Lesson 01

Title of the Experiment: Measurement of meteorological parameters/variables which are affecting biosystems

(Activity number of the GCE Advanced Level practical Guide – 01)

Name and affiliation of the author:
Dr (Mrs) V P A Weerasinghe
Department of Zoology and Environmental Management, University of Kelaniya

Introduction

Meteorological observations are made for a variety of reasons. They are used for the real-time preparation of weather analyses, forecasts and severe weather warnings, for the study of climate, for local weather dependent operations (for example, flying operations, construction work on land and at sea), for hydrology (runoff estimation) and agricultural meteorology, and for research in meteorology and climatology. Precisely located, properly established meteorological stations observe all kinds of meteorological parameters using automatic/non automatic instruments for different purposes as mentioned above. The World Meteorology Organization (WMO) coordinates with the whole world to get meteorological parameters at the same time of the day using similar techniques. Table 1 shows main meteorological parameters and instruments for measuring them.

Table 1: Meteorological parameters and instruments

Meteorological parameter	Instrument
01. Wind direction	Wind vane
02. Wind speed	Anemometer
03. Pressure	Barometer, Barograph
04. Temperature	Thermometer, Thermograph Maximum-Minimum thermometer
05. Relative humidity	Wet and dry thermometer, Hygrograph
06. Rainfall	Rain gauge (recording and non- recording)
07. Sunshine	Sunshine recorder
08. Solar radiation	Actinograph, Pyrenometer
09. Evaporation	Evaporation gauge

Other than ground observation stations, ocean/sea observation stations and remote sensing techniques such as radar and other weather satellites are used to obtain weather parameters at different levels of the atmosphere.

Although there are many meteorological parameters such as rainfall, atmospheric temperature, relative humidity, solar intensity, atmospheric pressure, etc. affecting the bio-systems, in this practical, rainfall, temperature, and relative humidity are considered to be measured.

Rainfall measurements using non-recording type rain gauge

A rain gauge is also known as a udometer, pluviometer, or an ombrometer. It is a type of instrument used by meteorologists and hydrologists to gather and measure the amount of liquid precipitation over a set period of time.

There are many different types of rain gauges. Mainly non-recording type rain gauges and recording type rain gauges. Rainfall measurements are particularly sensitive to exposure, wind and topography. The total amount of precipitation which reaches the ground in a stated period is expressed in terms of vertical depth of water to which it would cover a horizontal projection of the Earth’s surface.

The unit of rainfall is linear depth, usually in millimeters. The rate of rainfall (intensity) is similarly expressed in linear measures per unit time, usually millimeters per hour.

Theory:

The commonly used non-recording type rain gauge consists of a collector placed above a funnel leading into a container where the accumulated water is stored between observation times. Different gauge shapes are in use worldwide as shown in Figure 1.

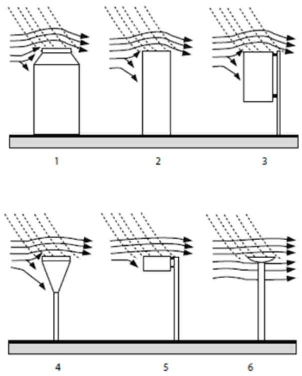

Figure 1: Different shapes of standard non recording type of rain gauges. Dash lines represent the rainfall and solid lines represent stream line.

Non-recording gauges usually consist of a collector above a funnel which passes collected rain into a receiving vessel. Important requirements are that the collector walls should be vertical inside and steeply beveled outside. It should prevent rain splashing in or out by having a sufficiently deep wall and a funnel with steep sides (at least 45 degrees). The area of orifices should be consistent. The receiving vessel should have a narrow neck (to prevent evaporation losses). It is usual to use a larger vessel in the same gauge, where it is impractical to visit the gauge on a daily basis. Figure 02 shows the different parts of the non- recording type of rain gauges.

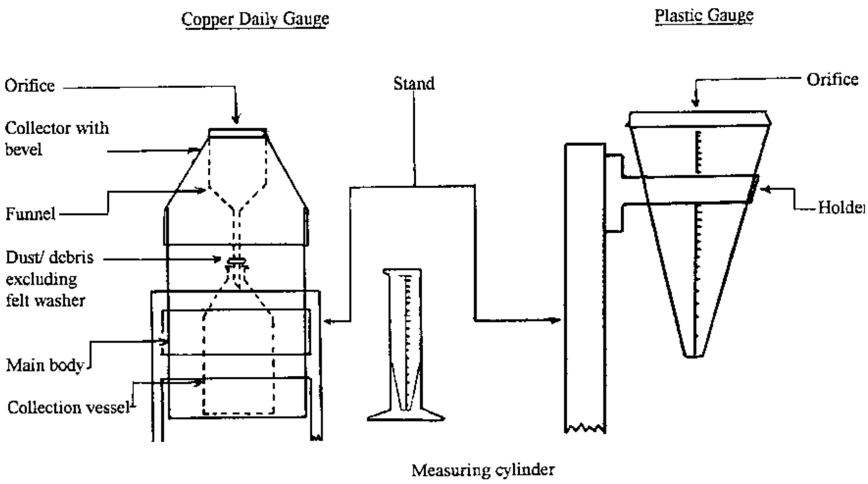

Figure 2: Parts of the non-recording type of rain gauges

The standard US Weather Bureau non-recording gauge has an 8 inch (20.3 cm) orifice, the UK standard gauge (commonly adopted by former colonies) has a 5 inch (12.7 cm) opening. There is little to choose in design accuracy, but in general, smaller gauges tend to be less expensive.

Installation of non-recording type rain gauge:

The location of the gauge is the primary consideration in obtaining accurate rainfall measurements and the most serious problem is wind turbulence. Buildings, trees, fences produce eddies and reduce accuracy. Isolated obstructions should not be closer than twice their height to the gauge (further away if possible). Sloping ground should be avoided and surrounding vegetation should be cut low. In general, smooth artificial surfaces are not suitable as they tend to cause splashing and may attain high surface temperatures. It is important to provide an enclosure for the rain gauge to reduce the risk of damage from animals and to prevent interference with normal land use.

Learning outcomes:

At the end of the practical, student will be able to;

- describe important parts of the non-recording type rain gauge with respect to precise observations
- use the non-recording type rain gauge for rain fall measurements
- analyze collected rainfall data

Materials/Equipment:

Non-recording type rain gauge

Measuring cylinder

Graph papers

Methodology/Procedure:

- Identify the parts of the non- recording type rain gauge and their usage.
- Install the rain gauge in a proper place with permission
- Take measurements at 8.30 am every day using a standard measuring cylinder with height in mm.
- Record the reading in the table (Table 2)
- Calculate monthly and yearly rainfall

Readings/Observations:

(If necessary, please include relevant tables with appropriate headings)

Table 2: Daily rainfall measurements of non- recoding type rain gauge

Month	Date	Time	Daily rainfall (mm)	Remarks
	1	8.30 am		Sunny day
	2	8.35 am		Grass cut
	3	8.25 am		Clean the vessel

Diagrams/Graphs: (If necessary, please attach blank graph papers/pages)

Represent the monthly rainfall data using a bar chart. (Computer based calculation software can be used.)

Calculations:

Average Monthly rainfall is calculated by using the following equation (Eq.01)

$$Average\ Monthly\ rainfall = \frac{sum\ of\ daily\ rainfall\ for\ the\ month}{number\ of\ days\ in\ the\ month} \qquad \text{Eq.01}$$

If a measuring cylinder is not available to measure the rainfall, following steps need to be followed.

- Measure the volume of the water collected in the vessel
- Measure the radius of the funnel
- Calculate the height of the water using equation 02.

$$\pi r^2 h = V \qquad \text{Eq.02}$$

$$\boldsymbol{h} = \frac{\boldsymbol{V}}{\pi r^2}$$

Discussions:

- Discuss monthly rainfall pattern with respect to the location of the rain gauge in Sri Lanka.
- Observe the maximum and minimum monthly rainfall in the area.
- Search extreme rainfall events by referring to past monthly average rainfall values of the area.
- Relate the rainfall pattern with S-W monsoon and N-E monsoon or inter monsoon rainfall for the particular area where measurements were conducted.

Conclusions:

- Shape of the orifice of non-recording type rain gauge is not affecting the depth of the rainfall.
- Rainfall depth and the rainfall intensity of the area for the particular duration of the year

References:

Guide to Meteorological instruments & Methods of observation, World Meteorological Organization, WMO-NO.8

S. Miller, Handbook for agrohydrology, (1994) Natural Resources Institute, UK.

Rainfall measurements using recording type rain gauge

Recording type rain gauge has the advantage that it can provide better time resolution than manual measurements, and it is possible to reduce the evaporation and wetting losses. But the readings are of course subject to the wind effect. Three types of automatic recording type of rain gauges are in use, namely the weighing type (Figure 3), tilting or tipping bucket type (Figure 4) and the float (or syphon) type (Figure 5). Recent advances have led to the use of electronic loggers which now frequently replace the usual chart and pen clockwork systems. Since there are many different mechanisms in recording type rain gauges, the manufacturer's manual must be followed carefully for better usage.

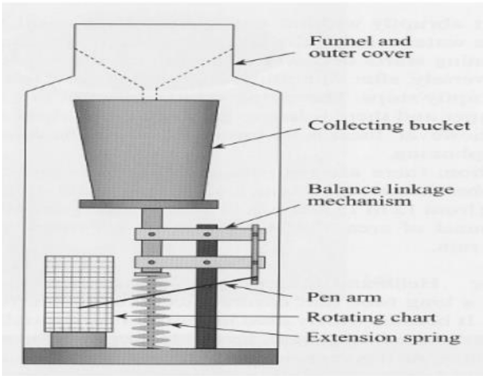

Figure 3: Weighing type rain gauge

Weighing type rain gauge: This type is especially useful where snow is frequently experienced. Precipitation is collected from a funnel into a bucket which, as the frame upon which it stands falls with increasing collection, stretches an isoelastic spring. The movement of the frame is proportional to precipitation and linked to a pen by a series of levers. This records on a clock-driven drum chart.

Floating type rain gauge: Rain is collected and falls into chamber A, and raises float B. In response, the pen moves upward and its trace is recorded on the chart fixed to the drum, H. The chamber is on a pivot (C), over-balances when full and empties through the syphon tube (D). The pen is then reset to the zero position while lifted clear of the chart by the rod G. The over- balancing is controlled by the trip, E and the chamber is restored to its original position by F, the counterweight. The siphoning takes approximately 15 seconds.

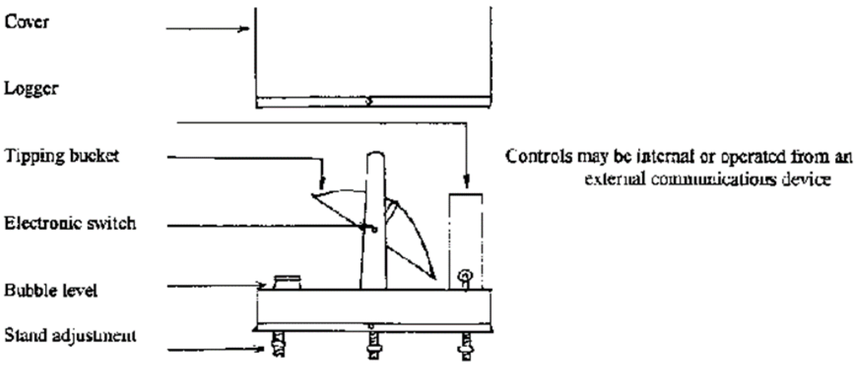

Figure 4: Tipping bucket type rain gauge

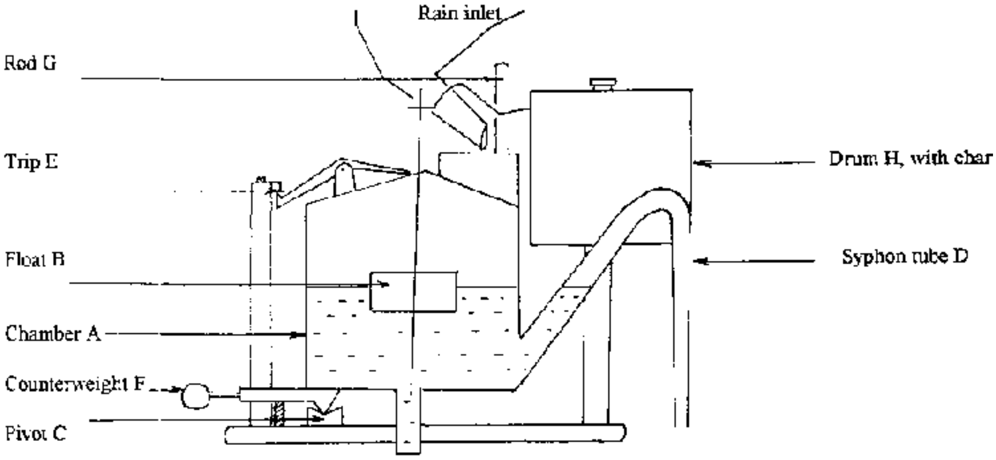

Figure 5: Floating type rain gauge

Theory:

The tipping-bucket rain gauge is used for measuring accumulated totals and the rate of rainfall. The principle behind the operation of this instrument is simple.

A dual tipping bucket pivots on a horizontal axis which lies beneath the funnel of the orifice, such that only one bucket receives rainfall at a time. When filled the bucket tips and is emptied, leaving the second bucket to receive rain. Tips are recorded electronically and individually as pulses. The main requirement of the rain gauge is to have an instrument to record pulses. Figure 7 shows an electrical switch (Reed switch) to generate pulses. The duration between each pulse on the record represents the time taken for a specified small amount of rain to fall. Alternatively, the data may be recorded on a mechanically driven chart (Figure 6). Closer view of the recoding graph shows in Figure 7. Horizontal line represent the duration of no rainfall.

In general the tipping mechanism works well, but sometimes does not register very light rain in hot climates. It may also under-register during very intense storms, because of the finite time taken for the buckets to exchange positions. Therefore it does not meet required accuracy. Tipping rate can be changed according to the rainfall intensity. Here also same precautions has to be made to prevent from wetting surfaces and evaporation and the wind.

There can be electronic data logger type to record continuous data. Then the data are downloaded and analyzed using computer software. There are many advantages like automatic data recording for a long period and easy download etc. But the main disadvantage is if something goes wrong with the data logger, all data will be lost and it is expensive with a computer and other computer peripherals.

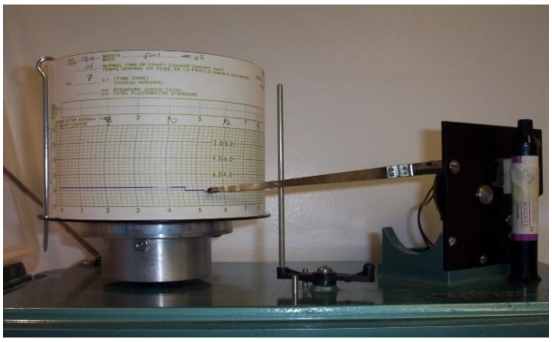

Figure 6: Mechanically driven drum in tipping bucket rain gauge

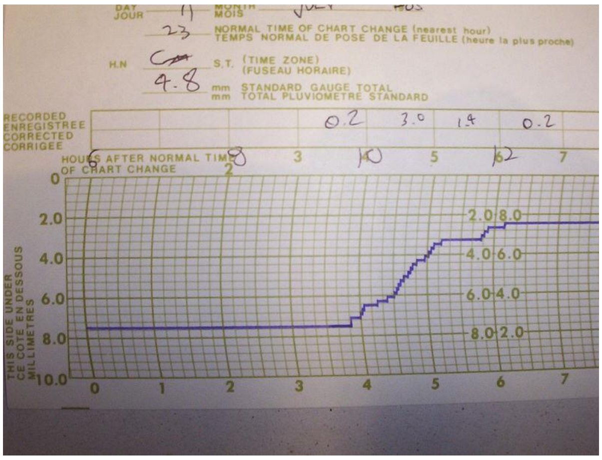

Figure 7: Closer view of the mechanically driven tipping bucket graph

Maintenance of the tipping bucket for precise observation is essential. Eg: Cleanliness and efficient working of tipping buckets (oiling) and switch, installation place and position etc.

Learning outcomes:

At the end of the practical session, student will be able to;

- be familiar with the parts of tipping bucket type of recoding rain gauge
- be familiar with the rainfall recording mechanism of the tipping bucket
- calculate rainfall intensity for a rainfall event

Materials/Equipment:

- Tipping bucket recording type rain gauge
- Graph sheets (if necessary)

Methodology/Procedure:

- Identify the parts of tipping bucket type rain gauge (if possible use manufacturer's manual)
- Find the volume of each tipping bucket
- Install the tipping bucket at a suitable place with proper permission.
- Take measurements at 8.30 am every day using available recoding instrument
- Observations has to be continue at least 6-8 months
- Calculate monthly rainfall

Readings/Observations:

(If necessary, please include relevant tables with appropriate headings)

- Record the number of pulses in a Table (Table 3)
- Calculate daily rainfall using number of pulses.

Table 3: Daily rainfall measurements of tipping bucket type rain gauge

Month	Date	Time	No. of Pulses	Volume of rainfall (cm^3)	Remarks
	1				
	2				
	3				

Diagrams/Graphs:

- Plot a bar graph for monthly rainfall values.

Calculations:

- Calculate the total daily rainfall using number or pulses or any recoding instrument.

Discussions:

- Compare it with non-recoding type rain gauge rainfall measurements
- Discuss the monthly rainfall pattern with respect to the area

Conclusions:

- Monthly mean rainfall of the area.
- Rainfall intensity for rainfall events if mechanical recoding is available.

References:

Guide to Meteorological instruments & Methods of observation, World Meteorological Organization, WMO-NO.8

S. Miller, Handbook for agrohydrology, (1994) Natural Resources Institute, UK.

Atmospheric Temperature Measurement

Temperature is characterized by the behavior whereby two bodies in thermal contact tend to become an equal temperature. Thus, temperature represents the thermodynamic state of a body, and its value is determined by the direction of the net flow of heat between two bodies. In such a system, the body which overall loses heat to the other is said to be at the higher temperature. For meteorological purposes, temperatures are measured for a number of media. The most common variable measured is air temperature (at various heights). Other variables are ground, soil and seawater temperature. These measurements are required, either jointly or independently and locally or globally, for input to numerical weather prediction models, for hydrological and agricultural purposes, and as indicators of climatic variability. Local temperature also has direct physiological significance for the day-to-day activities of the world's population and other bio-systems. For routine observations of air temperature, including maximum, minimum and wet-bulb temperatures, liquid-in-glass thermometers are still commonly used. There are other types: Bimetallic thermographs connected with a clock driven drum (Figure 8) or bimetallic thermometers with digital display of temperature (Figure 9). Temperature changes will draw on the graph paper which is connected to a drum. There are many other methods to measure temperature at the upper atmosphere namely satellite images, weather balloons with different thermo sensors etc.

In order to ensure that the thermometer is at true air temperature it is necessary to protect the thermometer from radiation by a screen or shield that also serves to support the thermometer. This screen also shelters it from precipitation while allowing the free circulation. Stevenson screen provides good air circulation for the thermometers and hydrometers (Figure 10).

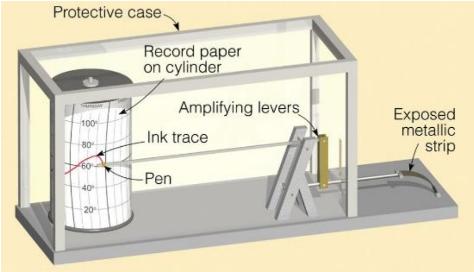

Figure 8: Bimetalic thermograph

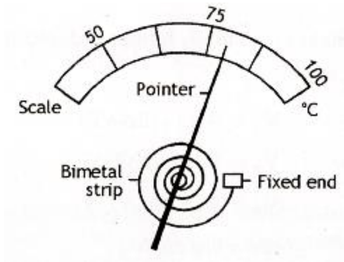

Figure 9: Bimetalic thermometer

Figure 10: Stevenson screen

Theory: Ordinary thermometer

This is the most accurate instrument of all meteorological thermometers. Usually it is a mercury-in-glass-type thermometer (Figure 11). Its scale markings have an increment of 0.2 K or 0.5 K, and the scale is longer than that of the other meteorological thermometers. The ordinary thermometer is used in a thermometer screen to avoid radiation errors. A support keeps it in a vertical position with the bulb at the lower end. The form of the bulb is that of a cylinder or an onion shape.

Maximum and Minimum thermometer

The recommended type for maximum thermometers is a mercury-in-glass thermometer with a constriction in the bore between the bulb and the beginning of the scale. This constriction prevents the mercury column from receding with falling temperatures. However, observers can reset by holding it firmly, bulb-end downwards, and swinging their arm until the mercury column is reunited. A maximum thermometer should be mounted at an angle of about 2° from the horizontal position, with the bulb at the lower end to ensure that the mercury column rests against the constriction without gravity forcing it to pass.

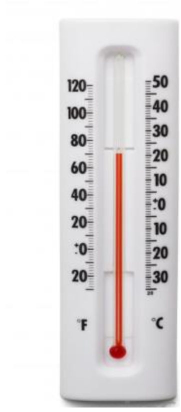

Figure 11: Mercury-in-glass-type thermometer

Minimum thermometer is a spirit thermometer which should be supported in a similar manner to maximum thermometers, in a near-horizontal position. Various liquids can be used in minimum thermometers, such as ethyl alcohol, pentane and toluol. As the air temperature falls, the index is dragged by the surface tension of the spirit and moves toward the bulb with the top of the column. When the temperature rises, the index is left in position because the spirit flows through it. As a result, it remains in the column indicating the minimum temperature. After measurement, the column is inclined while keeping the bulb higher than the head, and the index is gradually slid back to the top of the column. If the index is steel, magnet can be used to replace it. Maximum-Minimum thermometer shows in Figure 12. WMO recommends to measure atmospheric temperature at the height from 1.25 to 2m above ground at a representative location of region, as standard.

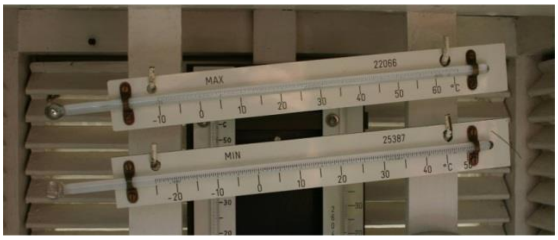

Figure 12: Maximum-Minimum thermometer

Learning outcomes:

At the end of the practical session, student will be able to;

- understand the importance of the temperature for the bio-system function
- use normal and maximum-minimum temperature for atmospheric temperature measurement in an appropriate way
- calculate average monthly temperature for the area
- plot monthly average temperature values

Materials/Equipment:

- Ordinary type mercury in glass thermometer
- Maximum-Minimum thermometer
- A magnet
- Stevenson screen
- Graph papers

Methodology/Procedure:

- Identify the parts of the given thermometers
- Install the thermometers in Stevenson screen in proper manner
- Place indicator/index in the proper place in minimum thermometer every day after taking measurements
- Take observations at 8.30 am every day for at least 06 months
- Record the observations in the table (Table 4)
- Calculate mean monthly temperature with ordinary type thermometer and Maximum-Minimum thermometer (Eq.04)
- Plot mean monthly temperature values (Eq.03)

Readings/Observations: (If necessary, please include relevant tables with appropriate headings)

Table 4: Daily temperature measurements

Month	Date	Time	Temp.°C (ordinary type)	Temp.°C (Maximum)	Temp.°C (Minimum)	Daily average temperature
	1	8.35 am				
	2	8.25 am				
	3	8.40 am				

Diagrams/Graphs: (If necessary, please attach blank graph papers/pages)

- Plot mean monthly temperature values (Y axis-Average monthly mean temperature°C, X axis-Month)

Calculations:

$$Monthly\ mean\ temperature = \frac{sum\ of\ the\ temperature\ values\ in\ days}{number\ of\ days\ in\ the\ month} \qquad \text{Eq 03}$$

$$Daily\ mean\ temperature = \frac{Maximum\ temperature + Minimum\ temperature}{2} \qquad \text{Eq 04}$$

Discussions:

- Compare monthly mean temperature values with past temperature data of the area
- Explain how the installation procedure affects the measurements of temperature
- Explain monthly mean temperature values in relation to the bio-system functions

Conclusions:

- Monthly mean temperature values from two different thermometers.

References:

Guide to Meteorological instruments & Methods of observation, World Meteorological Organization, WMO-NO.8

Relative humidity measurements using wet and dry bulb thermometer

Humidity measurements at the Earth's surface are required for meteorological analysis and forecasting, for climate studies, and for many special applications in hydrology, agriculture, aeronautical services and environmental studies, in general. They are particularly important because of their relevance to the changes of state of water in the atmosphere. Relative humidity is one of the humidity measurements of the atmosphere. The Instrument which measures relative humidity is called a hygrometer or Psychrometer. According to the differences of working principle, there can be different instrument. Eg: Hair hygrometer, optical hygrometer, electrolytic hygrometer, whirling psychrometer etc.

Theory: Wet and Dry bulb thermometer

Figure 13 shows a wet and dry bulb thermometer.

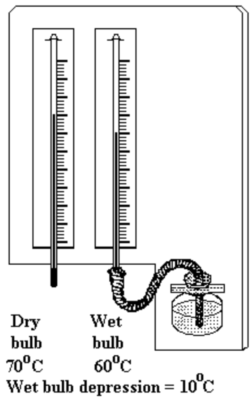

Figure 13: Diagram of the wet and dry bulb thermometer

Dry bulb thermometer: The Dry Bulb temperature, usually referred to as air temperature, is the air property that is most commonly used. Dry-bulb temperature can be measured using a normal thermometer freely exposed to the air but shielded from radiation and moisture. The temperature is usually given in degrees Celsius (^oC) or degrees Fahrenheit (^oF). The SI unit is Kelvin (K). Zero Kelvin equals to -273^oC.

Wet bulb thermometer: Wet Bulb temperature can be measured by using a thermometer with the bulb wrapped in wet muslin. The adiabatic evaporation of water from the thermometer and the cooling effect is indicated by a "wet bulb temperature" lower than the "dry bulb temperature" in the air. The rate of evaporation from the wet bandage on the bulb, and the temperature difference between the dry bulb and wet bulb, depends on the humidity of the air. By using the relative humidity chart, atmospheric relative humidity can be found with dry bulb temperature (^oC) and drop of the wet bulb temperature.

Learning outcomes:

At the end of this practical session, student will be able to;

- Understand the importance of relative humidity of the atmosphere for the bio-systems
- Explain the working principle of the wet and dry bulb thermometer
- Use the wet and dry bulb thermometer relative humidity chart to get the relative humidity value for the atmosphere.
- Maintain wet and dry bulb thermometer for a long time to get accurate measurements of relative humidity of the atmosphere

Materials/Equipment:

- Wet and dry bulb thermometer
- Wet and dry bulb thermometer relative humidity chart

Methodology/Procedure:

- Identify the parts of wet and dry bulb thermometer
- Install the instrument properly in Stevenson screen
- Take measurements two times at 8.30 am and 15.30 pm daily
- Record the readings in the table (Table 5)
- Find the relative humidity value using dry bulb temperature and drop of the wet bulb thermometer temperature values and the relative humidity chart.

Readings/Observations: (If necessary, please include relevant tables with appropriate headings)

Table 5: Daily wet and dry bulb temperature measurements

Month	Date	Time	Wet bulb temperature (°C) (A)	Dry bulb temperature (°C) (B)	Drop of the wet bulb temperature (B-A)	Relative humidity (using chart)	Remarks
	1	8.30 am					
	1	15.30 pm					

Diagrams/Graphs: (If necessary, please attach blank graph papers/pages)

Wet and dry bulb thermometer relative humidity chart (provide by manufacturer or given chart with the manual-Table 6).

Calculations:

Using observations of wet and dry bulb thermometers and the relative humidity chart, atmospheric Relative Humidity (RH %) can be derived.

Discussions:

- Importance of using Stevenson screen for wet and dry bulb thermometer
- RH% changes in morning and afternoon in your area
- How RH% changes in dry zone, wet zone and intermediate zone in Sri Lanka

Conclusions:

- RH % of your area

References:

Guide to Meteorological instruments & Methods of observation, World Meteorological Organization, WMO-NO.8

Table 6: Wet and dry bulb thermometer relative humidity chart

B \ B-A	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0
50	97	94	92	89	87	84	83	79	77	74	72	70	68	56	63	61
49	97	94	92	89	86	84	81	79	77	74	72	70	67	65	63	61
48	97	94	92	89	86	84	81	79	76	74	71	69	67	63	62	60
47	97	94	92	89	86	83	81	78	76	73	71	69	66	64	62	60
46	97	94	91	89	83	83	81	78	76	73	71	68	66	64	62	59
45	97	94	91	88	86	83	80	78	75	73	70	68	66	63	61	59
44	97	94	91	88	86	83	80	78	75	72	70	68	65	63	61	58
43	97	97	91	88	85	83	80	77	75	72	70	67	65	62	60	58
42	97	94	91	88	85	82	80	77	74	72	69	67	64	62	59	57
41	97	94	91	88	85	82	79	77	74	71	69	66	61	61	59	56
40	97	94	91	88	85	82	79	76	73	71	68	66	63	61	58	56
39	97	94	91	87	84	82	79	76	73	70	68	65	63	60	58	55
38	97	94	90	87	84	81	78	76	73	70	67	65	62	59	57	54
37	97	93	90	87	84	81	78	75	72	69	67	64	61	59	55	54
36	97	93	90	87	84	81	78	75	72	69	66	63	61	58	55	53
35	97	93	90	87	83	80	77	74	71	68	65	63	60	57	55	52
34	96	93	90	86	83	80	77	74	71	68	65	62	59	56	54	51
33	96	93	89	86	83	80	76	73	70	67	64	61	58	56	53	50
32	96	93	89	86	83	79	76	73	70	67	64	61	58	55	52	49
31	96	93	89	86	82	79	75	72	69	66	63	60	57	54	51	48
30	96	93	89	85	82	78	75	72	68	65	62	59	56	53	50	47
29	96	92	89	85	81	78	74	71	68	65	61	58	55	52	49	48
28	96	92	88	85	81	77	74	70	67	64	60	57	54	51	48	45
27	96	92	88	84	81	77	73	70	66	63	60	56	53	50	47	44
26	96	92	88	84	80	76	73	69	66	62	59	55	52	49	45	42
25	96	92	88	84	80	76	72	68	65	61	58	54	51	47	44	41
24	96	91	87	83	79	75	71	68	64	60	57	53	50	46	43	39
23	96	91	87	83	79	75	71	67	63	59	56	52	48	45	41	38
22	95	91	87	82	78	74	70	66	62	58	54	51	47	43	40	36
21	95	91	86	82	78	73	69	65	61	57	53	49	45	42	38	35
20	95	91	86	81	77	73	68	64	60	56	52	48	44	40	36	33
19	95	90	86	81	76	72	67	63	59	55	50	46	42	38	34	31
18	95	90	85	80	76	71	66	62	58	53	49	45	41	36	32	29
17	95	90	85	80	75	70	65	61	56	52	47	43	39	34	30	26
16	95	89	84	79	74	69	64	60	55	50	46	41	37	32	28	24
15	94	89	84	78	73	68	63	58	53	49	44	39	35	30	26	21
14	94	89	83	78	72	67	62	57	52	47	42	37	32	28	23	18
13	94	88	83	77	71	66	61	55	50	45	40	35	30	25	20	16
12	94	88	82	76	70	65	59	54	48	43	38	32	27	22	17	12
11	94	87	81	75	69	63	58	52	46	41	35	30	25	19	14	9
10	93	87	81	74	68	62	56	50	44	38	33	27	22	16	11	5
9	93	86	80	73	67	61	54	48	42	36	30	24	18	13	7	2
8	93	86	79	72	66	59	52	46	40	33	27	21	15	9	3	
7	93	85	78	71	64	57	50	44	37	31	24	18	11	5		
6	92	85	77	70	63	55	48	41	34	28	21	14				
5	92	84	76	69	61	53	46	39	31	24						
4	92	83	78	67	59	51	44	36								
3	91	83	74	66	57	49										
2	91	82	73	64												
1	90	81														