St. Anne College Lucena Inc.
Elementary & Higher Surveying
1st Semester AY 2024 – 2025

SURVEYING MEASUREMENTS

A measurement is the process of determining the extent, size or dimensions of a particular quantity in comparison to a given standard. In surveying, measurements are usually concentrated on angles, elevations, times, lines, areas, and volumes. Making measurements and the subsequent computations utilizing them are basic and essential tasks of a surveyor.

UNIT OF MEASURE

The international unit of linear measure is the meter. This was proposed sometime in 1789 by French scientists who hoped to establish a system suitable for all times and all people, and which could be based upon permanent natural standards. Originally, the meter was defined as 1/10,000,000 of the Earth's meridional quadrant.

Here are basic equivalents of measurement of distance used on Engineering Surveying:

1 kilometer (km)	= 1, 000 meters (m)	1 meter	= 3.281 feet (ft)
1 meter (m)	= 100 centimeter (cm)	1 inch (in)	= 2.54 centimeters
1 decimeter (dm)	= 10 centimeters (cm)	1 foot (ft)	= 12 inches (in)
1 centimeters	= 10 millimeters (mm)	1 mile (mi)	= 1.6093 (km)

AREA MEASUREMENT

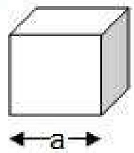
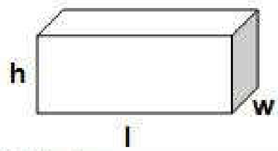
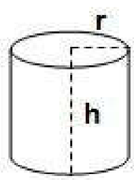
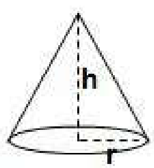
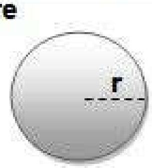
The unit of area in SI Units is the square meter (m^2). For very small areas, square millimeters (mm^2) or square centimeters (cm^2) is used. For very large areas like big portions of land, the hectare (ha) is commonly used although it is not part of the SI unit of measurement.

1 hectare (ha) = 10, 000 square meters (m^2)
1 square meter (m^2) = 10, 000 square centimeter (cm^2)
1 square kilometer (km^2) = 1,000,000 square meters (m^2)
1 square meter (m^2) = 10.7639 square feet (ft^2)

Figures	Area Formula	Variables
Area of Rectangle	**Area = l × w**	l = length w = width
Area of Square	Area = a^2	a = sides of the square
Area of a Triangle	Area = 1/2 b×h	b = base h = height
Area of a Circle	Area = πr^2	r = radius of the circle

Volume Measurement

The common metric units for volume are the cubic meter, liter, and the milliliter. Precise volumes, actual physical volumes, and the volumes of solids and liquids should be expressed depending on magnitude, in cubic meters, cubic centimeters, or cubic millimeter. When converting units of volume measurement, it is advisable to convert the distance measurement before computing for the volume.

Figure	Formula	Variables
Cube 	a^3	a = length of edge
Rectangular prism 	l × w × h	l = length w = width h = height
Cylinder 	$\pi \times r^2 \times h$	r = radius of circular face h = height
Cone 	$1/3 \times \pi \times r^2 \times h$	r = radius of circular base h = height from tip to base
Sphere 	$4/3 \times \pi \times r^3$	r = radius

SIGNIFICANT FIGURES

In recording results from values obtained by measurements and in making computations, it is important to determine which should be retained as significant figures. By definition, the number of significant figures in any value includes the number of certain digits plus one digit that is estimated and, therefore, questionable or uncertain.

*For uniformity, it is common practice to report final answers with two decimal places.

Illustrative Problems:

1. The measured lengths of a proposed airport runways are: 2, 100m; 1, 570.5m; 1775.9m
   Please convert the following measurements into centimeters, kilometers, feet, miles.

2100m x $\frac{100cm}{1m}$ = **210,000cm**

2100m x $\frac{1km}{1000m}$ = **2.1km**

2100m x $\frac{3.281ft}{1m}$ = **6,890.1 ft**

2100m x $\frac{1mile}{1,609.344m}$ = **1.30mile**

1570.5m x $\frac{100cm}{1m}$ = **157,050cm**

1570.5m x $\frac{1km}{1000m}$ = **1.57km**

1570.5m x $\frac{3.281ft}{1m}$ = **5,152.81 ft**

1570.5m x $\frac{1mile}{1,609.344m}$ = **0.98mile**

1775.9m x $\frac{100cm}{1m}$ = **177,590cm**

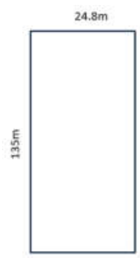
1775.9m x $\frac{1km}{1000m}$ = **1.78km**

1775.9m x $\frac{3.281ft}{1m}$ = **5,826.73 ft**

1775.9m x $\frac{1mile}{1,609.344m}$ = **1.1mile**

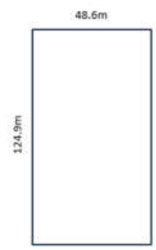
2. Given the dimensions of the following portions of land:
    a. 135m x 24.8m
    b. 124.9m x 48.6m
    c. 1, 276.8m x 138.2m
    d. 250 ft x 75 ft

Please calculate the area of the land and report your answers in sq. m.



A= L x W
A= 135m x 24.8m
A= 3348 m^2

A= L x W
A= 1,276.8m x 138.2m
A= 176,453.76 m^2



A= L x W
A= 124.9m x 48.6m
A= 6,070.14 m^2

250ft x $\frac{1m}{3.281ft}$= 76.1963m

75 x $\frac{1m}{3.281ft}$= 22.8589m

A= L x W
A= 76.1963m x 22.8589m
A= 1741.76m^2

3. Given the area and the width of the following cuts of land:
    a. 555sq. m and 25m
    b. 1768.9 sq.m and 54.12m
    c. 2754.3sq. m. and 41m

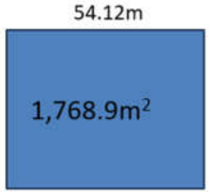
Determine the length of each property in m.

A = L x W

L = $\frac{A}{W}$

L = $\frac{555m^2}{25m}$

L = 22.2 m

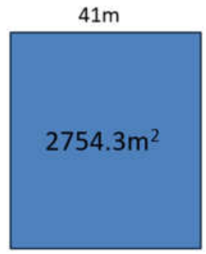


A = L x W

L = $\frac{A}{W}$

L = $\frac{1,768.9m^2}{54.12m}$

L = 32.68m



A = L x W

L = $\frac{A}{W}$

L = $\frac{2,754.3m^2}{41m}$

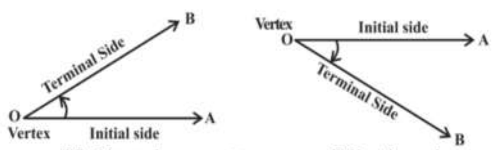
L = 67.18m

4. Calculate the volume for the given dimension to be excavated.
   a. 45m x 32m x 12m
   b. 44.46m x 27.89m 15.65m
   c. 75ft x 89ft x 20ft

V= L x W x H	V= L x W x H	V= L x W x H
V= 45m x 32m x 12m	V= 44.6m x 27.89m x 15.65m	V= 75ft x 89ft x 20ft
V= 17, 280 m³	**V= 19,466.94m³**	**V= 133,500 ft³**

ANGLE MEASUREMENT

An angle is made by rotating a ray or a line segment from an initial point to a terminal point. An angle can be measured using a protractor, precisely. An angle is measured in degrees, hence its called 'degree measure'. One complete revolution is equal to 360 degrees, hence it is divided into 360 parts.



(i)Positive angle Fig. 1 (ii) Negative angle

A complete revolution, i.e. when the initial and terminal sides are in the same position after rotating clockwise or anticlockwise, is divided into 360 units called degrees. So, if the rotation from the initial side to the terminal side is (1/360)th of a revolution, then the angle is said to have a measure of one degree. It is denoted as 1°.

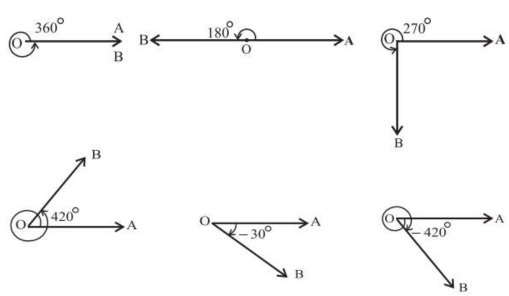
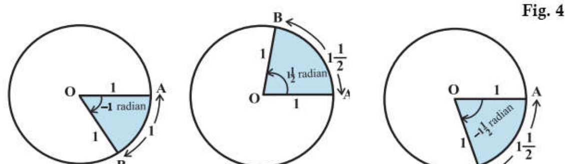


Fig. 2

Radian measure is slightly mo[...] le with a radius of 1 unit. Next, imagine an arc of the circle having a length of 1 unit. The angle subtended by this arc at the centre of the circle has a measure of 1 radian.

Fig. 4



By the definitions of degree and radian measures, we know that the angle subtended by a circle at the centre is:

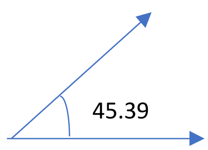
- 360° – according to degree measure
- 2π radian – according to radian measure

Hence, 2π radian = 360° ⇒ π radian = 180°. Now, we substitute the approximate value of π as 22/7 in the equation above and get, 1 radian = 180°/π = 57° 16′ approximately. Also, 1° = π/180° radian = 0.01746 radian approximately.

Degree	30°	45°	60°	90°	180°	270°	360°
Radian	$\frac{\pi}{6}$	$\frac{\pi}{4}$	$\frac{\pi}{3}$	$\frac{\pi}{2}$	π	$\frac{3\pi}{2}$	2π

- Radian measure = $\frac{\pi}{180^\circ}$ x Degree measure
- Degree measure = $\frac{180^\circ}{\pi}$ x Radian measure

Illustrative Sample:
Convert the following angle measurement into degree-minute-second unit and radian unit.



45.39°= X-X'(decimal*60minutes)
=45.39°- 45°(.39*60minutes)
=23.4minutes

23.4minutes = Xmin-Xmin'(decimal*60seconds)
= 23.4-23(.4*60seconds)
= 24 seconds

45.39°= 45°23'24"

To convert to radian measure:

Radian measure = Degree measure x $\frac{\pi}{180}$
Radian measure = 45.39 x $\frac{\pi}{180}$
Radian measure = 0.252167 π
Radian measure = 0.25 π rad

What is Surveying?

Surveying is the science or art of making such measurements as are necessary to determine the relative position of points above, on, or beneath the surface of the earth, or to establish such points. In a more general sense, however, surveying can be regarded as that discipline which encompasses all methods for measuring and collecting information about the physical earth and our environment, processing that information, and disseminating a variety of resulting products to a wide range of clients.

"A surveyor is a professional person with the academic qualifications and technical expertise to conduct one, or more, of the following activities;

• to determine, measure and represent the land, three-dimensional objects, point-fields, and trajectories;
• to assemble and interpret land and geographically related information;
• to use that information for the planning and efficient administration of the land, the sea and any structures thereon; and
• to conduct research into the above practices and to develop them.

Types of Surveys

- Cadastral Surveying
- City Surveying
- Construction Surveying
- Forestry Surveying
- Hydrographic Surveying
- Industrial Surveying
- Mine Surveying
- Photogrammetric Surveying
- Route Surveying
- Topographic Surveying

Types of Measurements

- **Direct Measurement** - a comparison of the measured quantity with a standard measuring unit or units employed for measuring a quantity of that kind.
- **Indirect Measurement** - When it is not possible to apply a measuring instrument directly to a quantity to be measured. The answer is therefore determined by its relationship to some other observed value or values.

Field Survey Party

- Chief of Party
- Assistant Chief of Party
- Instrument Personnel
- Technician
- Recorder
- Lead Tapeman
- Rear Tapeman
- Flagman

ERRORS

Making observations (measurements), and subsequent computations and analyses using them, are fundamental tasks of surveyors. Good observations require a combination of human skill and mechanical equipment applied with the utmost judgment. However, no matter how carefully made, observations are never exact and will always contain errors. Surveyors (geomatics engineers), whose work must be performed to exacting standards, should therefore thoroughly understand the different kinds of errors, their sources and expected magnitudes under varying conditions, and their manner of propagation. Only then can they select instruments and procedures necessary to reduce error sizes to within tolerable limits.

By definition, an error is the difference between an observed value for a quantity and its true value, or

$$E = X - \overline{X}$$

where E is the error in an observation, X the observed value, and its true value. It can be unconditionally stated that:

(1) no observation is exact,
(2) every observation contains errors,
(3) the true value of an observation is never known, and
(4) the exact error present is always unknown

Sources of Errors

Natural Errors - are caused by variations in wind, temperature, humidity, atmospheric pressure, atmospheric refraction, gravity, and magnetic declination. An example is a steel tape whose length varies with changes in temperature.

Instrumental Errors - result from any imperfection in the construction or adjustment of instruments and from the movement of individual parts. For example, the graduations on a scale may not be perfectly spaced, or the scale may be warped. The effect of many instrumental errors can be reduced, or even eliminated, by adopting proper surveying procedures or applying computed corrections.

Personal Errors - arise principally from limitations of the human senses of sight and touch. As an example, a small error occurs in the observed value of a horizontal angle if the vertical crosshair in a total station instrument is not aligned perfectly on the target, or if the target is the top of a rod that is being held slightly out of plumb.

Types of Errors

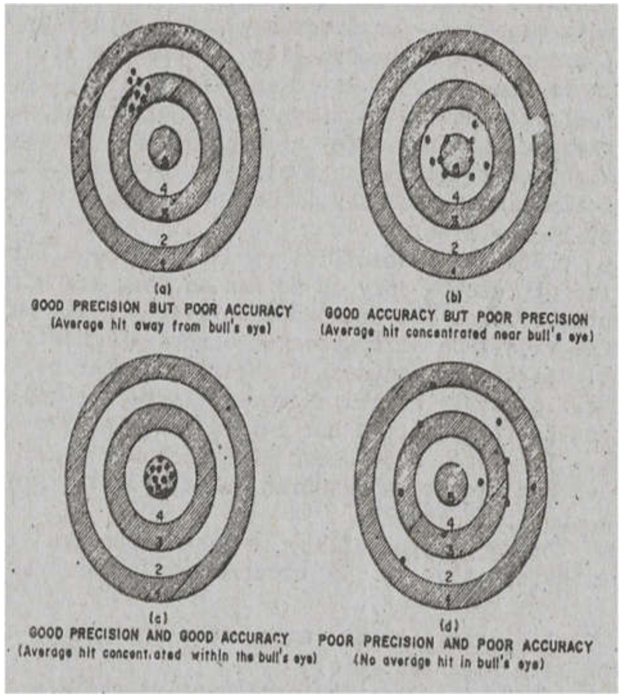
Systematic Errors - also known as biases, result from factors that comprise the “measuring system” and include the environment, instrument, and observer. So long as system conditions remain constant, the systematic errors will likewise remain constant. If conditions change, the magnitudes of systematic errors also change. Because systematic errors tend to accumulate, they are sometimes called cumulative errors.

Random Errors - are those that remain in measured values after mistakes and systematic errors have been eliminated. They are caused by factors beyond the control of the observer, obey the laws of probability, and are sometimes called accidental errors. They are present in all surveying observations.

A ***discrepancy*** is the difference between two observed values of the same quantity. A small discrepancy indicates there are probably no mistakes and random errors are small. However, small discrepancies do not preclude the presence of systematic errors.

Precision refers to the degree of refinement or consistency of a group of observations and is evaluated on the basis of discrepancy size. If multiple observations are made of the same quantity and small discrepancies result, this indicates high precision. The degree of precision attainable is dependent on equipment sensitivity and observer skill.

Accuracy denotes the absolute nearness of observed quantities to their true values. The difference between precision and accuracy is perhaps best illustrated with reference to target shooting.



Probability

Probability may be defined as the ratio of the number of times a result should occur to its total number of possibilities. For example, in the toss of a fair die there is a one-sixth probability that a 2 will come up. This simply means that there are six possibilities, and only one of them is a 2.

Most Probable Value can be calculated if repeated observations have been made. Repeated observations are measurements in excess of the minimum needed to determine a quantity. For a single unknown, such as a line length that has been directly and independently observed a number of times using the same equipment and procedures,1 the first observation establishes a value for the quantity and all additional observations are redundant. The most probable value in this case is simply the arithmetic mean, or

$$\textbf{mpv} = \Sigma x/n = (x1+x2+x3+....+xn)/n$$

Illustrative Problem:

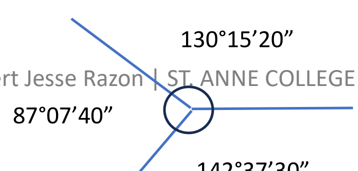
A surveying instructor sent out six group of students to measure the distance between two points marked on the ground. The following measurements were obtained by the students.

250.25m
250.15m
249.90m
251.04m
250.50m
251.22m

mpv= (250.25+250.15+249.90+251.04+250.50
+251.22)/6
mpv= 250.51m

Illustrative Problem:

The angles about a point Q have the following observed values. 130'15'20" ; 142'37'30" ; 87'07'40". Determine the most probable value of each angle.



Determining the correction to be applied:
Sum= O1+O2+03= 130°15'20"+142°37'30"+87°07'40"
Sum= 360°00'30"
true value = 360°00'00"
diff= 360°00'00"- 360°00'30"
diff= 00°00'30"

Residuals

Having determined the most probable value of a quantity, it is possible to calculate *residuals*. A residual is simply the difference between the most probable value and any observed value of a quantity, which in equation form is

$$v = x - \bar{x}$$

Probable Error

The probable error is a quantity which, when added to and subtracted from the most probable value, defines a range within which there is a 50 percent chance that the true value of the measured quantity lies inside (or outside) the limits thus set.

$$PE_m = \pm 0.6745\sqrt{\frac{\sum v^2}{n(n-1)}}$$

Where,

PE_m= probable error of the mean

V^2= square of the residuals

N = no. of trials

Illustrative Problem

The following values were determined in a series fo tape measurements of a line: 1000.58, 1000.40, 1000.38, 1000.48, 1000.40, 1000.46m. Determine the most probable value and probable error of the line.

Given: n = 6

x1 = 1000.58m MPV= $\sum x/n$

x2 = 1000.40m
x3 = 1000.38m
x4 = 1000.48m
x5 = 1000.40m
x6 = 1000.46m

MPV = 1000.58+1000.40+1000.38+1000.48+1000.40+1000.46/6
MPV = 6002.70/6
MPV = 1000.45m

TRIAL	MEASUREMENT	RESIDUAL	V^2
1	1000.58	+.013	0.0169
2	1000.40	- 0.05	0.0025
3	1000.38	- 0.07	0.0049
4	1000.48	+ 0.03	0.0009
5	1000.40	- 0.05	0.0025
6	1000.46	+ 0.01	0.0001
	$\sum X$= 6002.70		$\sum V^2$=0.0278

$$PE_m = \pm 0.6745\sqrt{\frac{\sum v^2}{n(n-1)}}$$

$$PE_m = \pm 0.6745\sqrt{\frac{0.0278}{6(6-1)}}$$

$PE_m = \pm 0.02$

Therefore, the length of the measured line may be expressed as 1000.45 ± 0.02m. This means that there is a 50% chance that the true distance measured probably falls between 1000.43 and 1000.47m, and that its most probable value is 1000.45m. There is also, however, a 50% chance that the true distance lies outside this range.

SEATWORK #1

A route surveyor needs to determine the most probable value of the distance from the new city hall of Lucena city to St. Anne Colege Lucena Inc. He used a measuring wheel and walked between the points and recorded the following data:

Trial 1: 2501.52m
Trial 2: 2499.87m
Trial 3: 2499.67m
Trial 4: 2500.28m
Trial 5: 2500.76m
Trial 6: 2500.04m
Trial 7: 2498.99m
Trial 8: 2500.03m

Determine the most probable value and the probable error for the mean.
Please report your final answers with 2 decimal places only. Round off your final answers only.

MPV= ΣX/n

MPV = 20001.16/8

MPV= 2500.145m

MPV=2500.15m

TRIAL	MEASURED DISTANCE	RESDIUAL	V^2
1	2501.52	+1.37	1.8769
2	2499.87	-0.28	0.0784
3	2499.67	-0.48	0.2304
4	2500.28	+0.13	0.0169
5	2500.76	+0.61	0.3721

6	2500.04	-0.11	0.0121
7	2498.99	-1.16	1.3456
8	2500.03	-0.12	0.0144
	$\sum X$= 20001.16		$\sum V^2$=3.9468

$PE_m = \pm 0.6745\sqrt{\frac{\sum V^2}{n(n-1)}}$

$PE_m = \pm .6745\sqrt{\frac{3.9468}{8(8-1)}}$

$PE_m = \pm 0.18$

2500.15m $\pm$0.18

Illustrative Problem

A rich man bought a rectangular vacant lot in Lucena City without finding out the details about the lot. He hired an engineer to determine the measurements of the lot. The following data was taken at the location of the vacant lot:

Determine the most probable value for the length and the width.

Determine the area of the lot using the most probable length and width.

Determine the probable error for the length and the probable error for the width.

TRIAL	LENGTH	RESIDUAL	V^2
1	50.05	0.05	0.0025
2	49.89	-0.11	0.0121
3	50.12	0.12	0.0144
4	49.95	-0.05	0.0025
	200.01		0.0315

TRIAL	WIDTH	RESIDUAL	V^2
1	50.05	0.05	0.0025
2	49.89	-0.11	0.0121
3	50.12	0.12	0.0144
4	49.95	-0.05	0.0025
	200.01		0.0315

MPV= ΣX/n

MPV = 200.01/4

MPV= 50.0025m

MPV=50.00m

$PE_m = \pm 0.6745\sqrt{\frac{\sum V^2}{n(n-1)}}$

$PE_m = \pm .6745\sqrt{\frac{0.0315}{4(4-1)}}$

$PE_m = \pm 0.03$

50.00m $\pm$0.18

MPV= ΣX/n

MPV = 272.01/4

MPV= 68.0025m

MPV=68.00m

$PE_m = \pm 0.6745\sqrt{\frac{\sum V^2}{n(n-1)}}$

$PE_m = \pm .6745\sqrt{\frac{0.0273}{4(4-1)}}$

$PE_m = \pm 0.03$

68.00m $\pm$0.18

$A = MPVL\ x\ MPVW$

$A = 50.00\ x\ 68.00$

A= 3400m

$A = (MPVL - PEL)x\ (MPVW - PEW)$

A= (50.00-.03) x (68.00 - .03)

A= 3396.46m

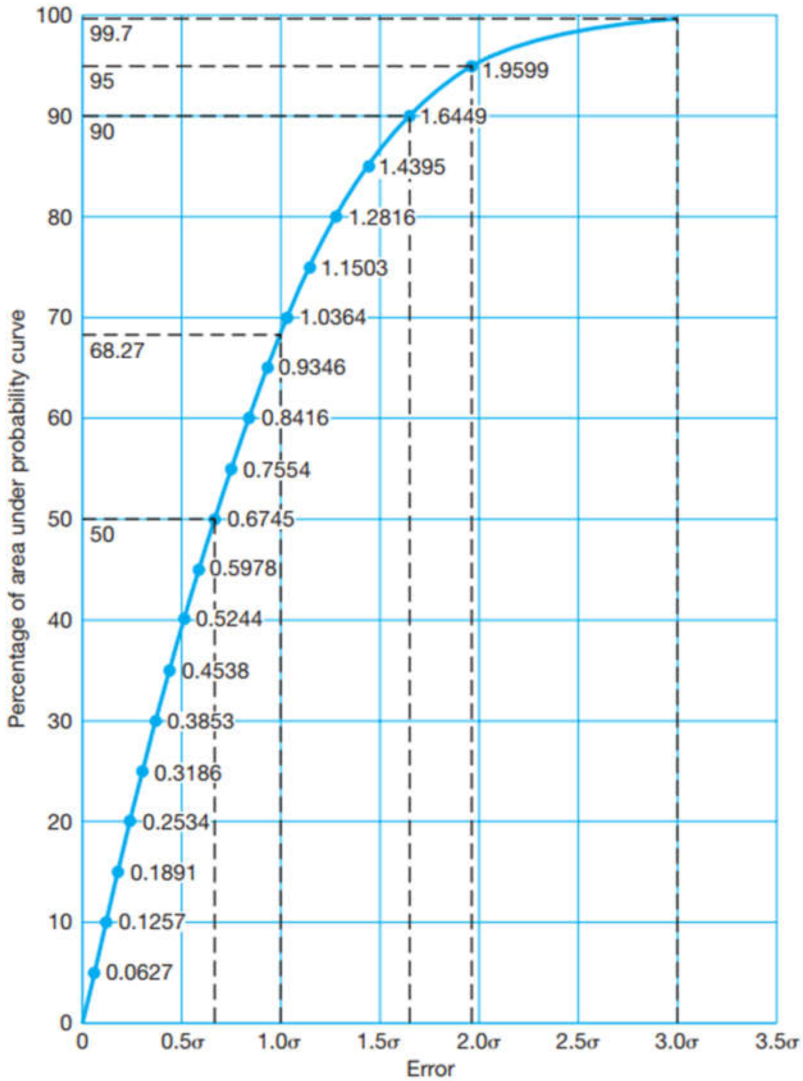
$A = (MPVL + PEL)x\ (MPVW + PEW)$

A= (50.00 + .03) x (68.00 + .03)

A= 3403.54m

A= 3396.45 TO 3403.54m

THE 50TH, 90TH, 95TH PERCENT ERRORS



$$E_{50} = 0.6745\sigma$$
$$E_{90} = 1.6449\sigma$$
$$E_{95} = 1.9599\sigma$$