupant. The highest value of the air temperature is 24.8°C and the lowest value of the air temperature is 23.8°C. Hence, the average value obtained for this measurement session is 24.44°C. The next physical parameter is relative humidity which is Figure 4.41 show the graph of relative humidity against time. The maximum value of relative humidity in this measurement is 74.2% and the minimum value obtained is 65%. Hence, the average value gained for relative humidity in this measurement is 67.13%. For the physical parameter of air velocity (Va), the maximum value obtained for BK10 in the morning session with occupant is 0.14m/s and the minimum value

obtained is 0m/s. Hence the average value obtained in this measurement is 0.04m/s. The range of the air velocity value against time is shown in Figure 4.42.

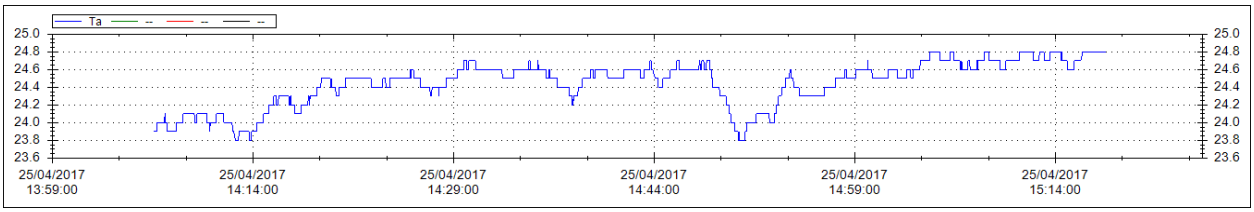


Figure 4.40 The graph of air temperature against time

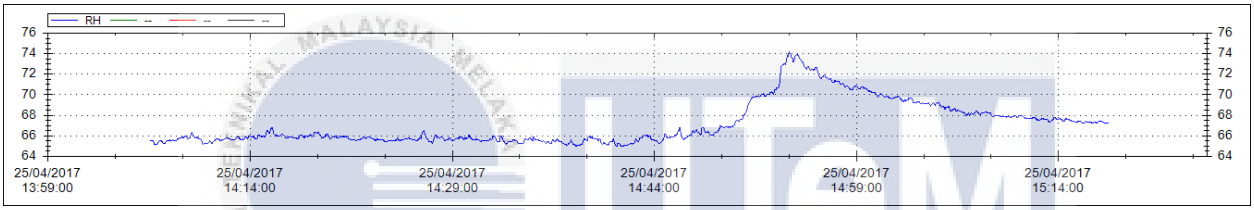


Figure 4.41 The graph of relative humidity against time

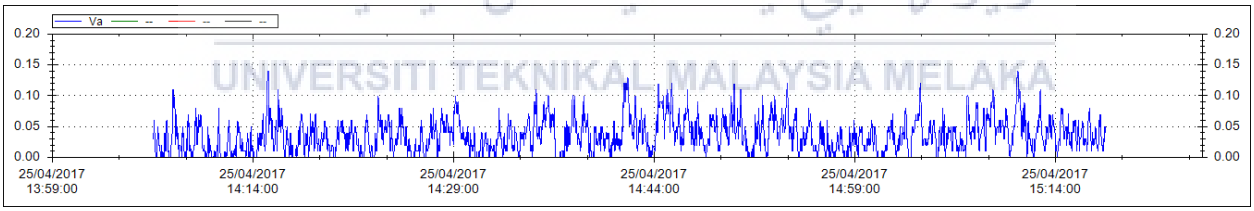


Figure 4.42 The graph of air velocity against time

According to the obtained data, the average value of the air temperature (24.44^{o}C) is satisfied the standard of ASHRAE Standard 55 and Malaysian Standard MS1525 2014. The ASHRAE Standard 55 and Malaysian Standard MS1525 2014 recommended that the suitable range of air velocity is between 22.5^{o}C to 26^{o}C and 23^{o}C to 26^{o}C. For the physical parameter of relative humidity, Malaysian Standard MS1525 2014 recommended the suitable relative humidity is between 50% to 70%. When comparing to the data obtained, the average relative

humidity obtained (67.13%) is within the standard. For the last physical parameter, the average value air velocity obtained (0.04m/s) is not satisfied the standard seems that both of the standard recommended the range of air velocity between 0.15m/s to 0.5m/s.

4.1.15 BK12 WITH OCCUPANT (MORNING)

There were 50 persons attended the class during the lecturer sessions. For the morning session of BK12 with occupant, the time was measured between 9.00am to 10.30pm. The position of the measurement is also at the back of the class seems that the classroom is quite full with student. Figure 4.43 show the graph of the air temperature against time for the morning session with occupant. The highest value of the air temperature is 24.2°C and the lowest value of the air temperature is 23°C. Hence, the average value obtained for this measurement session is 23.66°C. The next physical parameter is relative humidity which is Figure 4.44 show the graph of relative humidity against time. The maximum value of relative humidity in this measurement is 78.2% and the minimum value obtained is 72.6%. Hence, the average value gained for relative humidity in this measurement is 74.6%. For the physical parameter of air velocity (Va), the maximum value obtained for BK10 in the morning session with occupant is 0.41m/s and the minimum value obtained is 0m/s. Hence the average value obtained in this measurement is 0.07m/s. The range of the air velocity value against time is shown in Figure 4.45.

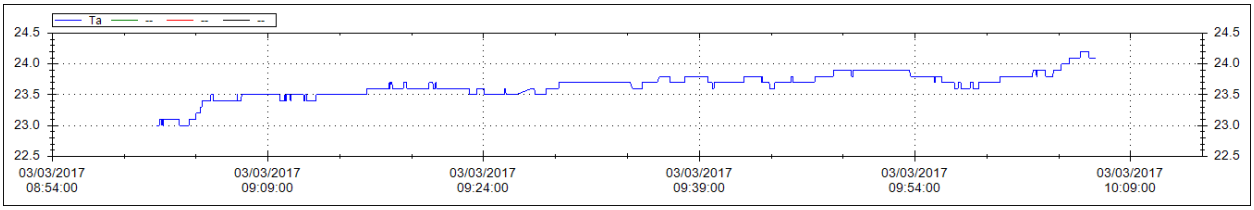


Figure 4.43 The graph of air temperature against time

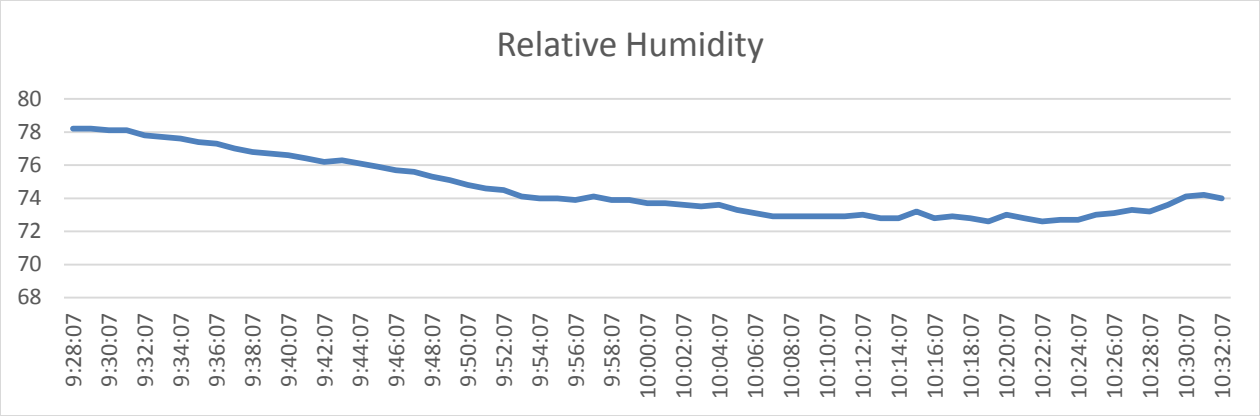


Figure 4.44 The graph of relative humidity against time

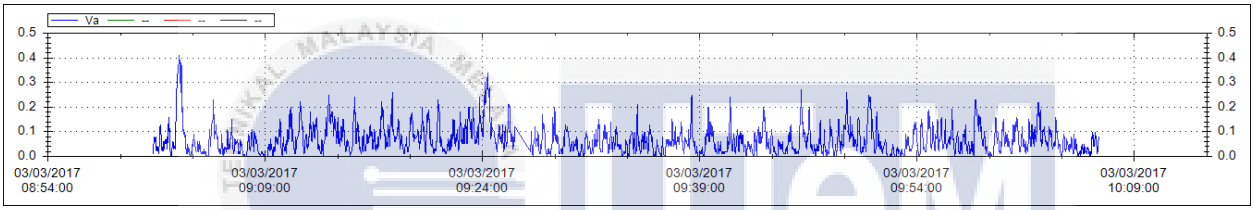


Figure 4.45 The graph of air velocity against time

Based on the measurement, the average value of the air temperature (23.66^{o}C) is within ASHRAE Standard 55 and Malaysian Standard MS1525 2014. The ASHRAE Standard 55 and Malaysian Standard MS1525 2014 recommended that the suitable range of air velocity is between 22.5^{o}C to 26^{o}C and 23^{o}C to 26^{o}C. For the physical parameter of relative humidity, Malaysian Standard MS1525 2014 recommended the suitable relative humidity is between 50% to 70%. The average relative humidity obtained (74.6%) is not satisfied the standard when comparing with MS 1525 2014. For the last physical parameter, the average value air velocity obtained (0.07m/s) is not comply the standard seems that both of the standard recommended the range of air velocity between 0.15m/s to 0.5m/s.

4.1.16 BK12 WITH OCCUPANT (EVENING)

The starting time for BK12 with occupant was measured in the range time of 2.00pm to 4.00pm. The total student attended the class during the lecturer sessions was 33 persons. For the evening session of BK12 with occupant, the time was started from 9.00am to 10.00pm. The position of the measurement is at the back of the middle of the class. Figure 4.46 show the graph of the air temperature against time for the morning session with occupant. The highest value of the air temperature is 23.9^{o}C and the lowest value of the air temperature is 23.1^{o}C. Hence, the average value obtained for this measurement session is 23.5^{o}C. The next physical parameter is relative humidity which is Figure 4.47 show the graph of relative humidity against time. The highest value of relative humidity in this measurement is 73.1% and the minimum value obtained is 72.6%. Hence, the average value gained for relative humidity in this measurement is 71.7%. For the physical parameter of air velocity (Va), the maximum value obtained for BK10 in the morning session with occupant is 0.39m/s and the minimum value obtained is 0m/s. Hence the average value obtained in this measurement is 0.09m/s. The range of the air velocity value against time is shown in Figure 4.48.

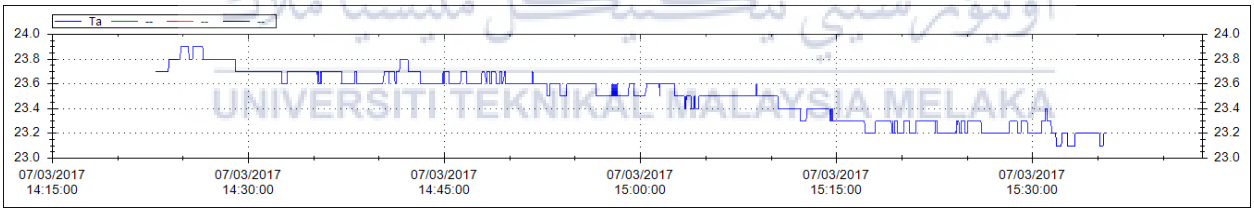


Figure 4.46 The graph of air temperature against time

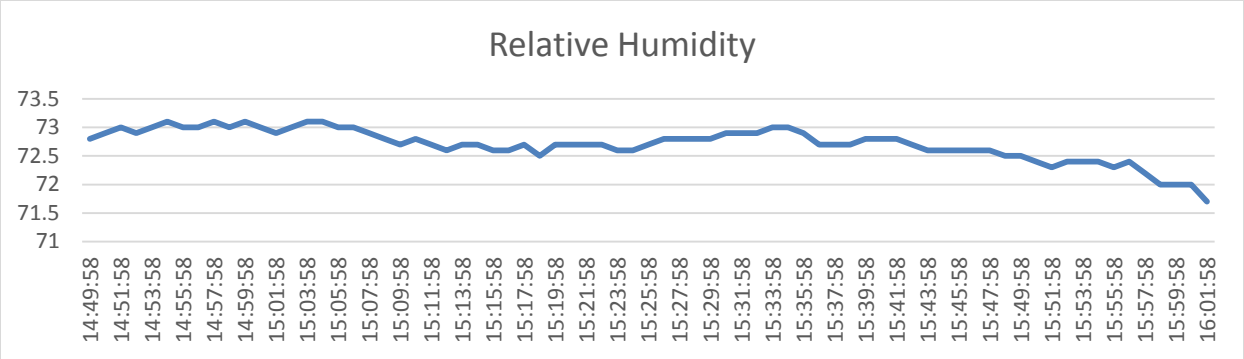


Figure 4.47 The graph of relative humidity against time

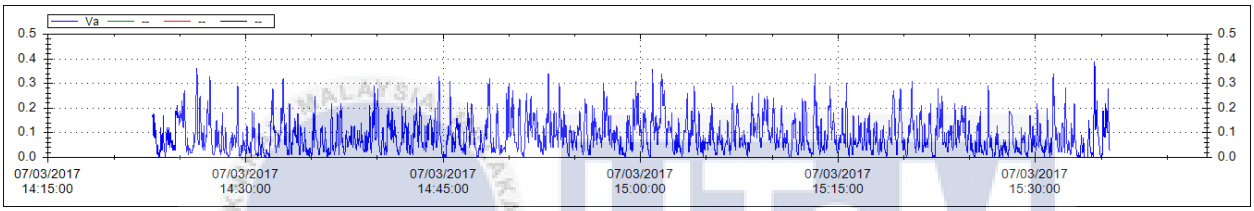


Figure 4.48 The graph of air velocity against time

Based on the measurement, the average value of the air temperature (23.5°C) is satisfied the standard seems that the data obtained is fall in the range recommended of ASHRAE Standard 55 and Malaysian Standard MS1525 2014. The ASHRAE Standard 55 and Malaysian Standard MS1525 2014 recommended that the suitable range of air velocity is between 22.5°C to 26°C and 23°C to 26°C. For the physical parameter of relative humidity, Malaysian Standard MS1525 2014 recommended the suitable relative humidity is between 50% to 70%. The average relative humidity obtained (72.7%) is not satisfied the standard when comparing with MS 1525 2014. For the last physical parameter, the average value air velocity obtained (0.09m/s) is not comply the standard seems that both of the standard recommended the range of air velocity between 0.15m/s to 0.5m/s.

4.1.17 BK13 WITH OCCUPANT (AFTERNOON)

The measurement of the BK13 is measured in afternoon from 11.00am to 12.00pm respectively. There were 19 students total that attended the class. The maximum and minimum value of the air temperature of BK13 with occupant in afternoon is 24.1°C and 23.7°C. then, the average value of air temperature 23.99°C. The graph of air temperature against time is shown in Figure 4.49. for the next physical parameter relative humidity, the maximum value obtained is 70.3% and the minimum value is 68%. Figure 4.50 show that the graph of air velocity against time Hence, the average value of relative humidity for BK13 with occupant in afternoon session is 68.96%. for the physical parameter of air velocity, the maximum value is 0.17m/s and the minimum value is 0m/s. Then, the average value of air velocity is 0.01m/s. Figure 4.51 show that the graph of air velocity against time.

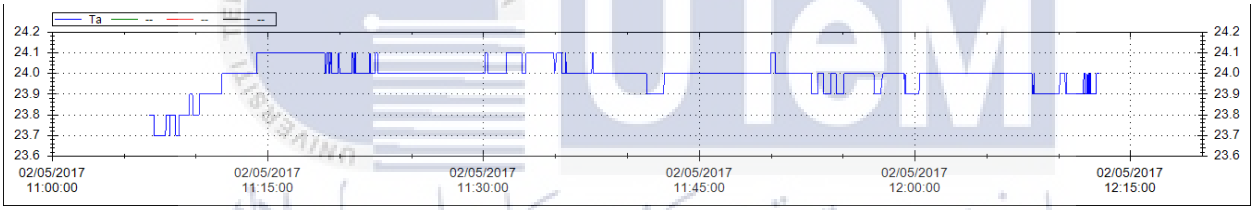


Figure 4.49 The graph of air temperature against time for BK13 (afternoon) with occupant

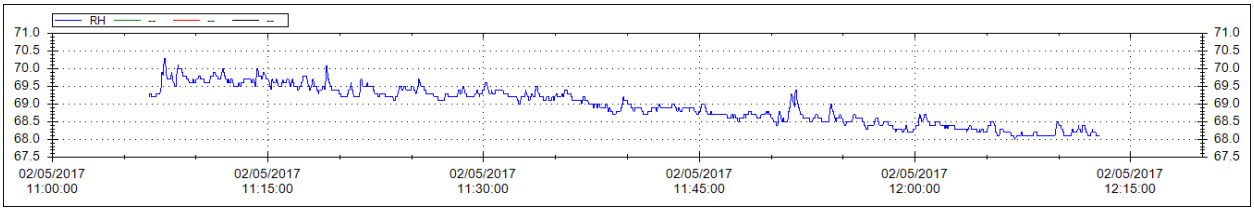


Figure 4.50 The graph of relative humidity against time for BK13 (afternoon) with occupant

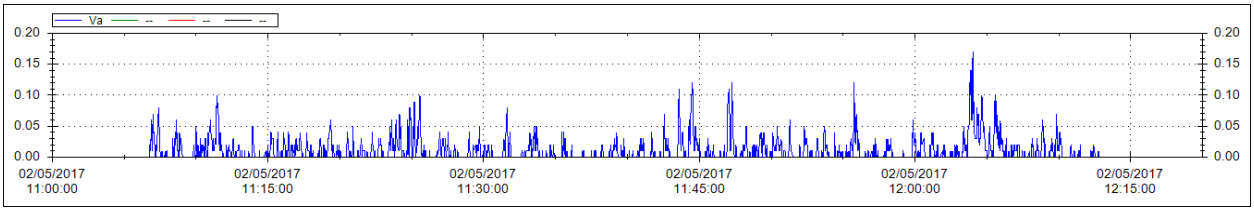


Figure 4.51 The graph of air velocity against time for BK13 (afternoon) with occupant

When comparing to ASHRAE Standard 55 and Malaysian Standard MS1525 2014, the average value of air temperature (23.99^{o}C) and the average value of relative humidity (68.96%) is comply with the recommended value. But unfortunately, the average value of the air velocity is not comply with the standard seems that both of the standard suggested the range of air velocity is in between 0.15m/s to 0.5m/s.

4.1.18 BK13 WITH OCCUPANT (EVENING)

The measurement of the BK13 is measured in evening from 2.00pm to 3.00pm respectively. There were 34 students total that attended the class. The maximum and minimum value of the air temperature of BK13 with occupant in afternoon is 24.2^{o}C and 23.4^{o}C. then, the average value of air temperature 23.96^{o}C. The graph of air temperature against time is shown in Figure 4.52. for the next physical parameter relative humidity, the maximum value obtained is 71.7% and the minimum value is 67.5%. Figure 4.53 show that the graph of air velocity against time Hence, the average value of relative humidity for BK13 with occupant in afternoon session is 69.02%. for the physical parameter of air velocity, the maximum value is 0.24m/s and the minimum value is 0m/s. Then, the average value of air velocity is 0.04m/s. Figure 4.54 show that the graph of air velocity against time.

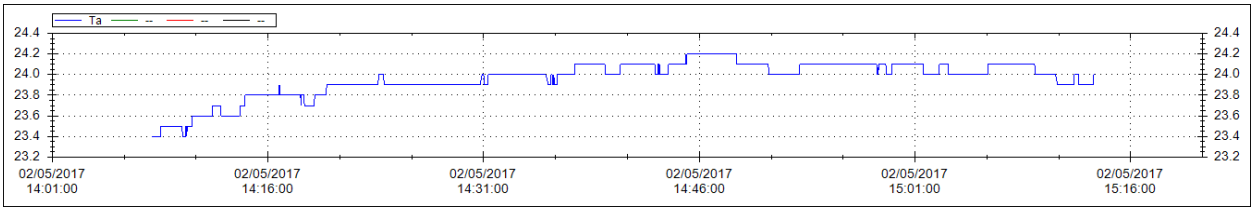


Figure 4.52 The graph of air temperature against time for BK13 (evening) with occupant

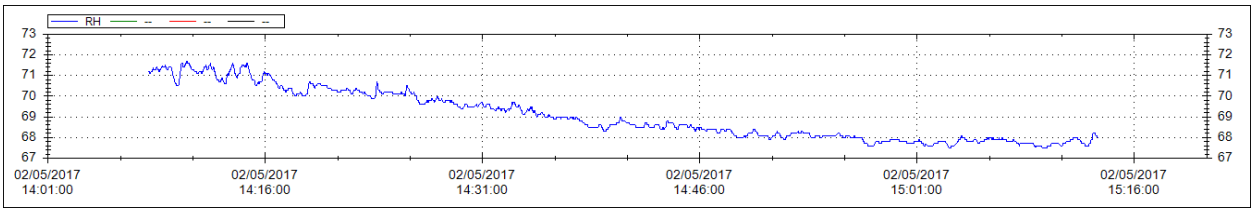


Figure 4.53 The graph of relative humidity against time for BK13 (evening) with occupant

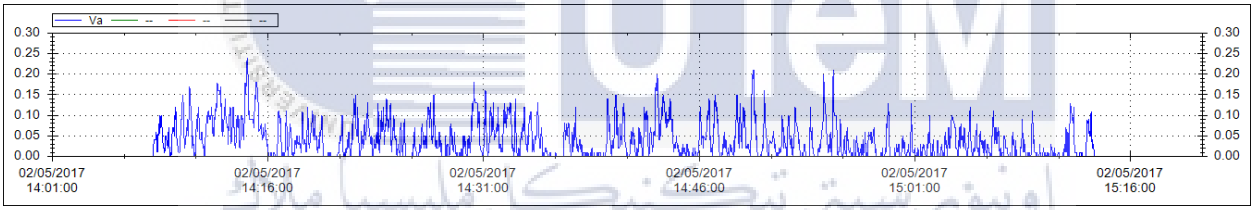


Figure 4.54 The graph of air velocity against time for BK13 (evening) with occupant

According to ASHRAE Standard 55 and Malaysian Standard MS1525 2014, the average value of air temperature (23.96^{o}C) and the average value of relative humidity (69.02%) is comply with the recommended value. But unfortunately, the average value of the air velocity (0.04m/s) is not comply with the standard seems that both of the standard suggested the range of air velocity is in between 0.15m/s to 0.5m/s.

4.1.19 BK17 WITH OCCUPANT (MORNING)

The measurement of the BK17 is measured during morning session between 9.00am to 10.00am respectively. There were 45 total of students that attended the class. The maximum and minimum value of the air temperature of BK17 with occupant in morning session is 23.9^{o}C and 23^{o}C. Then, the average value of air temperature 23.68^{o}C. The graph of air temperature against time is shown in Figure 4.55. For the next physical parameter relative humidity, the maximum value obtained is 78.4% and the minimum value is 71.3%. Figure 4.56 show that the graph of air velocity against time Hence, the average value of relative humidity for BK17 with occupant in afternoon session is 73.65%. for the physical parameter of air velocity, the maximum value is 0.3m/s and the minimum value is 0m/s. Then, the average value of air velocity is 0.08m/s. Figure 4.57 show that the graph of air velocity against time for BK17 with occupant in the morning session.

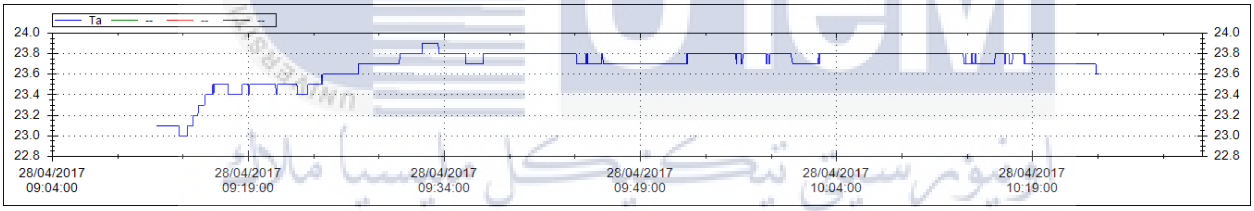


Figure 4.55 The graph of air temperature against time for BK17 (morning) with occupant

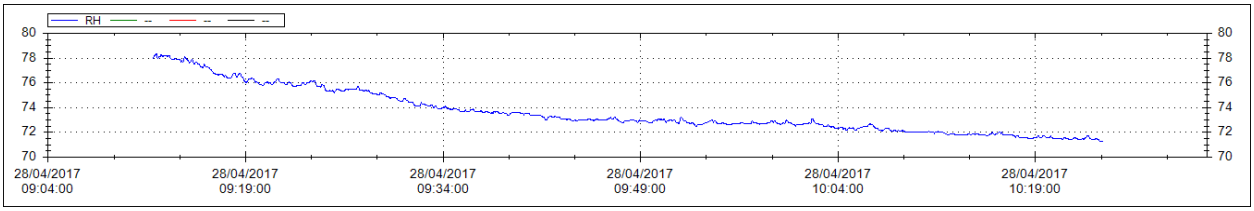


Figure 4.56 The graph of relative humidity against time for BK17 (morning) with occupant

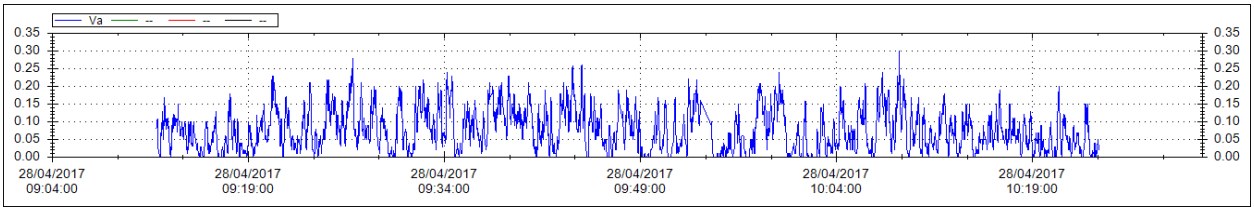


Figure 4.57 The graph of air velocity against time for BK17 (morning) with occupant

According to ASHRAE Standard 55 and Malaysian Standard MS1525 2014, the average value of air temperature (23.68°C) for BK17 with occupants in morning session is comply with the recommended value. But unfortunately, the average value of relative humidity (73.65%) and the average value of air velocity (0.08m/s) is not comply with the standard seems that both of the standard suggested the range of air velocity is in between 0.15m/s to 0.5m/s and Malaysian Standard MS1525 2014 recommended the relative humidity from 50% to 70%.

4.1.20 BK17 WITH OCCUPANT (AFTERNOON)

The first set of BK17 data is shown in Figure 4.58, Figure 4.59 and Figure 4.60 represent that the graph of air temperature, relative humidity and air velocity against time in the afternoon session with occupant. The maximum and minimum value of the air temperature (Ta) are 23.2°C and 23°C. For the average value of the air temperature (Ta) is 23.57°C. For the physical parameter of relative humidity (RH), the maximum and minimum value are 74.6% and 67.7%. The average value of relative humidity is 68.94%. for the value of air velocity, the maximum and minimum value are 0.4m/s and 0m/s. The average value of air velocity is 0.07m/s.

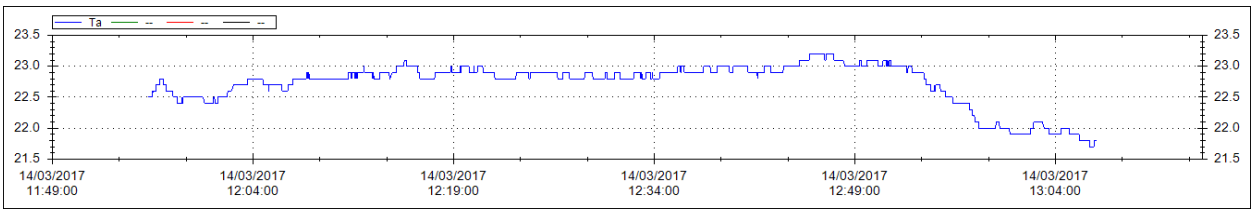


Figure 4.58 The graph of air temperature against time for BK17 (afternoon) with occupant

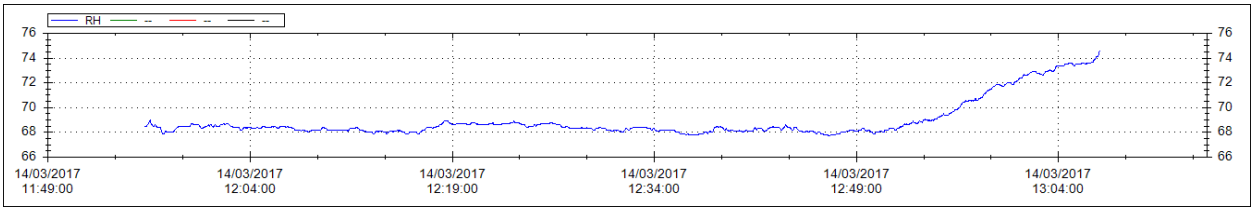


Figure 4.59 The graph of relative humidity against time for BK17 (afternoon) with occupant

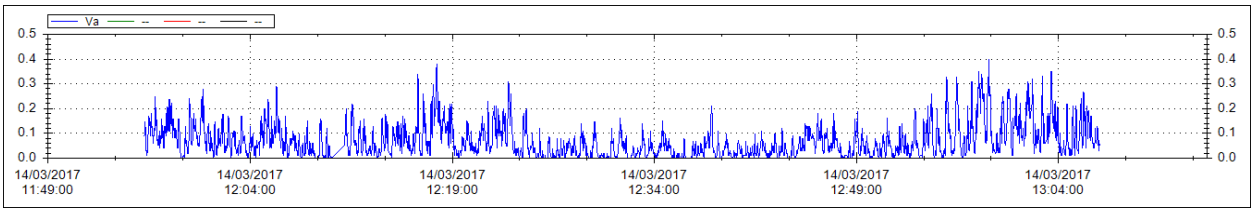


Figure 4.60 The graph of air velocity against time for BK17 (afternoon) with occupant

According to ASHRAE Standard 55 and Malaysian Standard MS1525 2014, the average value of air temperature (23.57^{o}C) for BK17 with occupants in afternoon session is comply with the recommended value. Same goes to the relative humidity, the average value of relative humidity (68.94%) is comply with the standard. Seems that both of the standard suggested the range of air velocity is in between 0.15m/s to 0.5m/s, the average value of air velocity (0.07m/s) is not satisfied with both of standards.

4.1.21 BK17 WITH OCCUPANT (EVENING)

The first set of BK17 data is shown in Figure 4.61, Figure 4.62 and Figure 4.63 represent that the graph of air temperature, relative humidity and air velocity against time in the evening session with occupant. The maximum and minimum value of the air temperature (Ta) are 21.9^{o}C and 21.3^{o}C. For the average value of the air temperature (Ta) is 21.59^{o}C. For the physical parameter of relative humidity (RH), the maximum and minimum value are 74.7% and 72.6%. The average value of relative humidity is 73.57%. For the value of air velocity, the maximum and minimum value are 0.58m/s and 0m/s. The average value of air velocity is 0.25m/s.

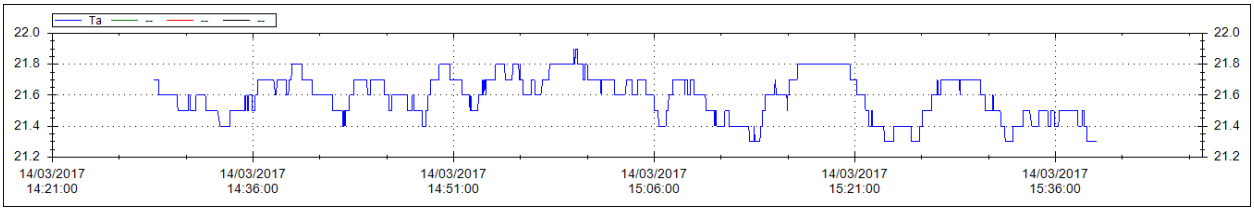


Figure 4.61 The graph of air temperature against time for BK17 (evening) with occupant

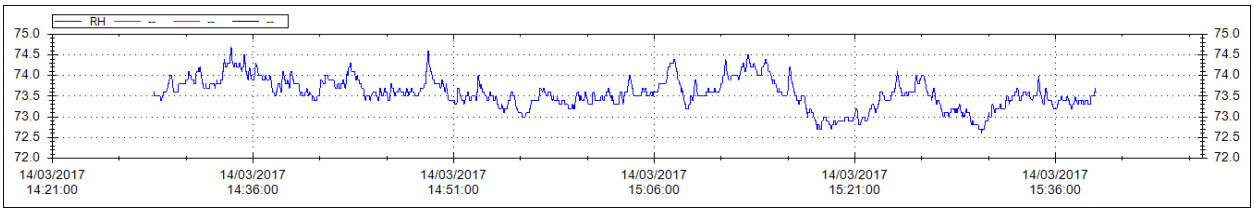


Figure 4.62 The graph of relative humidity against time for BK17 (evening) with occupant

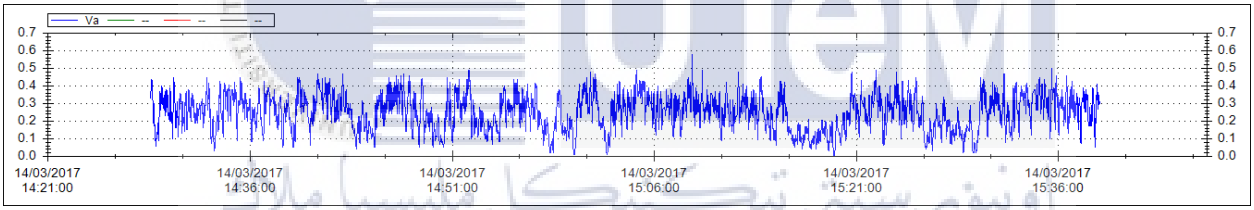


Figure 4.63 The graph of air velocity against time for BK17 (evening) with occupant

According to ASHRAE Standard 55 and Malaysian Standard MS1525 2014, the average value of air temperature (21.59^{o}C) for BK17 with occupants in afternoon session is not comply with the recommended value. Same goes to the relative humidity, the average value of relative humidity (73.57%) is not comply with the standard. Seems that both of the standard suggested the range of air velocity is in between 0.15m/s to 0.5m/s, the average value of air velocity (0.25m/s) is satisfied with both of standards.

4.1.22 DUST TRAK MEASUREMENT OF BK10

The measurement of dust concentration is measured during the measurement of thermal comfort parameter. The data of dust concentration of BK10 with occupant and without occupant for the morning, afternoon and evening session are tabulated in Table 4.9.

Table 4.9 The Physical Parameter of Dust Concentration Measurements in BK10

Session	Concentration	Physiscal Parameter	Dust (mg/m^3)	
			With Occupants	Without Occupants
Morning	10µm	Maximum Value	0.04	0.047
		Minimum Value	0.033	0.031
		Average Value	0.038	0.035
	2.5µm	Maximum Value	0.032	0.033
		Minimum Value	0.022	0.029
		Average Value	0.023	0.031
Afternoon	10µm	Maximum Value		0.027
		Minimum Value		0.021
		Average Value		0.023
	2.5µm	Maximum Value		0.025
		Minimum Value		0.021
		Average Value		0.024
Evening	10µm	Maximum Value	0.052	0.032
		Minimum Value	0.031	0.016
		Average Value	0.035	0.018
	2.5µm	Maximum Value	0.104	0.043
		Minimum Value	0.032	0.015
		Average Value	0.037	0.021

The reading of dust concentration is carried out by dividing into two specifications of particulate matter size's which are 10µm and 2.5µm. The measurement is also taken in three phase of session which are in morning, afternoon and evening session for with occupant and without occupant. For the morning session with occupant, the maximum and minimum value of the particulate matter of 10µm are 0.04 mg/m^3 and 0.033 mg/m^3. For the average value of morning session is 0.038 mg/m^3. For the particulate matter size of 2.5µm, the maximum value and minimum value are 0.032mg/m^3, 0.022mg/m^3 for with occupant. Hence, the average value of particulate matter of 2.5µm with occupant is 0.023 mg/m^3. For the without occupant condition, the maximum and minimum value of the particulate matter of 10µm are 0.047mg/m^3 and 0.031mg/m^3. Then, the average value of particulate matter 10µm without occupant in morning session is 0.035mg/m^3. The maximum, minimum and average value for particulate matter of 2.5µm without occupant are 0.33mg/m^3, 0.029mg/m^3 and 0.031mg/m^3.

For the second measurement which is during the afternoon session. For the particulate matter of 10µm without occupant condition, the maximum, minimum are 0.027 mg/m^3, 0.021 mg/m^3. For the average value of particulate matter 10µm obtained is 0.023 mg/m^3. The second measurement is particulate matter of 2.5µm. The maximum and minimum value of the dust obtained are 0.025 mg/m^3 and 0.021 mg/m^3. the average value of the particulate matter of 2.5µm is 0.024 mg/m^3.

For the last session which is during evening session, the maximum and minimum value of particulate matter of 10µm with occupant are 0.052mg/m^3 and 0.031mg/m^3. So, the average value of particulate matter 10µm with occupant is 0.035mg/m^3. For the particulate matter of 2.5µm, the maximum and minimum value are 0.104mg/m^3 and 0.032mg/m^3. Then the average value is 0.037mg/m^3. For the without occupant condition of BK10, the maximum, minimum and average value of particulate matter 10µm are 0.032mg/m^3, 0.016mg/m^3 and 0.018mg/m^3. For the particulate matter of 2.5µm, the maximum, minimum and average value of are 0.043mg/m^3, 0.015mg/m^3 and 0.021mg/m^3.

4.1.23 DUST TRAK MEASUREMENT OF BK12

The data of dust concentration of BK12 with occupant and without occupant for the morning, afternoon and evening session are tabulated in Table 4.9.

Table 4.10 The Physical Parameter of Dust Concentration Measurements in BK12

Session	Concentration	Physiscal Parameter	Dust (mg/m^3)	
			With Occupants	Without Occupants
Morning	10µm	Maximum Value	0.041	0.016
		Minimum Value	0.022	0.01
		Average Value	0.027	0.012
	2.5µm	Maximum Value	0.021	0.012
		Minimum Value	0.017	0.009
		Average Value	0.021	0.011
Afternoon	10µm	Maximum Value		0.043
		Minimum Value		0.026
		Average Value		0.03
	2.5µm	Maximum Value		0.033
		Minimum Value		0.024
		Average Value		0.026
Evening	10µm	Maximum Value	0.029	0.045
		Minimum Value	0.019	0.041
		Average Value	0.021	0.042
	2.5µm	Maximum Value	0.025	0.045
		Minimum Value	0.019	0.04
		Average Value	0.021	0.042

The reading of dust concentration is carried out by divided into two specifications of particulate matter size's which are 10µm and 2.5µm. The measurement is also taken in three phase of session which are in morning, afternoon and evening session. The first condition which is with occupant condition in the morning session got 0.041mg/m^3, 0.022mg/m^3 and 0.027mg/m^3 maximum, minimum and average value for the particulate matter of 10µm. For the maximum and minimum value of the particulate matter of 10µm without occupant are 0.016 mg/m^3 and 0.01 mg/m^3. For the average value of morning session is 0.012 mg/m^3. For the particulate matter of 2.5µm, the maximum, minimum and average value are 0.012 mg/m^3, 0.009 mg/m^3 and 0.011 mg/m^3.

For the second measurement which is during the afternoon session. For the particulate matter of 10µm, the maximum, minimum and average value are 0.043 mg/m^3, 0.026 mg/m^3 and 0.03 mg/m^3 in condition of without occupant. The second measurement is particulate matter of 2.5µm. The maximum and minimum value of the dust obtained are 0.033 mg/m^3 and 0.024 mg/m^3. the average value of the particulate matter of 2.5µm is 0.026 mg/m^3.

The last session of the measurement in lecture room of BK12 is in the evening session. The condition of with occupant got 0.029mg/m^3, 0.019mg/m^3 and 0.021mg/m^3 maximum, minimum and average value for the particulate matter of 10µm. For the particulate matter of 2.5µm, the maximum and minimum value are 0.025mg/m^3 and 0.019mg/m^3. Hence, for the average value is 0.021mg/m^3. For the particulate matter of 10µm, the maximum, minimum and average value are 0.045 mg/m^3, 0.041 mg/m^3 and 0.042 mg/m^3 for the condition of without occupant. The second measurement is particulate matter of 2.5µm. The maximum and minimum value of the dust obtained are 0.045 mg/m^3 and 0.04 mg/m^3. The average value of the particulate matter of 2.5µm is 0.042 mg/m^3 for the evening session without occupant.

4.1.24 DUST TRAK MEASUREMENT OF BK13

The data of dust concentration of BK13 with occupant and without occupant for the morning, afternoon and evening session are tabulated in Table 4.9.

Table 4.11 The Physical Parameter of Dust Concentration Measurements in BK13

Session	Concentration	Physiscal Parameter	Dust (mg/m^3)	
			With Occupants	Without Occupants
Morning	10µm	Maximum Value		0.025
		Minimum Value		0.022
		Average Value		0.024
	2.5µm	Maximum Value		0.037
		Minimum Value		0.02
		Average Value		0.022
Afternoon	10µm	Maximum Value	0.045	0.047
		Minimum Value	0.025	0.035
		Average Value	0.028	0.037
	2.5µm	Maximum Value	0.045	0.062
		Minimum Value	0.025	0.03
		Average Value	0.029	0.033
Evening	10µm	Maximum Value	0.065	0.035
		Minimum Value	0.029	0.027
		Average Value	0.033	0.03
	2.5µm	Maximum Value	0.046	0.032
		Minimum Value	0.025	0.028
		Average Value	0.028	0.03

For morning session without occupant condition, the maximum, minimum and average value are 0.025mg/m^3, 0.022mg/m^3 and 0.024mg/m^3 for particulate matter of 10µm. The second measurement is particulate matter of 2.5µm. The maximum and minimum value of the dust obtained are 0.037mg/m^3 and 0.02mg/m^3. The average value of the particulate matter of 2.5µm is 0.022mg/m^3.

The afternoon with occupant condition got the maximum, minimum and average value of 0.045mg/m^3, 0.025mg/m^3 and 0.028mg/m^3 for the particulate matter of 10µm. For the particulate matter of 2.5µm, the maximum and minimum value are 0.045mg/m^3, 0.025mg/$m^3$and 0.029mg/m^3. For the without occupant condition, the maximum, minimum and average value are 0.047mg/m^3, 0.035mg/m^3 and 0.037mg/m^3 for particulate matter of 10µm. The second measurement is particulate matter of 2.5µm. The maximum and minimum value of the dust obtained are 0.062mg/m^3 and 0.03mg/m^3. The average value of the particulate matter of 2.5µm is 0.033mg/m^3.

The last session of the measurement in lecture room of BK13 is in the evening session. For the with occupant condition, the particulate matter of 10µm got 0.065mg/m^3, 0.029mg/m^3, 0.033mg/m^3 for maximum, minimum and average value. For the particulate matter of 2.5µm, the maximum, minimum and average value are 0.046mg/m^3 ,0.025mg/m^3 and 0.028mg/m^3. For the without occupant condition particulate matter of 10µm, the maximum, minimum and average value are 0.035 mg/m^3, 0.027 mg/m^3 and 0.03 mg/m^3. The second measurement is particulate matter of 2.5µm. The maximum and minimum value of the dust obtained are 0.032 mg/m^3 and 0.028 mg/m^3. the average value of the particulate matter of 2.5µm is 0.03 mg/m^3.

4.1.25 DUST TRAK MEASUREMENT OF BK17

The data of dust concentration of BK17 with occupant and without occupant for the morning, afternoon and evening session are tabulated in Table 4.11.

Table 4.12 The Physical Parameter of Dust Concentration Measurements in BK17

Session	Concentration	Physiscal Parameter	Dust (mg/m^3)	
			With Occupants	Without Occupants
Morning	10µm	Maximum Value	0.021	0.017
		Minimum Value	0.01	0.015
		Average Value	0.015	0.016
	2.5µm	Maximum Value	0.012	0.018
		Minimum Value	0.01	0.015
		Average Value	0.011	0.016
Afternoon	10µm	Maximum Value	0.134	0.019
		Minimum Value	0.087	0.016
		Average Value	0.098	0.018
	2.5µm	Maximum Value	0.085	0.058
		Minimum Value	0.074	0.015
		Average Value	0.078	0.017
Evening	10µm	Maximum Value	0.037	0.025
		Minimum Value	0.021	0.015
		Average Value	0.024	0.017
	2.5µm	Maximum Value	0.036	0.02
		Minimum Value	0.022	0.017
		Average Value	0.024	0.019

For the morning session with occupant condition, the maximum and minimum value of the particulate matter of 10µm are 0.021 mg/m^3 and 0.01 mg/m^3. For the average value of morning session is 0.015 mg/m^3. For the particulate matter size of 2.5µm, the maximum value and minimum value are 0.012 mg/m^3, 0.01 mg/m^3 for with occupant condition. Hence, the average value of particulate matter of 2.5µm with occupant is 0.011 mg/m^3. For the without occupant condition, the maximum and minimum value of the particulate matter of 10µm are 0.017 mg/m^3 and 0.015 mg/m^3. Then, the average value is 0.016mg/m^3. The maximum, minimum and average value for particulate matter of 2.5µm without occupant are 0.18mg/m^3, 0.015mg/m^3 and 0.016mg/m^3.

The second measurement which is in the afternoon session. For the with occupant condition, the particulate matter of 10µm got 0.134mg/m^3, 0.087mg/m^3, 0.098mg/m^3 for maximum, minimum and average value. For the particulate matter of 2.5µm, the maximum, minimum and average value are 0.085mg/m^3, 0.074mg/m^3 and 0.078mg/m^3. For the particulate matter of 10µm without occupant condition, the maximum, minimum are 0.019 mg/m^3, 0.016 mg/m^3. For the average value of particulate matter 10µm obtained is 0.018 mg/m^3. The second measurement is particulate matter of 2.5µm. The maximum and minimum value of the dust obtained are 0.058 mg/m^3 and 0.015 mg/m^3. the average value of the particulate matter of 2.5µm is 0.017 mg/m^3.

For the last session which is evening session, the maximum and minimum value of particulate matter of 10µm with occupant are 0.037mg/m^3 and 0.021mg/m^3. So, the average value of particulate matter 10µm with occupant is 0.024mg/m^3. For the particulate matter of 2.5µm, the maximum and minimum value are 0.36mg/m^3 and 0.022mg/m^3. Then the average value is 0.024mg/m^3. For the without occupant condition of BK10, the maximum, minimum and average value of particulate matter 10µm are 0.025mg/m^3, 0.015mg/m^3 and 0.017mg/m^3. For the particulate matter of 2.5µm, the maximum, minimum and average value of are 0.02mg/m^3, 0.017mg/m^3 and 0.019mg/m^3.

4.2 PHYSICAL PARAMETERS ANALYSIS

Several analyses had be done to the all physical parameter that had be taken. There are several ways to do analysis with physical parameter that had be measured. The first one is the physical parameter that had be taken to all area are compared to ASHRAE Standard 55 and Malaysian Standard MS1525 2014. Both of the standard had recommended the standard range of physical parameter involved in thermal comfort and dust concentration for indoor condition. If the physical parameter obtained satisfied the standard range, the area of measurement can be classified as good condition of thermal comfort and dust level. The second analysis is the comparison between physical parameter on different session which is in the morning, afternoon and evening. The purpose to compare on different session is to ensure that either the thermal comfort and dust concentration are affected with time. Then, the last analysis is the comparison between area condition which is with occupant condition and without occupant condition.

4.2.1 ANALYSIS ON BK10 PHYSICAL PARAMETER

The thermal comfort parameter measurement is taken each one minutes in one hour. Table 4.13 showed that the thermal comfort analysis. The green region represents the acceptable value and the red region is unacceptable value when comparing to ASHRAE Standard 55 and Malaysian Standard MS1525. As overall, the air temperature of the BK10 are satisfied the standards but only air temperature obtained at evening session without occupant is not achieved the standard. The value obtained is slightly lower than the standard range. When comparing with the condition of with occupant and without occupant, the value of air temperature showed with the present of the occupant is higher than without occupant. This proved that the present of occupant is affected the value of air temperature. In other hand, the result obtained for relative humidity is also showed the same behavior. The all value obtained is achieved the standard range but only at afternoon session without occupant, the value gained is slightly over the standard range. High temperatures reduced the concentration of pollutants while high relative humidity increase the concentration of air pollutants measured in indoor area (Yang Razali et al., 2015).

For the air velocity, it had shown that all the value obtained are not satisfied the standard but only at evening session without occupant the value is achieved the standard range.

Table 4.13 The thermal comfort parameter analysis of BK10

Condition	Sessions	Ta (C)	RH (%)	Va (m/s)
Without Occupant	Morning	24.1	69.71	0
	Afternoon	22.74	70.26	0.08
	Evening	22.46	66.47	0.31
With Occupant	Morning	25.95	69.81	0.01
	Evening	24.44	67.13	0.04

For the comparison in dust concentration or particulate matter analysis are shown in Table 4.14. The red green region represents the value that satisfied the standard while the red region is not satisfied the standards. According to the table above, the particulate matter of 10µm measurement is satisfied the standard in all sessions for condition of with occupant and without occupant. While the particulate matter of 2.5µm is not satisfied the standard seems that the Malaysian Standard MS1525 2014 recommended the value must obtain below 0.15mg/m^3 for particulate matter of 10µm and ASHRAE Standard 55 recommended below 0.015mg/m^3 for particulate matter of 2.5µm and 0.05mg/m^3 for particulate matter of 10µm.

For the comparison between condition seems that the value obtained for both of the condition with occupant and without occupant is not so differ. This is probably cause by the walking students in the class which is several students often go out and in during the lecture session and also there are much student come late to the class. The indoor particle number and mass concentration is affected considerably by human activities like cooking, vacuuming, burning candles, smoking, solid fuel combustion, walking or even the use of electric appliances (Chatoutsidou et al., 2015).

The data from morning to evening showed the decreasing on without occupant. The particulate matter on the morning behavior is slightly higher due to morning rush hour. But the particulate matter value is low during other period time (Han, Kwon, & Chun, 2016). This is probably during morning rush hour, people are going to work and attended the office at cubic building. For the behavior at with occupant condition, the value at the morning and evening is not much differ due to weather condition which is the wind at the outside is on high speed and starting to rain.

Table 4.14 The dust concentration analysis of BK10

Session	Concentration	Dust (mg/m^3)	
		With Occupant	Without Occupant
Morning	10µm	0.038	0.035
	2.5µm	0.023	0.031
Afternoon	10µm		0.023
	2.5µm		0.024
Evening	10µm	0.035	0.018
	2.5µm	0.037	0.021

4.2.2 ANALYSIS ON BK12 PHYSICAL PARAMETER

Table 4.15 below shoed that the thermal comfort analysis of BK12 with occupant and without occupant condition. The result obtained for air temperature is all achieved the standard range by ASHRAE Standard 55 (22.5°C to 26°C) and Malaysia Standard MS1525 2014 (23°C to 26°C). For the physical parameter of relative humidity and air velocity, the value obtained is all not satisfied the standard range. The suggested range for relative humidity is 50% to70% (Malaysian Standard MS1525 2014) and for air velocity is 0.15m/s to 0.5m/s (both standard). When comparing with session measurement, the measurement from morning to evening showed the decreasing value of relative humidity. This is showed that the relative humidity is affected by session. The morning session measurement is started from 8.30am to 9.30am.

Table 4.15 The thermal comfort analysis of BK12

Condition	Sessions	Ta (C)	RH (%)	Va (m/s)
Without Occupant	Morning	22.9	80.64	0.02
	Afternoon	23.8	71.92	0.004
	Evening	23.69	70.48	0.03
With Occupant	Morning	23.66	74.6	0.07
	Evening	23.5	72.7	0.09

Table 4.16 The dust concentration analysis of BK12

Session	Concentration	Dust (mg/m^3)	
		With Occupant	Without Occupant
Morning	10µm	0.027	0.012
	2.5µm	0.021	0.011
Afternoon	10µm		0.03
	2.5µm		0.026
Evening	10µm	0.021	0.042
	2.5µm	0.021	0.042

For the comparison in dust concentration or particulate matter analysis are shown in Table 4.16. The satisfied values are labelled in green region and unsatisfied values are labelled red region. Based on the table above, all the particulate matter of 10µm measurement value are satisfied the standard in all sessions for condition of with occupant and without occupant. While only in afternoon session the particulate matter of 2.5µm satisfied the standard seems that the Malaysian Standard MS1525 2014 recommended the value must obtain below $0.15mg/m^3$ for particulate matter of 10µm and ASHRAE Standard 55 recommended below $0.015mg/m^3$ for particulate matter of 2.5µm and below $0.05mg/m^3$ for particulate matter of 10µm.

For the comparison between condition, seems that the value obtained for both of the condition with occupant and without occupant is different in morning session. The value obtained at condition of with occupant is higher than without occupant. This proved that with the present of occupant will increase the concentration of dust. But at the evening session the value obtained without occupant is higher than with occupant condition. The result obtained is unreasonable because the result should be obtained the present of occupant is higher than without occupant. This probably weather effect which is the condition of with occupant which is the measurement is taking during raining.

The data of with occupant condition showed that the morning session is slightly higher than evening session and the data of without occupant show that the value is increasing from morning to evening. This is happened probably due to the weather also which is at the evening session the weather is so hot. The measurement of dust concentration also will be disturbed if the speed of wind at outdoor environment is higher. The higher speed of outdoor will increase PM concentration inside classroom(Agarwal & Shiva Nagendra, 2016).

4.2.3 ANALYSIS ON BK13 PHYSICAL PARAMETER

The Table 4.17 below shows the thermal comfort level of BK13. For the air temperature, only for afternoon and evening session is not satisfied the standard range. But when comparing with condition indicator, the present of occupant had higher air temperature compare to without occupant in lecture room. For the physical parameter of relative humidity, it had shown that all the value obtained for without occupant condition is not satisfied the standard. When comparing to the session of the measurement, the value obtained from morning to evening is decreasing and the value obtained at without occupant condition is higher than with occupant condition. The uncontrolled the value of relative humidity need to be highlighted seems that the improperly controlled relative humidity will effect Sick Building Syndrome like headaches, nausea, irritations of eyes fatigue, rash and others (Yau et al., 2011). For the physical parameter of air velocity, all the value obtained are not satisfied the standard range. These need to be highlighted because of too low air movement may create a sensation of stuffiness (Guide, Indoor, &

Investigations, n.d.). For the value of air velocity obtained at afternoon session showed there is no different. This can be explained but the present of occupant is very low which is only 19 number of occupant.

Table 4.17 The thermal comfort analysis of BK13

Condition	Sessions	Ta (C)	RH (%)	Va (m/s)
Without Occupant	Morning	23.85	79.2	0.03
	Afternoon	20.43	72.23	0.01
	Evening	19.84	71.6	0.01
With Occupant	Afternoon	23.99	69.81	0.01
	Evening	23.96	69.02	0.04

The comparison in dust concentration or particulate matter analysis are shown in Table 4.18. Based on the table above, all the particulate matter of 10µm measurement value are satisfied the standard in all sessions for condition of with occupant and without occupant. While all the particulate matter of 2.5µm is unsatisfied the standard of Malaysian Standard MS1525 2014 and ASHRAE Standard 55.

The comparison between condition showed that the value obtained for both of the condition with occupant and without occupant is reliable in evening session. The value obtained at condition of with occupant is higher than without occupant. But at the afternoon session the value obtained without occupant is slightly higher than with occupant condition. The result obtained is look like unreasonable because the result should be obtained the present of occupant is higher than without occupant.

The data of with occupant condition showed that the condition of with occupant in afternoon session is not so different than evening session and the data of without occupant show that the value is increasing from morning to afternoon and the value obtained at evening session

is not so different with afternoon session. This is happened probably due to the weather also which is at the evening session the weather is so hot.

Table 4.18 The thermal comfort analysis of BK13

Session	Concentration	Dust (mg/m^3)	
		With Occupant	WithoutOccupant
Morning	10µm		0.024
	2.5µm		0.022
Afternoon	10µm	0.028	0.037
	2.5µm	0.029	0.033
Evening	10µm	0.033	0.03
	2.5µm	0.028	0.03

4.2.4 ANALYSIS ON BK17 PHYSICAL PARAMETER

The thermal comfort parameter measurement is taken each one minutes in one hour. Table 4.19 showed that the thermal comfort analysis. The green region represents the acceptable value and the red region is unacceptable value when comparing to ASHRAE Standard 55 and Malaysian Standard MS1525. The value obtained for air temperature showed that the afternoon and evening session got very low temperature and not satisfied the standard. Same goes to the air temperature of evening session with occupant, the temperature got is low and not achieved the standard range. But when comparing with temperature obtained with occupant and without occupant, the present of occupant got high value of air temperature compare to the without occupant. Also from the morning to evening session, the temperature behavior show the decreasing of value obtained.

On other hand, for the physical parameter of relative humidity, the values obtained are all not satisfied the standard range but only at afternoon session with occupant is achieved the standard range. These cases also need to be highlighted seems that the higher humidity can

causes the occupant feel stuffy and can contribute to separation of bacterial and fungal growth (Yau et al., 2011). The relative humidity behavior also shown that the present of occupant is reduce the value of relative humidity. Also from morning to evening session, the relative humidity behavior showed the decreasing of values. But only at evening session of with occupant, the value obtained is not decrease. This can be explained also by the present of occupant is very low which is only 17 occupants. For the physical parameter of air velocity, almost all value obtained are not satisfied the standard except at condition of without occupant in afternoon session and with occupant in evening session.

Table 4.19 The thermal comfort analysis of BK17

Condition	Sessions	Ta (C)	RH (%)	Va (m/s)
Without Occupant	Morning	23.4	78.14	0.04
	Afternoon	22.2	72.33	0.16
	Evening	19.08	73.6	0.12
With Occupant	Morning	23.68	73.65	0.08
	Afternoon	22.73	68.94	0.07
	Evening	21.59	73.57	0.25

The comparison in dust concentration or particulate matter analysis are shown in Table 4.20. According to the table above, all the particulate matter of 10µm measurement value are satisfied the standard in all sessions for condition of with occupant and without occupant. But only in afternoon session, the value obtained is satisfied the Malaysian Standard MS1525 2014 but not unsatisfied the ASHRAE Standard 55. While all the particulate matter of 2.5µm is unsatisfied the standard of Malaysian Standard MS1525 2014 and ASHRAE Standard 55.

The comparison between condition showed that the value obtained for both of the condition with occupant and without occupant is reliable in afternoon and evening session. The value obtained at condition of with occupant is higher than without occupant. For the afternoon

session, the value obtained with occupant is very high compare to others. This can be explained by the activity of occupant. The occupant movement is happened because of during the measurement, the student is attended for quiz. The movement of student because of they move to their friends to find the answer. Research done by Sofia Eirini and others stated that the human activities is affected the dust concentration (Chatoutsidou et al., 2015). But at the morning session the value obtained without occupant and with occupant is not so much different. The data of with occupant show that the value is increasing from morning to afternoon and decrease at evening session. For the without occupant condition the value obtained is not so different with afternoon session.

Table 4.20 The thermal comfort analysis of BK17

Session	Concentration	Dust (mg/m^3)	
		With Occupant	WithoutOccupant
Morning	10µm	0.015	0.016
	2.5µm	0.011	0.016
Afternoon	10µm	0.098	0.018
	2.5µm	0.078	0.017
Evening	10µm	0.024	0.017
	2.5µm	0.024	0.019

4.3 ANALYSIS ON PMV AND PPD INDEX

Predicted Mean Vote (PMV) is refer to thermal scale that listed from hot (+3) to cold (-3). It is originally developed by Fanger and later adopted as an ISO standard. Below are the PMV sensation scale in Table 4.21.

Table 4.21 The PMV sensation scale

Value	Sensation
-3	Cold
-2	Cool
-1	Slightly Cool
0	Neutral
1	Slightly Warm
2	Warm
3	Hot

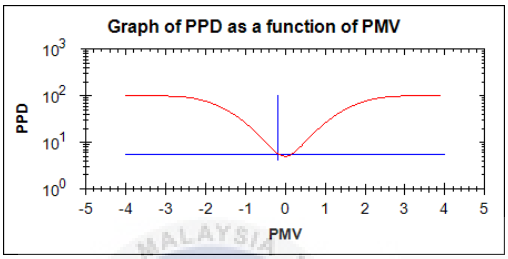
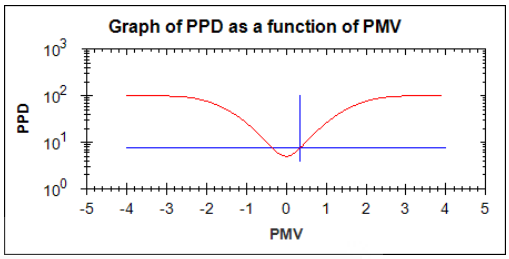
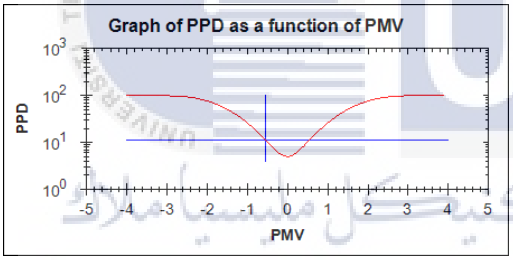
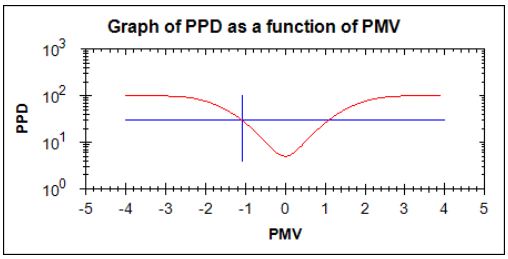
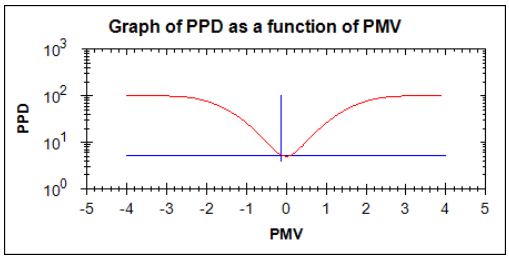
Based on the ASHRAE Standard 55, the recommended range of predicted mean vote is between -0.5 to 0.5 and for predicted percentage of dissatisfied is below 10%. The predicted percentage of dissatisfied is an index that showed the quantitative prediction of dissatisfied occupant on thermal sensation determined from PMV. The limit number of dissatisfied is 100% but it is impossible to please all the people all the time. The PPD is related to PMV and based on assumption of people voting on thermal sensation scale are dissatisfied and on simplification that PPD is symmetric around a neutral PMV.

4.3.1 ANALYSIS ON PMV AND PPD INDEX ON BK10

The graph showed that all the PMV and PPD index is achieved the ASHRAE Standard 55. But only PPD index for afternoon and evening session of without occupant is not achieved the standard. Based on the data obtained, the PMV and PPD index are -0.17, 5.81% (morning), -0.59, 12.34% (afternoon) and -1.07, 29.15% (evening) for without occupant condition. For the condition of with occupant, the PMV and PPD index are 0.35, 8.17% (morning) and -0.13, 5.42% (evening). Most of the PMV index showed that thermal sensation environment is in condition of neutral but only for evening session of without occupant the PMV index is slightly cool. However, the PMV index of all measurement is achieved the standard but only for afternoon and evening session of without occupant is not satisfied the standard. With the present

of occupant, the PMV index is increase. This is showed that the present of occupant is effected the thermal sensation scale. The graph of PMV and PPD index are shown in Table 4.22.

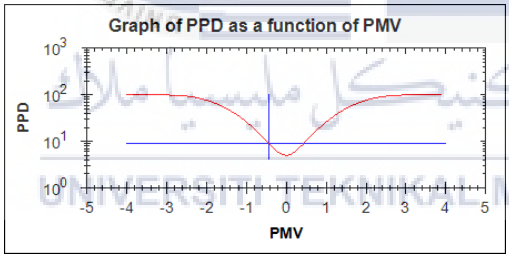
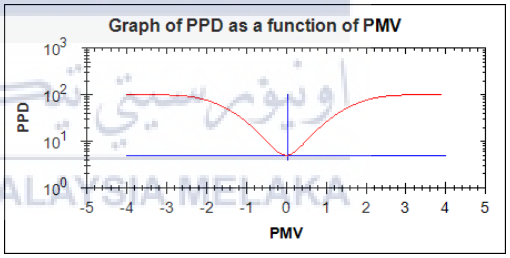
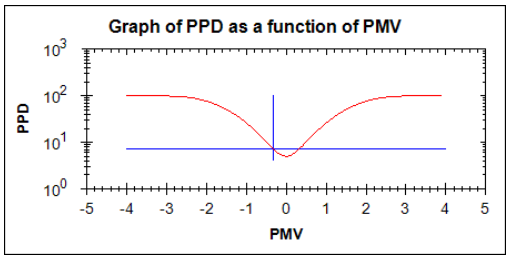
Table 4.22 The graph of PPD against PMV at BK10

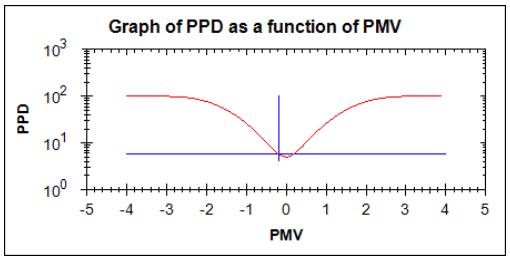
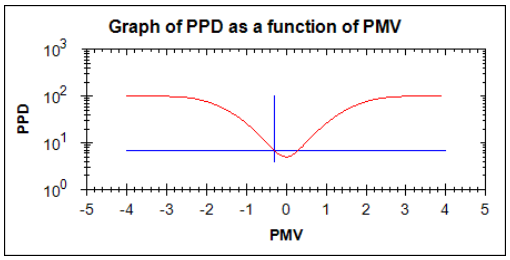
BK10	Without Occupants	With Occupants
Morning		
Afternoon		
Evening		

4.3.2 ANALYSIS ON PMV AND PPD INDEX ON BK12

According to the graph showed in Table 4.23, all the PMV and PPD index is achieved the ASHRAE Standard 55. Based on the data obtained, the PMV and PPD index are -0.43, 9.18% (morning), -0.32, 7.21% (afternoon) and -0.2, 6.02% (evening) for without occupant condition. In other hand, for the condition of with occupant, the PMV and PPD index are -0.01, 5.19% (morning) and -0.34, 7.82% (evening). Almost all of the PMV index showed that thermal sensation environment is in condition of neutral. Hence, the PMV index of all measurement is achieved the standard. With the present of occupant, the PMV index is increase but in the evening session the data of with occupant is increase a little bit value. The data also showed for PPD index also is all satisfied the standard.

Table 4.23 The graph of PPD against PMV at BK12

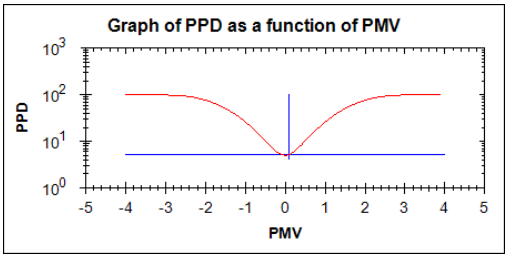
BK12	Without Occupants	With Occupants
Morning		
Afternoon		

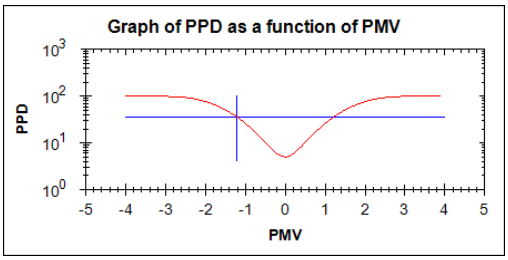
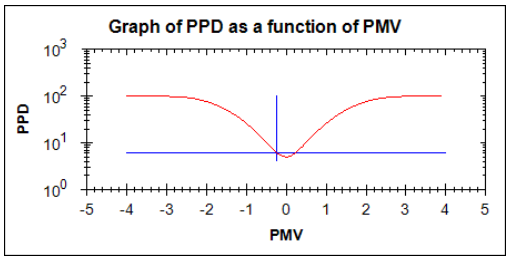
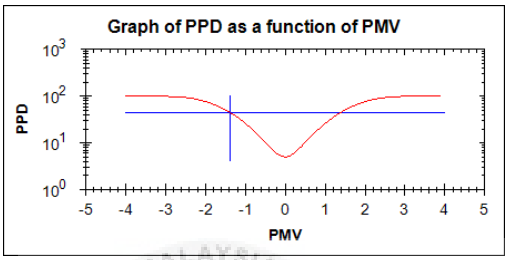
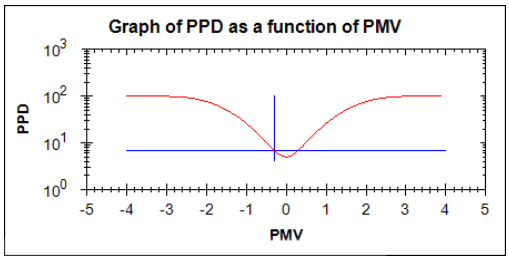
Evening		

4.3.3 ANALYSIS ON PMV AND PPD INDEX ON BK13

For the BK12 PMV and PPD index, the values obtained are, 0.08, 6.88% (morning), -1.2, 35.44% (afternoon) and -1.37, 43.97% (evening) for without occupant condition. In other hand, the values obtained for with occupant condition for PMV and PPD index are -0.25, 6.32% (afternoon) and -0.3, 6.96% (evening). As overall, all the PMV and PPD index obtained are satisfied the standard except afternoon and evening session for without occupant PMV and PPD index are not satisfied the standard. When comparing with occupant and without occupant condition, the PMV index are increasing. This proved that the present of occupant effect the PMV index. The graph of PMV and PPD index are shown in Table 4.24.

Table 4.24 The graph of PPD against PMV at BK13

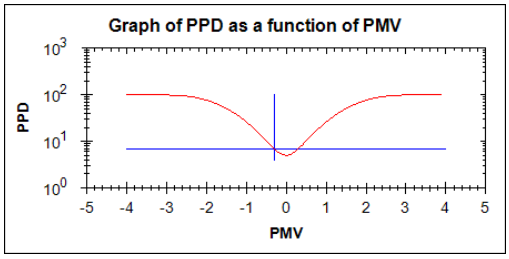
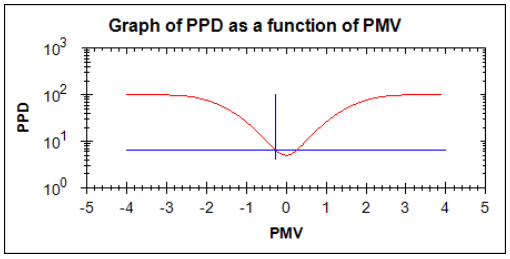
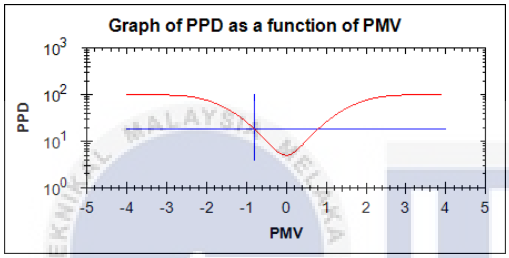
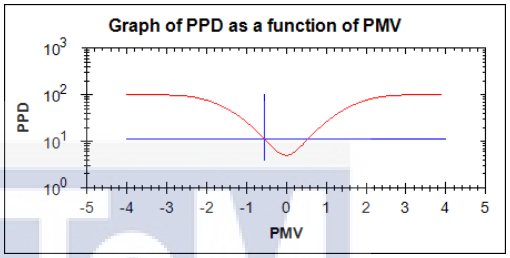
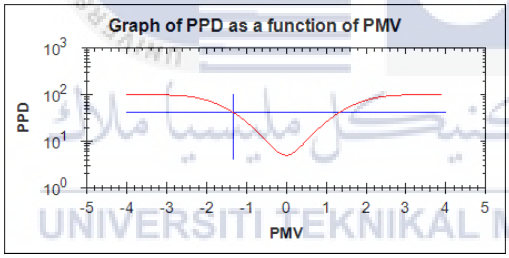
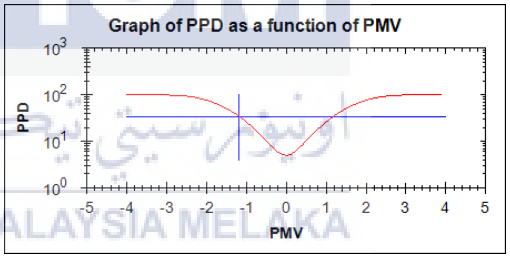
BK13	Without Occupants	With Occupants
Morning		

Afternoon		
Evening		

4.3.4 ANALYSIS ON PMV AND PPD INDEX ON BK17

The graphs showed that only the PMV and PPD index of morning session for with occupant and without occupant is satisfies the ASHRAE Standard 55. Based on the data obtained, the PMV and PPD index of BK17 are -0.3, 7.65% (morning), -0.8, 18.75% (afternoon) and -1.38, 44.4% (evening) for without occupant condition. For the condition of with occupant, the PMV and PPD index are 0.33, 7.33% (morning), -0.6, 12.72% (afternoon) and -1.16, 33.66% (evening). With the present of occupant, the PMV index of BK17 with occupant and without occupant is increase. This is showed that the present of occupant is effected the thermal sensation scale. The graph of PMV and PPD index are shown in Table 4.25.

Table 4.25 The graph of PPD against PMV at BK17

BK17	Without Occupants	With Occupants
Morning		
Afternoon		
Evening		

4.4 SUBJECTIVE ASSESSMENT

A questionnaire has been created in order to survey the occupant satisfaction. The questionnaire had been separated in lecture room based on total occupant have. Based on Table

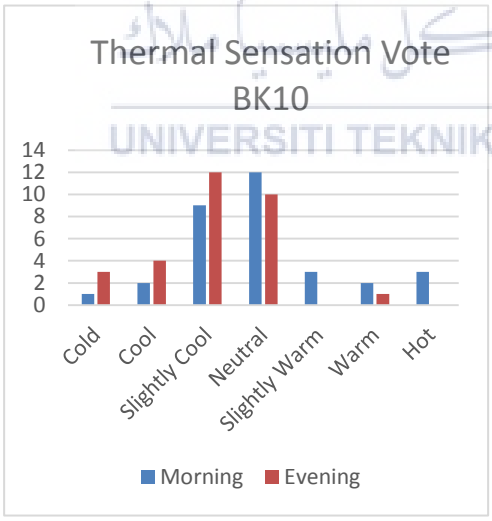
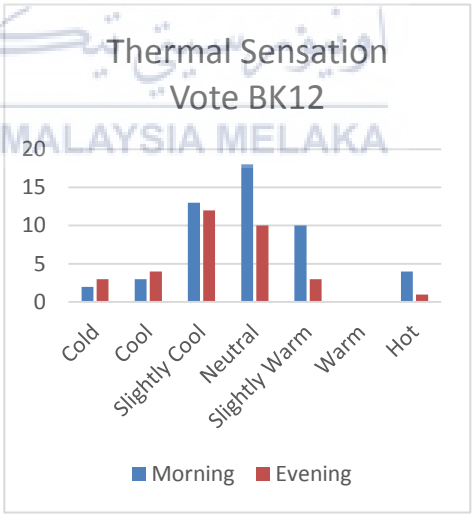
4.26 below, the graph of thermal sensation vote of BK10, BK12, BK13 and BK17 are shown. For BK10, there were 32 total occupants in the morning and 30 total occupants in the evening during lecture sessions. Most of occupant vote for neutral and slightly cool for the thermal sensation for morning session and evening session. As overall the average value of thermal sensation vote is 0 for morning session and -0.9 for evening session. These values obtained are not so far different with Predicted Mean Vote which is -0.13 for morning session but a little bit different with evening session which got 0.35 PMV value. Based on ASHRAE Standard 55, there should be 80% of occupants vote for slightly cool, neutral and slightly warm. For the morning session of BK10, the percentage was got 75% for slightly cool, neutral and slightly warm and for the evening session got 73.3% only. Thus, based on the subjective assessment from occupants, BK10 is not in thermally acceptable condition.

For BK12, there were 50 total occupants in the morning and 33 total occupants in the evening during lecture sessions. Randomly, almost occupant vote for slightly warm, neutral and slightly cool for the thermal sensation for morning session and evening session. The average value of thermal sensation vote is -0.14 for morning session and -0.7 for evening session. These values obtained are not so far different with Predicted Mean Vote which is -0.01 for morning session and evening session which got -0.34 PMV value. For the percentage of voting, in morning session of BK12 the percentage was got 78% for slightly cool, neutral and slightly warm and for the evening session got 75.8% only. Thus, based on the subjective assessment from occupants, BK12 is not in thermally acceptable condition.

For the next lecture room BK13, there were 19 total occupants in the afternoon and 34 total occupants in the evening during lecture sessions. Randomly, almost occupant vote for cool, neutral and slightly cool for the thermal sensation for afternoon session and evening session. The average value of thermal sensation vote is -0.95 for afternoon session and -0.53 for evening session. These values obtained are little bit different with Predicted Mean Vote which is -0.25 for afternoon session and -0.3 PMV value for evening session. For the percentage of voting, in afternoon session of BK13 the percentage was got 73.6% for slightly cool, neutral and slightly warm and for the evening session got 76.5% only. Then, according to the subjective assessment from occupants, BK13 is not in thermally acceptable condition.

For the last lecture room BK17, there were 45 total occupants in the morning, 50 total occupants in the afternoon and 17 total occupants in the evening during lecture sessions. The average value of thermal sensation vote is -1.17 for morning session, -1.72 in the afternoon session and -1.47 for evening session. These values obtained also are quite different with Predicted Mean Vote which is -0.33 for morning session, -0.6 for afternoon session and -1.16 PMV value for evening session. For the percentage of voting, in morning session of BK17 the percentage was got 64.4% for slightly cool, neutral and slightly warm and for the afternoon session got 44% only. And for the evening session, the percentage got 52.9% only. Then, according to the subjective assessment from occupants, BK17 is not in thermally acceptable condition.

Table 4.26 The thermal sensation vote in BK10, BK12, BK13 and BK17

BK10	BK12
	
BK13	BK17

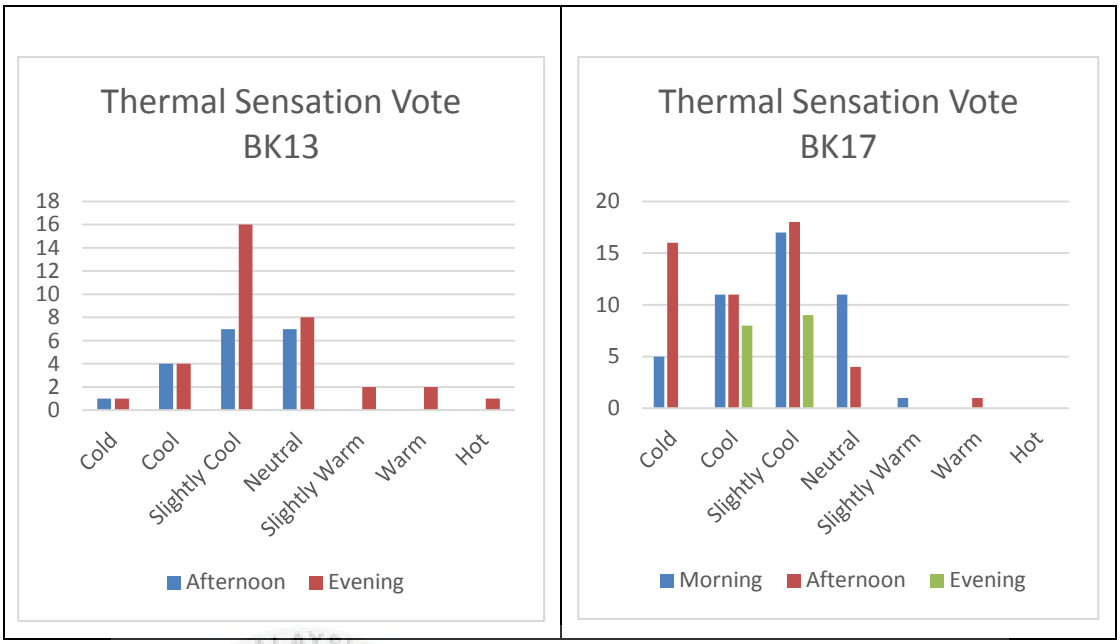
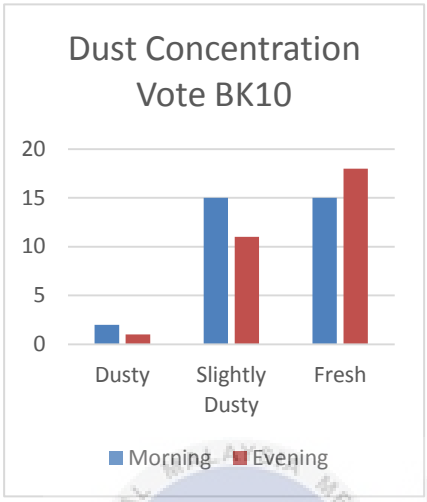
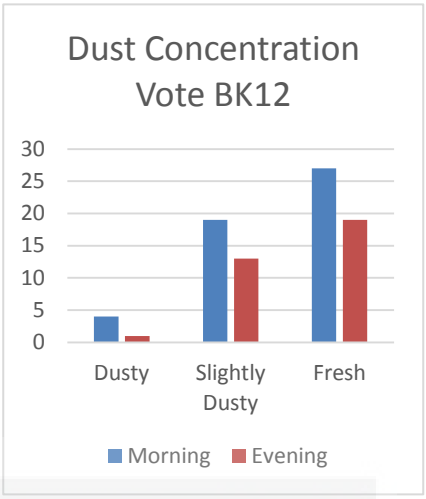
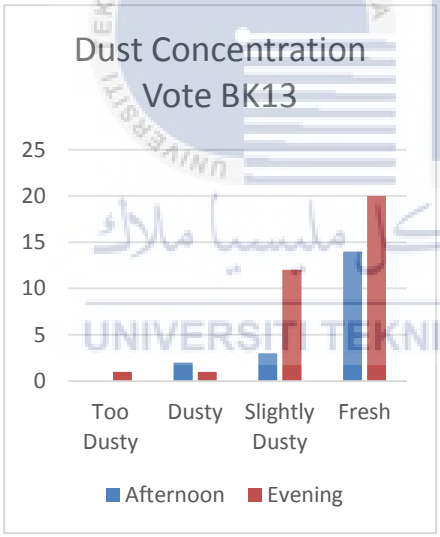
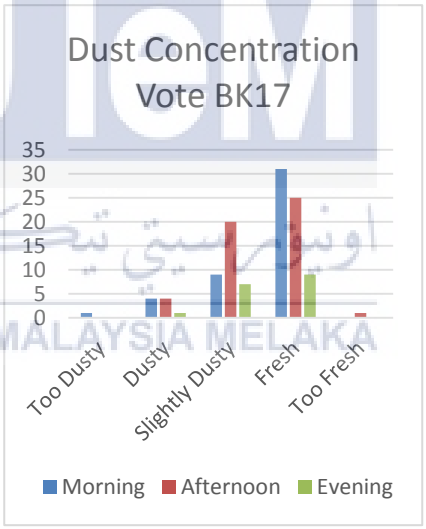


Table 4.27 shows that the graph of dust concentration vote for BK10, BK12, BK13 and BK17. Based on the data obtained there were 15 occupant vote for slightly dust and fresh condition in lecture room for morning session. On other hand, the evening session got most vote on fresh condition compare to the others. Same goes to lecture room of BK12, most of occupants vote for fresh condition of dust concentration for morning session and evening session. The second higher vote was go to slightly dust for BK12 morning and evening session. For the lecture room of BK13, it is also showed the same behavior. The highest vote was go to fresh condition in the afternoon session and evening session. And the last lecture room BK17, also showed the same behavior which is the fresh condition of dust concentration got highest vote for morning, afternoon and evening session.

Table 4.27 The dust concentration vote in BK10, BK12, BK13 and BK17

BK10	With Occupants
	
	

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The purpose for this analysis is to evaluate the current thermal condition of air-conditioned lecture rooms and also to evaluate the current condition of dust level analysis. The selected lecture rooms had been put in this thesis considerations with the perfect condition of lecture room which is the lecture rooms must have air conditioned and no leakage that allow the air to go out. The physical parameters involved in this study are air temperature, relative humidity, air velocity and particulate matter of 10µm and 2.5µm. Then the data obtained is compared to the existed standard which are ASHRAE Standard 55 and Malaysian Standard MS1525 2014.

Overall, for the thermal comfort parameter air temperature, almost all the air temperature obtained in the measurement at lecture rooms of BK10, BK12, BK13 and BK17 is satisfied the ASHRAE Standard 55 and Malaysian Standard MS1525 2014. Only air temperature obtained at BK10 without occupant in evening session, BK13 without occupant in afternoon and evening session, BK17 without occupant in afternoon and evening session, and BK17 with occupant in evening session is not satisfied the standard range. As overall at all lecture rooms, the range of air temperature obtained was 19.08^{o}C to 25.95^{o}C. The relative humidity obtained was in the range of 66.47% to 80.64% in all lecture rooms for both conditions with occupant and without occupant. The result obtained almost all is not satisfied the standard but only certain session at BK10, BK13 and BK17 is satisfied the standard. Meanwhile for the air velocity result, almost all the measurement is not satisfied the standard except for BK10 without occupant in evening

session and BK17 without occupant in afternoon session and with occupant in evening session. The range values obtained was 0m/s to 0.25m/s.

For the dust concentration level analysis, almost all the particulate matter of 10µm satisfied the standard range except the value obtained at BK17 in afternoon session for with occupant condition. The value is satisfied the Malaysian Standard MS1525 2014 but not comply with ASHRAE Standard 55. As overall, the value obtained was in the range of 0.012mg/m^3 to 0.098mg/m^3 for particulate matter of 10µm. Meanwhile, for the particulate matter of 2.5µm, almost all the value obtained at all lecture rooms is not satisfied with standard except the value obtained at BK12 in morning session without occupant and BK17 with occupant in morning session. As average, the value obtained was in range of 0.011mg/m^3 to 0.078mg/m^3. Every building has its own criteria of HVAC system designation, selection of construction material, building orientation and building dimension. This is one part of reason why several physical parameter is not achieved the current standard.

5.2 RECOMMENDATIONS

There are several suggestions to put into considerations for the future analysis.

1. The study on the design and operation of air conditioning system is put into the thermal comfort analysis considerations. The properly designed and operation air conditioning system will keep the relative humidity in good standard. Seems that almost of the result relative humidity is not achieved the standard, the problem that happen to relative humidity can be detected.
2. To solve the problem having at air velocity, the air conditioning design should be increasing the air speed rather than lowering the air temperature and humidity to get the same level of comfort.
3. The outside temperature and wind speed need to be consider for next analysis in thermal comfort study. This is because lower indoor temperature compared to the outdoor

environment can causes accumulation PM in indoor. Also higher wind speed at outside may increase PM concentrations of inside.

4. The study on ventilation of building need to be put into considerations. The ventilation of building either natural or mechanical ventilation is important and has strong impact on particle penetration from outdoor.
5. Raising a little bit on air temperature of indoor area. The increasing of temperature of indoor air will reduce the relative humidity

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APPENDICES

Questionnaire (BK 10)

Thermal Comfort Analysis for Lecture Rooms

Date : _____ Time : _____

1) Gender:
   a) Male b) Female

2) Race:
   a) Malay b) Indian
   c) Chinese b) Others

3) Occupant health condition:
   a) Good b) Normal
   c) Not well d) Sick
   e) Others: _____

4) Choose the type of clothing you are wearing today. If your clothing is not listed below, please write down.

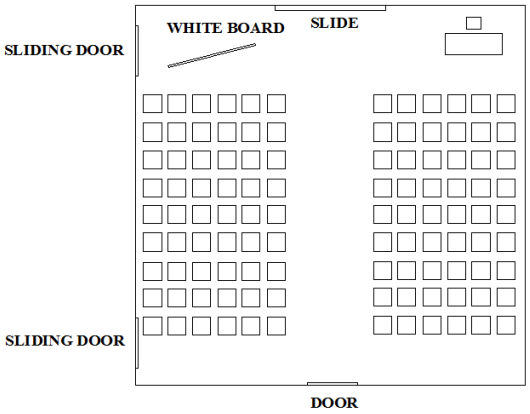
Singlet	( )
T-Shirt collar/non collar	( )
Long sleeve shirt	( )
Short sleeve shirt	( )
Mini skirt	( )
Long skirt	( )
Baju kurung	( )
Shawl	( )
Sweater	( )
Jacket	( )
Trousers	( )
Jeans	( )
Stoking	( )
Shoes	( )
Sandal	( )
Boot	( )

5) Lecture room condition:
   a) Cold b) Cool
   c) Slightly Cool d) Neutral
   e) Slightly Warm f) Warm
   g) Hot

6) Your current activity now:
   a) Reclining b) Seated office
   c) Standing Relaxed

7) Current situation of your lecture room:
   a) Too dusty b) Dusty
   c) Slightly dusty d) Fresh
   e) Too Fresh

8) Randomly write an 'X' the current place you are seating in figure below:



9) Air movement in your surroundings:
   a) Too windy b) Windy
   c) Normal d) Windless
   e) Too windless

Questionnaire (BK 12)

Thermal Comfort Analysis for Lecture Rooms

Date : _____ Time : _____

1) Gender:
   b) Male b) Female

2) Race:
   b) Malay b) Indian

   c) Chinese b) Others

3) Occupant health condition:

   a) Good b) Normal

   c) Not well d) Sick

   e) Others: _____

4) Choose the type of clothing you are wearing today. Choose one only. If your clothing is not listed below, please write down.

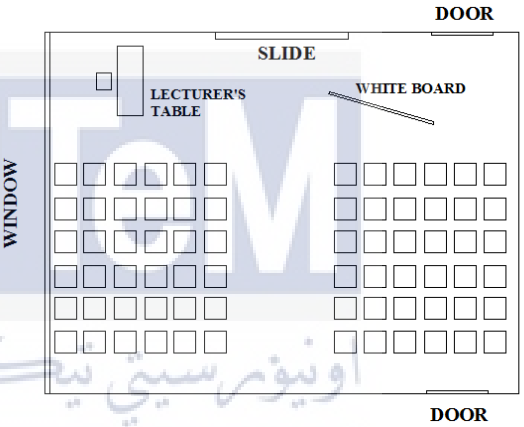
Singlet	( )
T-Shirt collar/non collar	( )
Long sleeve shirt	( )
Short sleeve shirt	( )
Mini skirt	( )
Long skirt	( )
Baju kurung	( )
Shawl	( )
Sweater	( )
Jacket	( )
Trousers	( )
Jeans	( )
Stoking	( )
Shoes	( )
Sandal	( )
Boot	( )

5) Lecture room condition:
   a) Cold b) Cool
   c) Slightly Cool d) Neutral
   e) Slightly Warm f) Warm
   g) Hot

6) Your current activity now:
   a) Reclining b) Seated office
   c) Standing Relaxed

7) Current situation of your lecture room:
   a) Too dusty b) Dusty
   c) Slightly dusty d) Fresh
   e) Too Fresh

8) Randomly write an 'X' the current place you are seating in figure below:



9) Air movement in your surroundings:
   a) Too windy b) Windy
   c) Normal d) Windless
   e) Too windless

Questionnaire (BK 13)

Thermal Comfort Analysis for Lecture Rooms

Date : _____ Time : _____

10) Gender:
c) Male b) Female

11) Race:
c) Malay b) Indian

c) Chinese b) Others

12) Occupant health condition:

a) Good b) Normal

c) Not well d) Sick

e) Others: _____

13) Choose the type of clothing you are wearing today. If your clothing is not listed below, please write down.

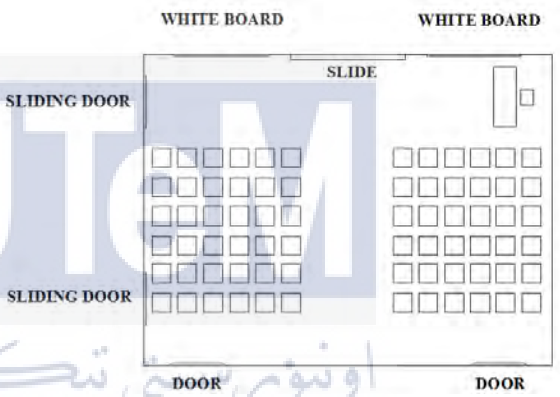
Singlet	( )
T-Shirt collar/non collar	( )
Long sleeve shirt	( )
Short sleeve shirt	( )
Mini skirt	( )
Long skirt	( )
Baju kurung	( )
Shawl	( )
Sweater	( )
Jacket	( )
Trousers	( )
Jeans	( )
Stoking	( )
Shoes	( )
Sandal	( )
Boot	( )

14) Lecture room condition:
a) Cold b) Cool
c) Slightly Cool d) Neutral
e) Slightly Warm f) Warm
g) Hot

15) Your current activity now:
a) Reclining b) Seated office
c) Standing Relaxed

16) Current situation of your lecture room:
a) Too dusty b) Dusty
c) Slightly dusty d) Fresh
e) Too Fresh

17) Randomly write an 'X' the current place you are seating in figure below:



18) Air movement in your surroundings:
a) Too windy b) Windy
c) Normal d) Windless
e) Too windless

Questionnaire (BK 17)

Thermal Comfort Analysis for Lecture Rooms

Date : _____ Time : _____

19) Gender:
d) Male b) Female

20) Race:
d) Malay b) Indian

c) Chinese b) Others

21) Occupant health condition:

a) Good b) Normal

c) Not well d) Sick

e) Others: _____

22) Choose the type of clothing you are wearing today. Choose one only. If your clothing is not listed below, please write down.

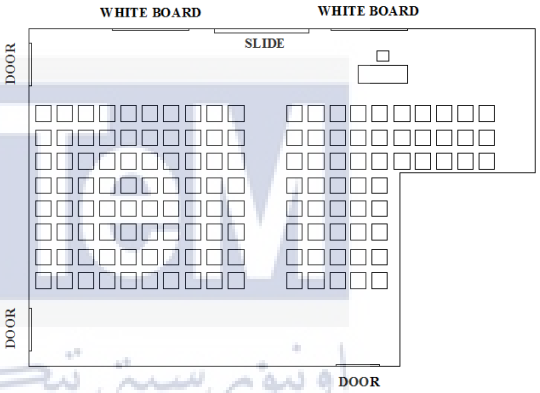
Singlet	( )
T-Shirt collar/non collar	( )
Long sleeve shirt	( )
Short sleeve shirt	( )
Mini skirt	( )
Long skirt	( )
Baju kurung	( )
Shawl	( )
Sweater	( )
Jacket	( )
Trousers	( )
Jeans	( )
Stoking	( )
Shoes	( )
Sandal	( )
Boot	( )

23) Lecture room condition:
a) Cold b) Cool
c) Slightly Cool d) Neutral
e) Slightly Warm f) Warm
g) Hot

24) Your current activity now:
a) Reclining b) Seated office
c) Standing Relaxed

25) Current situation of your lecture room:
a) Too dusty b) Dusty
c) Slightly dusty d) Fresh
e) Too Fresh

26) Randomly write an 'X' the current place you are seating in figure below:



27) Air movement in your surroundings:
a) Too windy b) Windy
c) Normal d) Windless
e) Too windless