Practical manual

Forest Mensuration

Course No. FSA 202 Credit Hrs. 3(2+1)

For B. Sc. (Hons.) Forestry III Semester students

Dr. PANKAJ LAVANIA
Dr. MANMOHAN J DOBRIYAL

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College of Horticulture & Forestry
Rani Lakshmi Bai Central Agricultural University,
Jhansi 284003

Syllabus (FSA 202 3(2+1):

Determination of pace length- Measurements of diameter-girth and basal area of trees using Callipers, Tape, Ruler, Penta Prism Tree Calliper etc. Measurement of height using non instrumental method- Preparation and use of simple height measuring instruments- Christens Hypsometer-Smithies Hypsometer- Modified Smithies Hypsometer-Measurement of tree height using instrumental methods- Abneys level- Haga altimeter- Relaskop- Clinometer- Blumeleiss Hypsometer-Laser Hypsometer- Volume determination of standing and felled trees. Exercise on Stump analysis. Exercise on stem analysis- Annual ring counting using ring borer. Preparation of volume tables- local volume table.

Name of Student .....

Roll No. .....

Batch .....

Session .....

Semester .....

Course Name: .....

Course No. : .....

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This is to certify that Shri./Km. .....ID No..... has completed the practical of course.....course No. ..... as per the syllabus of B.Sc. (Hons.) Agriculture/ Horticulture/ Forestry ..... semester in the year.....in the respective lab/field of College.

Date: Course Teacher

INDEX

Practical No. 1

Objective: To be familiar with units of measurement used for forest mensuration purpose and Conversion factors

Forest Mensuration: ……

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Types of system of measurements used worldwide

(I) ……

(II) ……

Unit of lengths in two systems

(I) ……

(II) ……

Units of area in two systems

(I) ……

(II) ……

Units of volume in two systems

(I) ……

(II) ……

Units of Weight in two systems:

(I) ……

(II) ……

Conversion factors:

<table>
<tr><th colspan="2">F.P.S. to C.G.S</th><th colspan="2">C.G.S. to F.P.S.</th></tr>
<tr><th>Length</th><th>Area</th><th>Length</th><th>Area</th></tr>
<tr><td>1 inch = …… mm</td><td>1 sq. inch = …….. sq. cm</td><td>1 cm = …… inch</td><td>1 Square metre = …….sq. feet</td></tr>
<tr><td>1 foot = ……. cm</td><td>1 sq. foot = ……. sq. decimeters</td><td>1 km = …….. mile</td><td rowspan="3">1 hectare = ……. acres</td></tr>
<tr><td>1 yard = ……mtr</td><td>1 sq. yard = ……. sq. m.</td><td rowspan="2">1mtr (m) = …….yards</td></tr>
<tr><td>1 Mile = …….Km</td><td>1 acre = ……ha</td></tr>
<tr><th>Volume</th><th>Weight</th><th>Volume</th><th>Weight</th></tr>
<tr><td>1 cu inch = …..cu cm</td><td>1 pound = …….. Kg</td><td>1 cu cm = …...cu inch</td><td>1 Kg = ……pounds</td></tr>
<tr><td>1 cu feet = …… cu m</td><td>1 ton = ……. metric ton</td><td>1 cu mtr = ….. cu feet</td><td>1 metric ton = ……. ton</td></tr>
</table>

Practical No. 2

Objective: To study the standard rules for measurement of Diameter or Girth at breast height (DBH or GBH) of standing trees.

Standard rules governing Breast Height measurements of trees principles

Rule 1: …… …… …… …… …… …… …… …… …… …… …… …… ……	**Fig-1**
Rule 2: …… …… …… …… …… …… …… …… …… …… …… …… ……	**Fig-2**

Rule 3: ……..… …… …… …… …… …… …… …… …… …… ……	**Fig-3**
Rule 4: …… …… …… …… …… …… …… …… …… …… ……	**Fig-4**
Rule 5: …… …… …… …… …… …… …… …… ……	**Fig-5**

Rule 6: …… …… …… …… …… …… …… …… …… …… ……	**Fig-6**
Rule 7: …… …… …… …… …… …… …… …… …… …… ……	**Fig-7**
Rule 8: …… …… …… …… …… …… …… …… ……	**Fig-8**

Rule 9: …… …… …… …… …… …… …… …… …… …… ……	**Fig-9**
Rule 10: …… …… …… …… …… …… …… …… …… …… ……	**Fig-10**

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Practical No. 3

Objective: To know about different instruments used for measurement of diameter and girth of standing or felled trees.

Instrument used: ……

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Tree Callipers: .....

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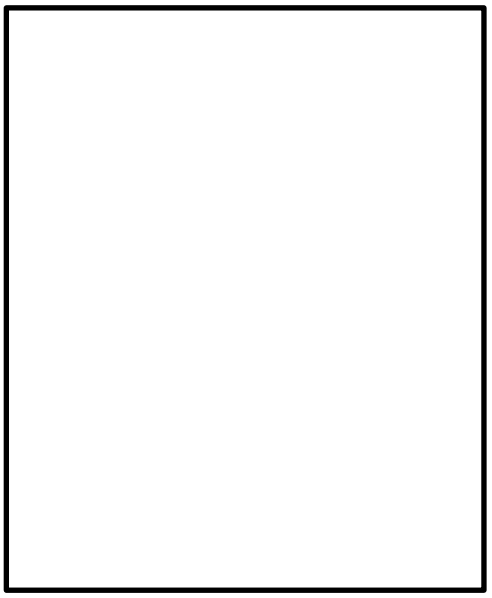

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Precautions in use: ……

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Tape:.....

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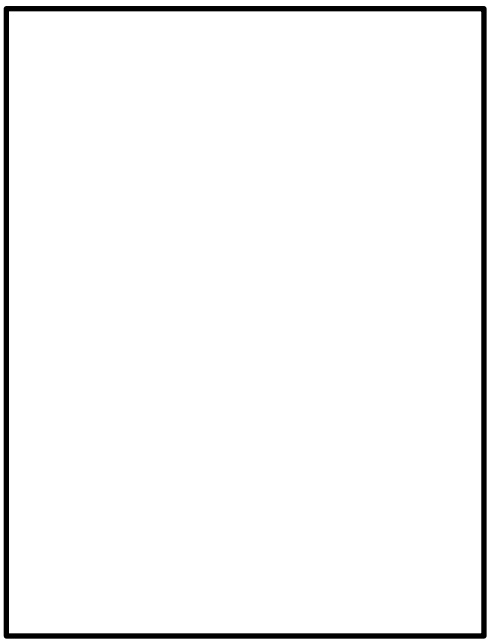

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Precautions in use: ……

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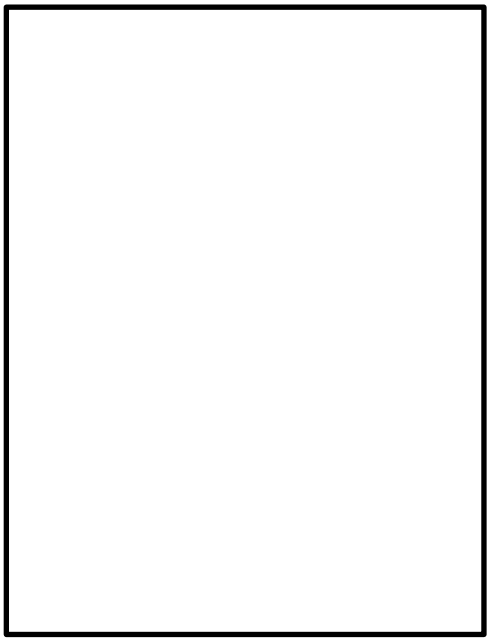
Wheeler Penta Prism:



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Precautions in use: ……

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Practical No. 4

Objective: To measure the DBH (OB) and GBH (OB) of trees in different forestry block at RLBCAU Campus.

Materials required: .....

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Procedure of DBH (OB) measurement: .....

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GBH (OB) measurement: .....

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Observation: .....

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S. No	Species	Condition of tree	Measuring Side	DBH (OB) in cm			GBH (OB) (m)	Remarks (if any)
				Major axis	Minor axis	Average		
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

Practical No. 5

Objective: To estimate the bark thickness of trees at RLBCAU, Campus.

Materials required: .....

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Procedure: .....

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Sl. No.	Species Name	Height of measurement from ground level in m	Bark thickness in cm				
			Major Axis		Minor Axis		Average
			D_1	D_2	D_3	D_4	
1.							
2.							
3.							
4.							
5.							
6.							
7.							
8.							
9.							
10.							

Practical No. 6

Objective: To measure DBH or GBH under bark (UB) for estimation of volume (commercial volume) of standing or felled trees.

Materials required: ……...

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Procedure: ……

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Formula

1. DBH DBH (UB) = ……
2. GBH (UB) = ……

Sl. No.	Species Name	DBH (OB) in cm	GBH (OB) in cm	Bark thickness in cm	DBH (UB) in cm	GBH (UB) in cm
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

Practical No. 7

Objective: To know about different instruments used for measurement of upper stem diameters for determination of volume and taper or form of standing tree.

Materials required: ……...

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Ruler:……

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Wheeler Penta Prism: ……

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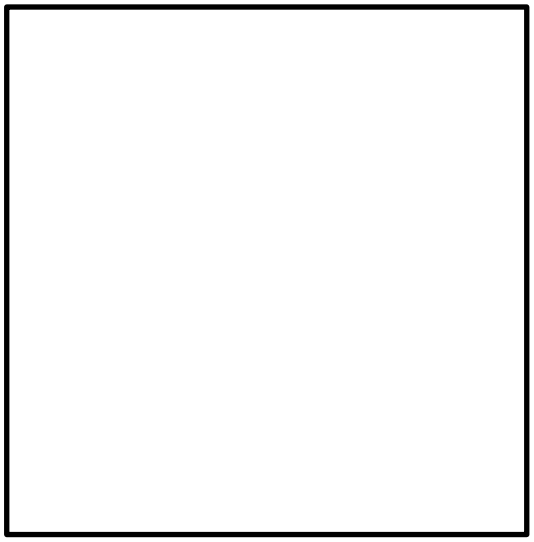
Spiegel Relaskop: ……



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Dendrometer:.....

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Observation

Sl. No.	Species Name	Stem diameters			
		Ruler	Wheeler Penta Prism	Spiegel Relaskop	Dendrometer
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

Practical No. 8

Objective: To measure the upper stem diameter by using Wheeler Pentaprism for determination of form of trees and preparation of taper table.

Procedure Wheeler Pentaprism: ……

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Observation:

Sl. No.	Species Name	Height from ground level (m)	Diameter at that height (cm)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Practical No. 9

Objective: To know about different instruments based on similar triangle principle for measurement of height of trees

Similar triangle principle: ……

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Christen's Hypsometer: ……

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Smythie's Hypsometer: ……

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Practical - 10

Objective: To know about different instruments based on trigonometric principles used for measurement of height of trees in various conditions.

Abney's Level: …… …… …… …… …… …… …… …… …… …… …… ……	Diagragram
Brandis Hypsometer: …… …… …… …… …… …… …… …… …… …… …… ……	Diagragram
Haga Altimeter: …… …… …… …… …… …… …… …… …… …… …… ……	Diagragram

Ravi Multimeter	Diagragram
Ravi Altimeter:	Diagragram
Spiegel Relaskope:	Diagragram

Clinometer/ Silva Ranger Compass: ……..……	Diagragram
Electronic Clinometer ……	Diagragram
Vertex Laser Hypsometer: ……	Diagragram

Practical No. 11

Objective: To measure height of standing trees in different conditions by using Abney's Level

Materials required: ……..…….....

Procedure: ……

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The height of the tree can be determined by using tangent or sine method: If AB = Height of tree, ED/EB = Horizontal distance, EF = Eye height, α = Angle of elevation and β = Angle of depression

Tangent Method- If Conditions are like

On level ground: ……..……..

On sloping ground, where the top of the tree is above the eye level and base below it:

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On sloping ground, where the top and base of the tree are present above the eye level:

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On sloping ground, where the top and base of the tree are present below the eye level:

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Observation:

Sl. No.	Species Name	Condition	Observer distance (m) [ED/EB]	Angle of elevation (^{0}) [α]	Angle of depression (^{0}) [β]	Height of tree (m) [AB]
1						
2						

3						
4						
5						
6						
7						
8						
9						
10						

The angle of elevation and angle of depression of trees are measured and height of tree can be calculated according to the condition of presence

Calculation: ……

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Practical - 12

Objective: To measure height of standing trees using Ravi Altimeter

Materials required: ……...……...

Procedure: ……

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Ways of calculating tree height:

Distance from tree	Height of tree above eye level (m) [A]	Height of tree below eye level (m) [B]	Total Height (m)
1. Convenient distance	% of reading on height scale x Convenient distance	Eye height	A+B
2. At 20m distance from tree	Reading on 20m scale	Eye height	A+B
3. At 30m distance from tree	Reading on 20m scale	Eye height	A+B

Observation:

Sl. No.	Species Name	Observer distance (m)	Height of tree (m)		
			Height above eye level (m) A	Height below eye level (m) B	Total height (m) A+B
1					
2					
3					
4					

5					
6					
7					
8					
9					
10					

Tree height vary from about 3 m to more than 60 m depending upon forest types or site situations. However, height of the tree is measured using altimeter with different scales as explained above.

Calculation:

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Practical No. 13

Objective: To study the form of tree (form factor and/or form ratio) for volume estimation of standing trees to prepare taper table and volume table

Materials required: ……...

Procedure: ……

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Form Factor: ……..

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Form factor (F) Formula: ……....

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Classification of form factor

Artificial form factor (Breast height form factor): ……...

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Absolute form factor: ……..……

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Normal (tree) form factor: ……..……

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Form Quotient (Developed by A. Schiffel): ……

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Formula = $\frac{\text{mid diameter}}{\text{DBH}}$ **or** $\frac{\text{mid girth}}{\text{GBH}}$

Classification of form quotient

Normal form quotient: ……

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Absolute form quotient: ……

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Observation:

Sl. No.	Species	DBH (cm)	Mid-dia. (cm)	Dia. at ½ the height above the DBH (cm)	Normal Form Quotient	Absolute Form Quotient	Remarks
1							
2							
3							
4							
5							
6							
7							
8							
10							

Calculation: ……

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Practical No. 14

Objective: - To estimate volume of standing tree for quantity or content of wood

Material required: ……

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Methods of Volume of standing trees: Ocular, Partly ocular and partly measurement, direct and indirect measurement and by volume tables. For getting relatively more accuracy, the last two methods *i.e.*-direct measurement and volume tables methods are used.

Direct measurement method

First method: ……

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By General formula-

If the tree is in conical shape: $V = S \times H/3$

$= (\pi D^2/4) \times H/3$

$= \pi D^2 H/12$

where, V= Volume of tree (m^3); S= Basal Area of tree (*i.e.* $S = \pi D^2/4$ & unit is m^2); H= Commercial bole height or height of tree (m)

If the tree is in cylindrical shape: $V = S \times H$

$= (\pi D^2/4) \times H$

where, V= Volume of tree (m^3); S= Basal Area of tree (*i.e.* $S = \pi D^2/4$ & unit is m^2) and H= Commercial bole height or height of tree (m)

Second method: ……

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By Quarter Girth formula: $V= (G/4)^2 \times H$
where, G= Girth at mid-point ($G = \pi d$ & unit is m; d is mid-point diameter); H= Commercial bole height or height of tree (m)

Third method: ……

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By using form quotient to get volume: $V = S \times F \times H$
$= (\pi D^2/4) \times F \times H$
where, V= Volume of tree (m^3); S = Basal Area of tree (*i.e.* $S = \pi D^2/4$ & unit is m^2); F = Normal Form Quotient (=Mid-diameter/DBH); H= Commercial bole height or height of tree (m)

Observation and Calculation:
Volume calculation by General formula

Sl. No.	Species Name	DBH in cm (D)	Commercial Bole height/ height of tree in meter (H)	Basal Area in m^2 ($S= \pi D^2/4$)	Volume (m^3)	
					Conical	Cylindrical
					$V= S \times H/3$ $= \pi D^2H/12$	$V= S \times H$ $= \pi D^2H/4$
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

Volume calculation by Quarter Girth formula

Sl No	Species Name	Mid-point diameter (d) in cm	Commercial Bole height/ height of tree(H) in m	Mid-point girth in m ($G = \pi d$)	Volume (m3) $V= (G/4)2 \times H$
1					
2					
3					
4					
5					

6					
7					
8					
9					
10					

Volume calculation by using form to calculate volume

Sl No	Species Name	Normal Form Quotient (F) Mid-point diameter/ DBH	Commercial Bole height/ height of tree (H) in m	Mid-point girth in m (G = πd)	Volume (m3) V= S x F x H = πD2 FH / 4
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

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Practical No. 15

Objective: To estimate the content of wood present in terms of volume per section of log over bark required for determination of value of log(s)

Materials required: ……...

Procedure: ……

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Volume calculation of logs of cylindrical form (over bark)

General formula (Measure the diameter at any point of log): V= S × L

Where, S= Basal Area; L= Length of log

Quarter Girth formula (Measure the diameter at middle of log): $V= (G/4)^2 \times L$

Where, G= Girth at mid-point of log; L= Length of log

Volume calculation of logs of taper form (over bark)

Smalian's formula, (Measure the diameter at thick end and thin end of log)

$$V = (S_1 + S_2)/2 \times L$$

Where, S_1 = Basal Area of thick end cross section; S_2 = Basal Area of thin end cross section and L = Length of log

Huber's formula (Measure the diameter at middle of log) V =Sm x L

Where, Sm = Basal Area at middle of log and L = Length of log

Newton's formula (Measure the diameter at thick end, middle and thin end of log)

$$V = (S_1 + 4\ Sm + S_2)/6 \times L$$

Where, S_1 = Basal Area of thick end cross section; S_2 = Basal Area of thin end cross section; Sm = Basal Area at mid-point and L = Length of log

Quarter Girth formula (Measure the diameter at middle of log): $V= (G/4)^2 \times L$

Where, G= Girth at mid-point of log and L= Length of log

Observation and Calculation:

Observation Table-

Sl No	Species Name	Length of log (L) in m	Dia (OB) at any point (d) in cm (Only for cylindrical form of logs)	Mid-Dia (OB) (D) in cm	Dia (OB) at thick end (D_1) in cm	Dia (OB) at thin end (D_2) in cm
1						
2						
3						
4						
5						
6						
7						

8						
9						
10						

Calculation Table- (Volume of log(s) over bark by different formulae)

Sl No	Vol. by General Formula (m^3) (Only for cylindrical form of logs)	Vol. by Quarter girth formula (m^3)	Vol. by Smalian's formula(m^3)	Vol. by Huber's formula (m^3)	Vol. by Newton's formula(m^3)
1.					
2.					
3.					
4.					
5.					
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Practical No. 16

Objective: To estimate the volume of felled trees to quantify the wood content as well as to determine the economic calculation/ value estimation

Materials required: .....

Procedure: .....

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Formula:

Diameter Under Bark (DUB) = …….. then,

Convert the DUB into GUB by using formula
Girth Under Bark (GUB) = ……..

Volume calculation of logs of cylindrical form (under bark)
General formula (Measure the diameter at any point of log): V= S x L
Where, S= Basal Area; L= Length of log
Quarter Girth formula (Measure the diameter at middle of log): $V= (G/4)^2 \times L$
Where, G= Girth at mid-point of log; L= Length of log

Volume calculation of logs of taper form (under bark)
Smalian's formula, (Measure the diameter at thick end and thin end of log) $V = (S_1 + S_2)/2 \times L$
Where, S_1 = Basal Area of thick end cross section; S_2 = Basal Area of thin end cross section and L = Length of log

Huber's formula (Measure the diameter at middle of log) V = Sm x L
Where, Sm = Basal Area at middle of log and L = Length of log

Newton's formula (Measure the diameter at thick end, middle and thin end of log): $V = (S_1 + 4\ Sm + S_2)/6 \times L$
Where, S_1 = Basal Area of thick end cross section; S_2 = Basal Area of thin end cross section; Sm = Basal Area at mid-point and L = Length of log

Quarter Girth formula (Measure the diameter at middle of log): $V= (G/4)^2 \times L$
Where, G= Girth at mid-point of log and L= Length of log

Observation and Calculation:

Sl No	Species Name	Length of log (L) in m	Dia (OB) at any point (d) in cm (Only for cylindrical form of logs)	Mid-Dia (OB) (D) in cm	Dia (OB) at thick end (D_1) in cm	Dia (OB) at thin end (D_2) in cm
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

Volume of log(s) over bark by different formulae

Sl No	Vol. by General Formula (m^3) (Only for cylindrical form of logs) [V= S x L]	Vol. by Quarter girth formula (m^3) [V= $(G/4)^2$ x L]	Vol. by Smalian's formula(m^3) [V=$(S_1+S_2)/2$ x L]	Vol. by Huber's formula (m^3) [V = Sm x L]	Vol. by Newton's formula (m^3) [V=$(S_1+4Sm+S_2)/6$ x L]
1					
2					
3					
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Practical No. 17

Objective: To determine the age of standing trees by counting the number of annual rings in the core obtained through increment borer.

Age of the standing trees in the natural forest is generally measured using increment borer. This parameter may be useful in calculation of periodic growth in terms of ring thickness, and also to determine site quality, site index, etc, for further growth prediction.

Materials required: ……..

Procedure: .....

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Observation and Calculation:

Sl. No.	Species Name	Height of coring (m)	Number of increment cores/ tree	Number of annual rings/core	Age of trees (year)
1					
2					
3					
4					
5					

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Practical no. 18

Objective: To find out the age of felled tree(s) by stump analysis.

The age of felled tree(s) can be determined by stump analysis. It is more practicable in ring porous wood species like teak. In this method, data can be collected from stumps of felled trees as long as the wood remains sound and no need for special fellings. Field work is simple and each stump provides data for the whole life of the tree.

Material required: 1. Measurement Tape, 2. Pin and 3. Pencil

Procedure: ……

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Observation Table:

Sl no	Species Name	Stump Height (m)	Number of annual rings on stump	Age of tree (year)
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2				
3				
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Glossary of Terms

Above Ground Biomass (AGB): Plant parts present above the ground, which includes stem, branches, leaves and twigs.

Absolute from factor: Basal area is measured at any convenient height but volume and height of the tree are above the point of the measurement.

Absolute form quotient: Ratio of diameter or girth of a stem at a height halfway above the breast height to the diameter or girth at breast height.

Age class: All trees in a stand within a given age interval, usually 10 or 20 years.

Annual growth: The yearly increase in wood volume, usually expressed in terms of board feet or cubic feet per acre.

Artificial form factor (Breast height form factor): Basal area is measured at B. H. and the volume refers to the whole tree both above and below the point of measurement of B.H.

Assortment tables: Volume tables which give volume in round down to various stated thin end diameter possible to find out volume of a tree of given linear dimensions when the conversion was done up to 25 cm, 20 cm, 15 cm diameter limit e.g. standard and commercial volume tables are special cases of assortment tables.

Basal area: Area of a cross section at breast height.

Basal Area Factor (BAF): This is the multiplying factor associated with any instrument.

BAF = 2500 K^2 [K = 2 sin $\frac{\theta}{2}$] = 10,000 $\sin^2$ (θ = angle of instrument).

Below Ground Biomass (BGB): Plant parts present below the ground which includes roots, rootlets.

Biomass of trees: It is the weight of the above ground vegetative matter produced per unit area. It includes wood, their branches, bark and leaves produced by trees, shrubs and herbs and other vegetation.

Bole height: Distance between ground level and crown-point. Crown Point is the position of the first crown forming of living or dead branch.

Breast Height (BH): The point where measurement of diameter or girth is done. It is universally adopted as standard height for measuring diameter, girth and basal area of standing trees. Breast height is measured at 1.37 m (4 ft 6 inch) from ground level in India.

Calibration distance factor: It indicates the distance at which a given angle gauge will exactly cover or a prism will exactly deviate, a rectangular target which is one meter wide.

Canopy: The uppermost layer in a forest, formed collectively by tree crowns.

Canopy density: It is a measure of relative completeness of canopy and is expressed as a decimal coefficient taking closed canopy as unity.

Canopy layers: Forests with varying age classes may have several height classes. For example, an over story canopy layer of trees overtopping a lower canopy of other trees or shrubs.

Commercial bole height: It is the height of bole that is usually fit for utilization as timber.

Commercial volume tables: Gives the volume measured down to a thin end diameter to which conversion is done, the stump volume being omitted. This table is used for preparation of local volume table and usually temporary tables for individual coupes.

Commercial volume: Volume of stem measurement up to a thin end diameter to which conversion is usually done, (excludes volume of stump).

Cord: A stack of wood that has a gross volume of 128 cubic feet. A standard cord measures 4 feet x 4 feet x 8 feet and should contain approximately 80 cubic feet of solid wood.

Crown class: A category of similar trees based upon the position or elevation of their crowns compared to the crowns of other nearby trees.

Crown competition Factor (CCF): It is another measure of density and is claimed to be independent of site quality and stand age.

Crown cover: The horizontal projection on the ground of the tree crown.

Crown height: It is the height of the crown as measured vertically from the ground level to the point half way between the lowest green branch and the green branches forming green crown all round.

Crown length: Vertical length (measurement) of the crown of a tree from the tip to the point half way between the lowest green branches forming green crown all round and the lowest green branch on the bole.

Crown closure: The point when in a young stand, the crowns of the trees begin to touch each other.

Crown differentiation: The process whereby some trees grow faster and develop large, full crowns, while others fall behind in height and have smaller, sparser crowns.

Crown ratio: It is the ratio between the crown length to the total height of the tree.

Crown width: The maximum spread of the crown along its widest diameter.

Cruise: A survey of forest land to estimate timber quantity.

Cull: The portion of the tree stem or log which is un-merchantable is called cull. It is mentioned as a percentage of the standard volume.

Current Annual Increment (CAI): It is the increment which a tree or a crop puts on in single year.

DBH (OB): Diameter at Breast Height Over Bark which is generally measured at height of
1.37 m from ground level.

DBH (UB): Diameter at Breast Height Under Bark which is generally measured at height of
1.37 m from ground level.

DBH: Diameter at Breast Height. Diameter is generally at height of 1.37 m from ground level.

Dead wood: A standing tree that has died before it is harvested, such as a tree that has been killed by fire or insects.

Debarking: The process of removing the bark from a log by applying pressure and frictions to its outer surfaces.

Diameter limit: The smallest (but occasionally the largest) size to which trees or logs are to be measured, cut, or used. Usually refers to the stump, breast height, or top diameter.

Diameter class: The measured diameter of trees are grouped into diameter class with an interval for easy record

keeping and easy for calculation. In Indian 2 cm, 5 cm and 10 cm diameter class are generally used.

Diopter: This is a measure of the value of an angle expressed as its sine. 1 Diopter = 0.57^0 or $34.36'$.

Dry Biomass: Plant parts dried and having moisture content of about 12 %.

Economic rotation age: The point in time (stand age) during the growth of a stand when the rate of increase of the net value of the stand begins to decline; the economic rotation age generally occurs before the physical rotation.

Felling: The cutting down or harvesting of forest trees.

Final MAI: When MAI, calculated at the rotation age, then known as final MAI.

Forest cover: All lands, more than one hectare in area, with a tree canopy density of more than 10 percent irrespective of ownership and legal status. Such lands may not necessarily be a recorded forest area. It also includes orchards, bamboos and palms.

Forest growth model: A computer program that prepares estimates of forest yields by applying all of the factors known to affect forest growth.

Forest growth: The increase in the volume of wood in a forest that occurs over a specific period of time.

Forest type map: A map of the locations of different type of trees prepared from aerial photographs of the forest with the aid of instruments called a stereoscope.

Forest management: The application of scientific, economic, and social principles to managing a forest property for specific objectives.

Forest inventory: It is a procedure for obtaining information on the quantity, quality and condition of the forest resource, associated vegetation and components and many of the characteristics of the land area on which the forest is located.

Forest mensuration: It is a branch of forestry which deals with the determination of dimensions (diameter, height, volume etc.), form, age and increment of single tree, stands or whole woods either standing or after felling.

Form class taper tables: Give for different form classes the diameters at fixed points on the stem expressed as percentages of DBH (UB).

Form class: One of the intervals in which the range of form quotients of trees is divided for classification and use. Also applies to the class of trees which fall into such an interval.

Form point: Point in the crown at which wind pressure is estimated to be cantered.

Form factor: The ratio of the volume of a tree or its part to the volume of a cylinder having the same length and cross section as the tree. (Or ratio between the volume of a tree to the product to the basal area and height).

Form height: The product of form factor and total height of tree or the ratio between the volume to basal area of a tree.

Form point or form height ratio: The relationship usually expressed as a percentage, of the height of the form point above ground level to the total height of the tree.

Form quotient: Form Quotient is the ratio between the diameter at some point above breast height to DBH.

Fractional quality: It is the site quality expressed as decimal subdivision of the height range of half a quality class, the figures running 0.0 to 2.0 within the whole quality class.

GBH: Girth at Breast Height. Diameter is generally at height of 1.37 m from ground level.

GBH (OB): Girth at Breast Height over Bark which is generally measured at height of 1.37 m from ground level.

GBH (UB): Girth at Breast Height Under Bark which is generally measured at height of 1.37 m from ground level.

General volume tables: Average volume of trees growing over a large geographical area are considered for preparation of this type of table by taking two variables as D.B.H. and total tree height.

Girth class: The measured girth of trees is grouped into girth class with an interval for easy record keeping and easy for calculation. The girth classes used in India are 30 cm, 15 cm and 5 cm for large, medium and small sized trees.

Green/ fresh Biomass: Freshly cut plant parts having moisture content more than 70 %.

Global Positioning System (GPS): The use of satellite technology to accurately and consistently identify exact locations.

Growing stock: The sum (by number or volume) of all the trees growing/living in the forest or a specific part of it.

Growth habit: The natural shape of a mature tree or other plant.

Growth impact: A calculation of the extent of insect damage, taking into account the timber losses due to reduced growth rates and deaths of trees.

Growth rings: The rings formed in the trunk of a tree as wood of different densities is produced at different times during the growing season.

Growing stock: All the trees growing in a stand, generally expressed in terms of number, basal area, or volume.

Height class: Height class is one of the intervals into which the range of tree heights is divided for classification and use. In India 1, 3 or 5 meter height classes are used.

Increment: Increase in girth, diameter, basal area, height, volume, quality, price or value of trees or crops during a given period.

Increment boring: The boring of a tree stem with the borer to determine increment of trees with annual rings.

Increment percent: It is defined as the average annual growth in diameter, basal area or volume over a specified period expressed as a percentage of diameter, basal area or volume either at the beginning or more usually halfway between the beginning and end of the period.

Local volume Tables: Only DBH (OB) is measured. Compiled from the measurement of trees growing on restricted locality like a coupe or compartment.

Mean Annual Increment (MAI): It is the mean volume of a tree or crop at the desired age, i.e. the total increment upto a given age divided by that age.

Normal form quotient: Ratio of mid- diameter or mid –girth of a tree to its diameter or girth at breast height.

Ordinary taper tables/diameter taper tables: Gives the taper directly for diameter at B. H. without reference to the tree form. Enable computation of volumes without reference to the tree form.

Periodic Annual Increment (PAI): It is the average annual increment for any short period.

Periodic MAI: When MAI is calculated for a portion of the

total age, then it is known as periodic MAI

Radial growth: Growth resulting in the increased diameter in a tree.

Regional volume tables: Compiled from measurement of trees growing in a region by taking diameter and height as variables, and having limited use.

Rotation age: The age or stage of maturity at which a stand of trees is harvested.

Rotation length: The number of years between planting and harvesting a forest.

Sawn outturn assortment tables: Similar to assortment tables expect that they give sawn outturn in the number of standardized pieces instead of volume in round.

Sawn outturn tables: Volume measured down to a thin end diameter to which conversion is done, stump volume being omitted (gives volume as sawn timber).

Single yield table: Data are given for one grade thinning which is usually C – grade.

Standard stem small wood volume: Volume of stem is calculated between 20cm diameter over bark and 5 cm diameter over bark. (Volume being taken inclusive of bark).

Standard stem timber volume: Volume of stem is calculated from ground level up to 20cm diameter over bark. (Volume being taken exclusive of bark).

Standard volume table: It gives separately the estimated outturn in the form of standard timber *i.e*. from ground level to the limit of the portion of tree stem or branch and small wood*, i.e.* the volume between the diameter limits of 20 cm and 5 cm and both measured over bark (volume is given in terms of round timber and includes volume of stump).

Standard timber bole height: Height of the bole from the ground level up to the point where average diameter over bark is 20 cm.

Stem analysis: It is the analysis of a complete stem by measuring annual rings on a number of cross – sections at different heights in order to determine its past rates of growth.

Stump analysis: Analysis of a stump cross- section by measuring annual rings in order to estimate the age of the tree and its past rate of diameter and basal area growth.

Stump Height: Height of the top of the stump above ground.

Taper: The gradual diameter reduction of a tree or a log from the base to the top.

Tariff Tables: This is the volume table which gives the volume in terms of girth at breast height (GBH) alone, without differentiation of height class. This type of volume table was frequently used in France, Switzerland, and Germany.

Timer calculators (Timer Measurement Tables): Give volume in metric system of round timber (calculated by quarter girth formula) for lengths from 1 to 25 m and girth up to 390cm and for sawn timber for length from 1 to 25m and cross section from 1×1 cm^2 to 25 × 25 cm^2.

Timber cruiser: A person who estimates the volume of marketable timber by taking sample measurements from sites throughout a stand of trees.

Timber yield: The timber volume in a forest on a particular date.

Total height: Straight line distance from the tip of the leading shoot (from the highest point of the crown where there is no leader) to the ground level.

Total increment (TI): It is the increment which a tree or a crop puts on from origin up to the age at which the tree or crop is cut. It is the sum of the CAIs and represents the volume of the tree or the crop.

Total/ complete enumeration: The enumeration of the desired species above the specified diameter limit carried out over the entire area of the forest unit under consideration.

Tree factor: This is the number of trees per hectare/ acre represented by each tree tallied. This is obtained by dividing the associated plot area into the square meter area of one hectare.

Tree quality volume table: It contents the height of an individual tree with respect to its diameter. These tables are applicable to mixed forests where site quality cannot be determined.

Tree stem form: It is the rate of taper of a log or stem. Taper is the decrease in diameter of a stem of a tree or of a log from base upwards.

Volume table: Volume table showing for a giver species the average contents of trees, logs or sawn timber for one or more given dimensions. [given dimension are, (a) d.b.h. alone, (B) d.b.h. and height (c) d.b.h, height and form or taper].

Volume yield table: It is a yield table which expresses outturn in terms of volumes.

Yield: The volume or number of stems that can be removed annually or periodically.

Yield table: A tabular statement which summarizes per unit area basis all the essential data relating to the development of a fully stocked and regularly thinned even aged crop at periodic intervals covering the greater part of its useful life. **Or** It is a tabular statement which summarizes on per unit area basis all the essential data relating to the development of a fully – stocked and regularly thinned even – aged crop at periodic intervals covering the greater part of its useful life. It gives parameters like- number of trees, crop height, crop diameter, crop basal area, volume of standing crop, volume removed in thinning, MAI, C.A.I etc. It gives all the quantitative information regarding development of a crop.

TYPES OF SYSTEM OF MEASUREMENTS USED

British system/F.P.S. (Foot Pound Second) system
French system/Metric system/C.G.S. (Centimeter Gram Second) system.
In both type of system of measurements include four types of units of measurements. The details and uses of these units of measurements are as-

A. **Units of measurement**: There are two systems of measurement followed mainly the world over.
British system (or F. P.S. system) and
French or Metric system (or C. G. S. system).

Units of Length: Units of length in two systems are as follows:

British system: Foot is the unit of length in British system and other measurements of this system are as follows
Metric system: Meter is the unit of length in metric system and other measurements of this system are given below.

British system (or F. P.S. system)	French or Metric system (or C. G. S. system).
12 inches = 1 foot	10 millimeters (mm = 1 centimeter (cm)
3 feet = 1 yard	10 cm = 1 decimeter
66 feet or 22 yards = 1 chain	10 decimeter or 100 cm = 1 meter (m)
1 chain = 100 links(Jarib)	10 meters = 1 decameter
10 chains or 220 yards = 1 furlong	10 decameters = 1 hectometer
8 Furlongs (1760 yards) = 1 mile	10 hectometer or 1000 meters = 1 Km
	meters (International) = 1 nautical mile

Uses: In forestry, the unit of lengths is used

- To express the height of the tree or any point on the tree or crown height, crown length and crown width can also be measured. In British system, unit of length is foot and in Metric system, it is meter.
- To express the height of sumps, height of seedlings, diameters of trees and their sections, both British and Metric systems are used. In British system, inch is used, however, in Metric system, centimeter is used as unit of measurement.
- To express the girth of trees (because trees girth vary from small to very large), unit in British system is feet and in Metric system, meter is used as unit of measurement.

Units of Area: Units of area in two systems are as follows:

British system: Square feet (ft^2) is the unit of area in British system and other measurements of this system are as
Metric system: Square meter (m^2) is the unit of area in metric system and other measurements are as

British system (or F. P.S. system)	French or Metric system (or C. G. S. system)
144 square inches = 1 square foot (sq. ft)	100 sq. (mm) = 1 sq. cm
9 square feet = 1 square yard (sq. yd)	100 sq. cm = 1 sq. decimeter
484 square yards = 1 sq. chain	100 sq. decimeter = 1sq. metre (sq.m or m^2)
10 sq. chains/4840 sq. yards = 1 acre	100 sq. metre = 1 acre or 1 sq. decameter
	100 ares or sq. hectares or sq. decameters
	= 1 hectare or 1 sq. hectometre
	100ha or (100 sq. hectometre)=1sq.km(km^2)

Now a day, we are mainly using metric system as a unit source of measurements.

Uses-

In forestry, unit of area is used to express the forest cover, tree cover, canopy cover in a locality or a region. In British system, square feet (ft^2) and in Metric system, square meter (m^2) are used as unit of measurements.
Also used to express the basal area of trees or logs, in British system is square inch ($inch^2$) and in Metric system is square meter (m^2) or square centimeter (cm^2)

Units of Volume: Useful for timber and firewood volume in Forestry

British system: Cubic feet (ft^3) is the unit of volume in British system and other related measurements of this system is given below:

Metric system

British system (or F. P.S. system)	French or Metric system (or C. G. S. system)
12" x 12" x12" = 1 cubic foot (cft)	1000 cubic mm (cu mm) = 1 cubic. cm (cu cm)
27 cubic feet = 1 cubic yard	1000 cu cm = 1 cu decimetere
12" x 12" x 1" = 1 board foot (bft)	1000 cu decimeter = 1 cubic metre (m^3)/cu m

12 board feet (an American measure) = 1 cubic foot.	

Uses-

In forest mensuration the units of volume are used to express the volume of a tree in standing or felled condition, in British system is cubic feet (ft^3) and in Metric system is cubic meter (m^3).

Also express the volume of trees in forest or in a stand in British system is cubic feet (ft^3) and in Metric system is cubic meter (m^3).

In forest mensuration, cubic metre (m^3) is used as the basic unit for tree volumes but as It is a fairly a large unit, it is not as popular in trade as the cubic foot (cft).

Units of Weight:

British system: Pound (lb) is unit of weight in British system and other measurements are as

Metric system: Kilogram (kg) is the unit of weight in metric system and other measurements are

British system	Metric system	Indian system (Earlier)
16 ounces = 1 pound 28 pounds = 1 quarter 4 quarters = 100 wt.(cwt.) 20 cwts. = 1 ton	10 grams = 1 decagram 10 decagrams = 1 hectogram 10 hectograms = 1 kilogram 100 kg = l Quintal(qt1) 1000 kg = 1 metric ton	8 Ratties = 1 masha 12 Mashas = l Tola 5 Tolas = 1 Chhatank 16 Chhatank = 1 Ser 40 Ser = 1 Maund Note Not in vogue at present

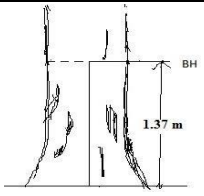
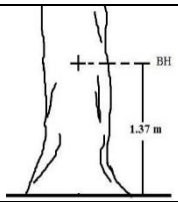
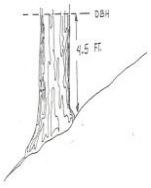
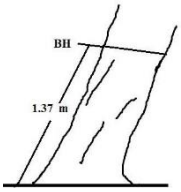
Uses: Different kinds of forest products like fuel wood, charcoal and other minor forest products are generally expressed in British system is pound and in Metric system is kilogram (kg).

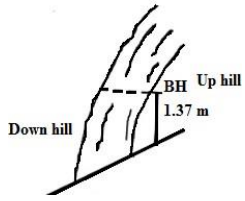
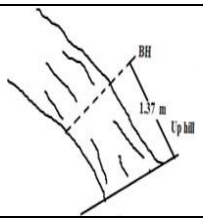
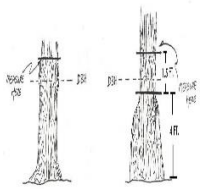
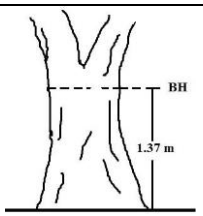
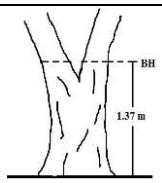
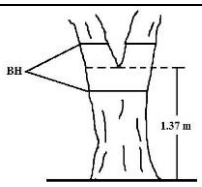
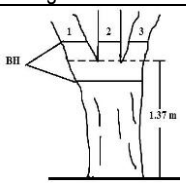
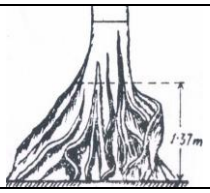
Conversion Factors: As some of the records (especially land area) are still available in British system and are being used intentionally or inadvertently, the conversion factors of commonly used, which are presented below as

F.P.S. to C.G.S	C.G.S. to F.P.S.
(a)Length: 1 inch = 25.4 mm 1 foot = 30.48 cm 1 yard = 0.9144 metre 1 Mile = 1.609344 Km **(b) Area** 1 sq. inch = 6.4516 sq cm 1 sq. foot = 9.2903 sq. decimaters 1 sq. yard = 0.83613 sq. m. 1 acre = 0.40468 hectare **(C)Volume:** 1 cubic inch = 16.3872 cu cm 1 cubic feet = 0.283 cu m **d) Weight:** 1 pound = 0.4535924 Kg 1 ton = 1.01605 metric tonnes	**(a)Length:** 1 cm = 0.393701 inch 1 metre (m) = 1.09361 yards 1 km = 0.62137 mile **(b) Area** 1 Square metre = 1.19599 sq. yards or 10.7639 sq. feet 1 hectare = 2.47105 acres **(C)Volume:** 1 cu centimetre = 0.0610 cu inch 1 cu metre = 35.3147 cu feet **d) Weight:** 1 Kilogram = 2.20462 pounds 1 metn'c tonne = 0.98420 ton

STANDARD RULES GOVERNING BREAST HEIGHT MEASUREMENTS OF TREES

Procedure: Generally, trees are grown in different situations like plane ground, hilly area, sloppy area, undulating area, *etc*. In such situation, single rule may not be feasible to get a precise data of DBH or GBH of standing trees. Hence, there are sets of rules governed during measurement of DBH or GBH based on situation of standing trees and these rules are explained below with figures. In all the situations, either DBH or GBH is measured at the height of 1.37 m from the ground level. However, position and direction while measuring/ recording this observation may vary according to situations.

			
Rule 1: Breast Height should be marked by means of a measuring stick on standing trees at 1.37 m (4ft 6 inch) above the ground level.	**Rule 2:** The Breast Height point should be marked by inserting vertical and horizontal lines of 12 cm long, painted with white paint. This is known as cross mark	**Rule 3:** On sloping ground, the diameter at Breast Height should be measured on the uphill side.	**Rule 4:** If the tree is leaning on flat ground then DBH or GBH is measured along the tree stem (i.e.- parallel to the stem), not vertically from the ground

			
Rule 5: If the tree is leaning on sloping ground, then DBH or GBH is measured on the uphill side.		**Rule 6:** When there is any abnormality found at the Breast Height, then B.H. mark should be shifted wither up or down as little as possible to a more normal position of the stem, where diameter or girth is measured.	**Rule 7:** When the tree is forked above the Breast Height, it is counted as single tree and diameter or girth is generally measured at Breast Height.
			
Rule 8: If the tree is forked below the Breast Height, then each forked stem should be treated as separate tree and DBH or GBH should be measured and recorded separately.	**Rule 9:** When forking renders the Breast Height point as abnormal, then the foregoing rules such as rule 7 & rule 8 should be applied and the tree counted as one or two depending on the place of measurement.		**Rule 10:** When buttress formation is found at the base of the tree which likely to extend upwards with the development of the tree, then the Breast Height should be taken at the lowest point above which the abnormal formation is not likely to extend.

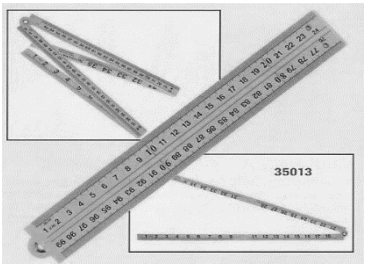
Rule 11: Moss, creepers, lichens and loose bark found on the tree must be removed before measuring the diameter or girth over bark.

Rule 12: Diameter measurements should be recorded in centimeters and to the nearest multiple of two millimeters. Girth should be measured in meter and to the nearest centimeter.

INSTRUMENTS ARE WIDELY USED FOR MEASURING DIAMETER OR GIRTH TREES

Procedure: In this experiment, you are learning about different instruments used while measuring diameter or girth of standing or fallen trees.

Wooden scale: Wooden scale is a flat wooden piece marked in centimeters and millimeters. It is available in two sizes, viz., 30 cm and 60 cm. The 30 cm wooden scale is about 3 cm wide but the 60 cm wooden scale is about 1.5 cm wide and has folding arrangement at every 15 cm length. It is first folded at 30 cm in such a way that both lengths come side by side and are held together with two small metal nails projecting from the thick end of the scale of the first 30 cm length and fitting in to the tiny holes in the other half , thus making the instrument 3 cm wide. After that is the instrument is folded along its length so as to become 15 cm long 3 cm wide wooden. It is used for measuring diameter of stump or end sections of logs exposed as a result of cross cutting.



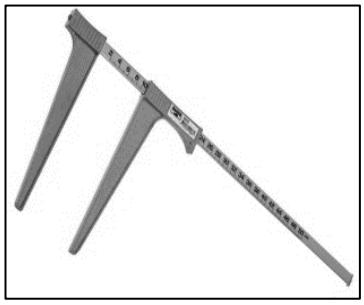
Precautions during use of Wooden Scale (Measurement scale)

- On cut stem/ stump, diameter should be measured along line passing through the pith. In case of eccentric stumps or logs, two diameters *i.e.,* one along the major axis and the other at right angles to the first, should be measured.
- In case of worn off conditions of wooden scale (between 0 and 1 cm scale), the measurement should be taken from first centimetre. In such case care should be taken to deduct one centimetre from the final reading to get correct diameter.
- The scale should be placed on exact edge of the stump so that the end of the line to be measured coincides with the mark of the scale.
- While reading measurement on the scale, the eye should be just above the mark, *i.e.* the line joining the eye with the end of the line joining measured should be perpendicular to the line.

Uses of wooden scale:

- It is used for measuring diameter of stump or end sections of logs exposed as a result of cross cutting.
- Radius measurement for successive decade marks for stump and stem analysis for determination of growth rate of trees.
- Generally, wooden scale is used for measuring diameter of cut stump. However, it is not used for measuring diameter of

standing tree. For this, tree calliper is used.



Callipers: Callipers are used to measure diameter of standing trees and logs. They consist of a graduated rule and two arms. Of the latter, one is fixed at right angles to one end of the rule so that its inner edge lies on the starting point of the graduated scale. The other arm moves along the rule parallel to the fixed arm. The lengths of the rule and the arms depend on the sizes of trees to be measured. Each arm should be at least half the length of rule. Callipers exceeding 120 cm in length are rarely used. The rule is divided into units, the size of which depends upon the desired degree of accuracy. Callipers used for research or sample plot work are generally marked to show centimeters and millimeters. But those used for routine forest works are marked in centimeters and show diameter classes painted in different colours to facilitate their reading by illiterate workers.

Precautions during use of Calliper

- The calliper must be placed on the tree with movable arm well opened and must not be forced on the tree, thereby causing stress or damage to the arms.
- The reading should be taken before removal of calliper from the tree.
- In case of elliptical shapes of bole/ trunk, two diameter measurements are required *i.e.* one along the major axis and other along the minor axis at perpendicular to major axis. Then, average of these two diameters will express as diameter of the tree.
- Calliper must be placed at right angles to the axis of the tree during diameter measurement.
- The two arms as well as movable arm should be contact with the tree and movable arm must be at right angles to the graduated arm.
- Similarly, the graduated arm also touches the bole of the tree.

Uses: Calliper is used to measure diameter of standing trees or felled logs.

Tape: It is a band of cloth, reinforced cloth, plastic or steel about 1.5 cm wide and of varying length and is used to measure girths of trees and logs. It is usually graduated on one side in centimetre and millimeters but sometimes it is graduated on both sides to give measurements in metric system on one side and those in British system on the other. The ends of the tape are usually plated with some metal to prevent their tearing off but in case of longer tapes which are kept encased in some cover by winding it in, or in some other cases too, the beginning of the tape has a metal ring to hold it. In western countries tapes are often provided with hook at the extremity to fix in the bark, an arrangement which enables one person to measure large trees with tapes lying flat in correct position on the tree. The cloth tapes are made of cloth, though they may be painted with some paint on both sides to give a better look and to protect them from the influence of water. These are cheap but are not very durable. They are also affected by fluctuations in length due to expansion in use. The better quality cloth tapes are usually reinforced inside by metal wires and are, therefore, called metallic tapes. They are also painted with some durable paint. So they are more durable and more reliable. Steel tapes are used for precise work and are mostly used in forests for measurements -in sample or research plots.

Precautions during use of Tape

- The tape should be of new one and avoid using old tape.
- In case, end of tape is worn-off, then take the measurement fro1m next centimetre and during final reading deduct the value from the observation.
- Tape must be flat against the tree and not in twisted manner.
- Also lie in a plane perpendicular to the axis of the tree otherwise error occurs.
- Sufficient care should be taken to see that no climber or creeper has vitiated around the stem.
- The end of the tape should be in right hand of the measurer and starting point should be in the left hand.
- The tape should not be trailed on the ground and not be rolled when or twisted.

Uses: Tapes are used to measure girth of trees and logs as well as length of logs.

Wheeler Penta Prism: Wheeler Penta Prism Caliper is a precision optical-prism to measure diameters of trees accurately at any point on tree from any clear, convenient, sighting position. No base line distance is required. It gives diameters correct to # 2 mm. It uses two Penta -prisms to maintain parallelism in the lines of sight. Of these left hand prism is fixed while the right hand prism can be moved along the scale. The reflection of the right side of stem is brought into coincidence with the left by moving the right hand prism. In order to use the instrument, it is held about 8-10 cm from the eye. The observer then looks through viewing slot. Through the upper part of the slot, he sees the left edge of the tree through the lower part, the right edge of tree reflected in the stationary prism.

DBH (OB) AND GBH (OB) MEASUREMENT

Materials required: Caliper, Tape, Chalk, Stick of 1.37 m length.
Procedure for DBH (OB) measurement: DBH of standing trees or logs are generally measured by caliper. In order to use caliper, the handles of the two arms of it's held in two hands. The movable arm is then tilted inwards so that it can move freely and moved in that position. After this, the two arms are separated enough to receive the tree between them without touching. When the tree touches the graduated rule, the movable arm is shifted inwards in the tilted position so that the tree touches the fixed arm and movable arm. In this position, the movable arm is then slowly brought in perpendicular position to the graduated scale and pressed so as to squeeze out any loose bark as well as ensure that there is no gap between the arms and the tree. The diameter is then read off on the graduated rule.
Procedure for GBH (OB) measurement Generally tape is used for measurement of GBH (OB) of trees. In order to use this, the tape is encircled around the bole of tree. The point of measurement should be at right angle to the main axis of tree. It should be held tightly to avoid over estimation. The reading should be recorded.

SWEDISH BARK GAUGE

Materials required: Swedish Bark Gauge, Measuring Stick.
Procedure: Bark gauge is in the form of a chisel which is pushed into the bark. It is also provided with a cross arm which is curved to fit-in with the curved tree surface. At the back of this, curved arm is fitted a tube which moves on chisel which is graduated in inches and tenths or centimeters and millimeters.
When the cross arm is at the extreme edge of the chisel, the tube touches the zero point. Mark the height where bark thickness is to be measured on the tree with the help of measuring stick and record it. At the point of measurement, push the chisel and as the edge penetrates the bark the tube is pushed back and the extent of penetration *i.e*., the thickness of the bark is read off on the scale. Follow the same method for getting the bark thickness in another three points on the same height and average of these four readings will give the bark thickness. Therefore, this instrument is used to measure bark thickness in different trees at different condition. Further, thickness of bark varies from species to species as well as within species from base to top.

BARK THICKNESS

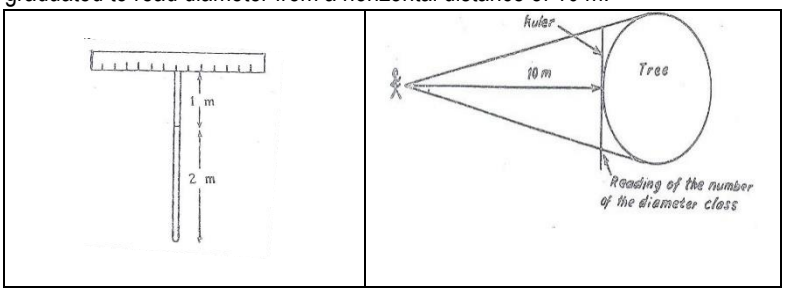
Procedure: For trees, DBH (OB) and GBH (OB) are first measured by following the standard procedure (As per experiment 4) of diameter and girth measurement at Breast Height. After this, bark thickness is measured as per experiment 5. From these data, DBH (UB) or GBH (UB) is calculated as per the following formulas:

DBH (UB) = DBH (OB) – 2(t), where „t' is the bark thickness
GBH (UB) = GBH (OB) – 2π(t), where „t" is the bark thickness

Here, unit of both the parameters-GBH/DBH and Bark thickness should be same.

MEASUREMENT OF TREES

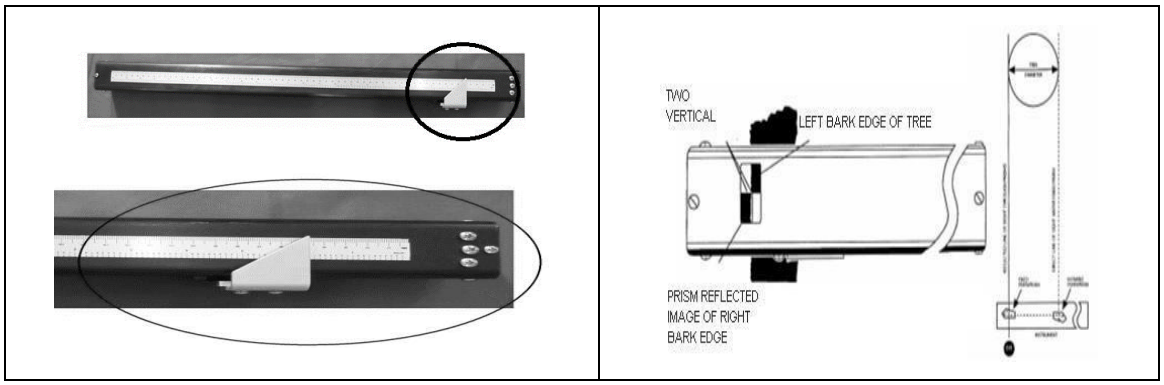
Required material- Ruler, Wheeler Penta Prism, Spiegel Relaskop, Dendrometer, field note book
Procedure: It is important to determine the diameter of trees at different heights for estimation of volume of standing trees. The instruments used for upper stem diameters are:
Ruler: This is a simple board of 150 cm x 10 cm x 1 cm with a one-meter rod attached to the middle. On this rod, a detachable handle of 2 m long can be fitted. The board is painted white with diameter marked on it with black paint. The diameter marks are not exact linear measurement but slightly corrected to avoid parallax errors. The Ruler is usually graduated to read diameter from a horizontal distance of 10 m.



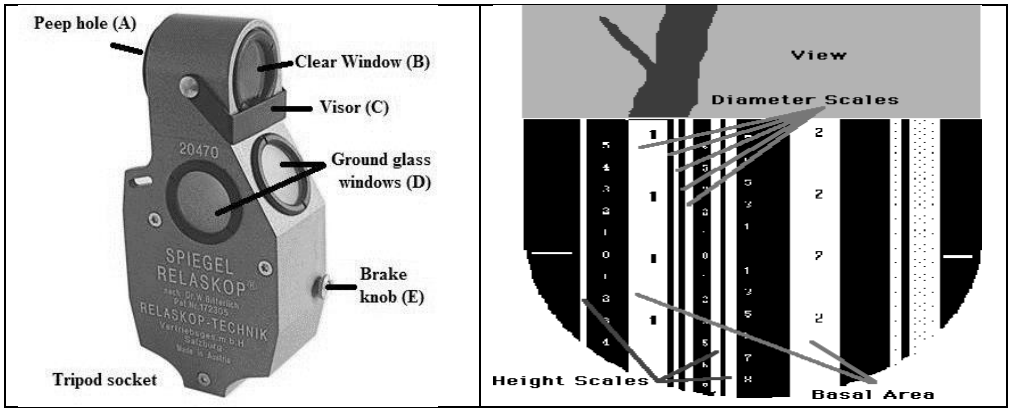
The ruler is usually graduated to read diameters from a horizontal distance of 10 m. In order to use the instrument, the observer stands at a horizontal distance of 10 m from the side i of the tree. A helper places the ruler against the tree at the height of measurement, keeping it perpendicular to the line of sight and the left edge of the rule r in line with the left edge of 2 m the stem in relation to observer. The diameter can then be read on the right-hand part of the ruler.

Wheeler Penta Prism: It is a precision optical-prism device to measure diameters of trees accurately at any point on the tree stem from any clear convenient sighting position. No base line distance is required. It gives diameters correct to ± 2

mm. It uses two penta-prisms to maintain parallelism in the lines of sight. Of these, left hand prism is fixed, while the right-hand prism can be moved along the scale. The reflection of the right side of stem is brought into coincidence with the left by moving the right-hand prism.
In order to use the instrument, it is held about 8-10 cm from the eye. The observer then looks through viewing slot. Through the upper part of the slot, he sees the left edge of the tree through the lower part, the right edge of tree reflected in the stationary prism.



Spiegel Relaskop: This is a small instrument and it contains a drum pendulum with graduations (measuring bands) precisely mounted on roller bearings, which is fitted inside the sturdy metal case. On the outer case, there is a peep-hole (A) at the top; on the back side, a clear window (B) in the top front in line with the peep-hole; a visor (C) used for shading the scales from bright sun light; three circular windows (D; two on sides and one in front) to provide light to the interior, particularly on the measuring bands; a button (E) which when pressed, frees the weighted drum and when not pressed it keeps the drum locked (All these parts are marked in the figure). The instrument can be used in hand or may be fitted on tripod for accurate readings for which a socket is provided in the case. Looking through the peep-hole (A) and window (B), there is clear wide-angle field of vision which is which is divided into two halves horizontally by a sharp line. In the upper half, the observer views the terrain and the trees. In the lower half, sees the bases of the trees as well as the scales. All the readings are taken where the scales touch the line.



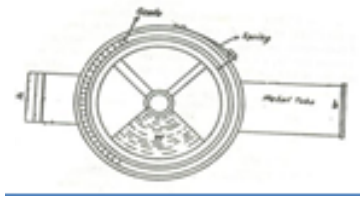
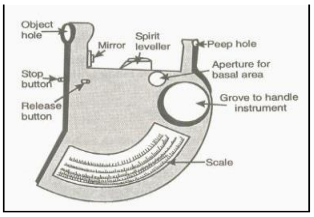
The Australian made Spiegel Relaskop contains the following scales from left to right: The 20 m height band, Band 1, The 4 narrow bands *i.e.* 2 white ones and 2 black ones in between, The 25 m height band. The 30 m height band, Band 2 and 7. The range finder bands Band 1 and 4 narrow bands are used for measuring tree diameter at any height on the tree stem.

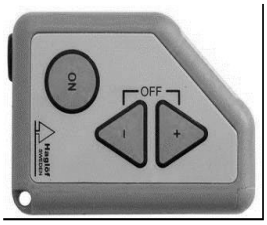
Dendrometer: The Criterion RD 1000 Dendrometer is primarily an optical device that provides real time results for calculations that have to do with the principle of Basal Area Factor (BAF), tree height and diameter. This instrument is built in laser technology, which helps in measuring the diameter of trees at different heights. This instrument is built up with following features:

In-scope LED offers adjustable brightness levels and projects a measurement bar scale that represents a subtended horizontal angle. The instrument uses this angular measurement and the horizontal distance to the target tree to calculate the diameter of the tree stem.
Further, Tilt sensor of this instrument measures vertical angles which uses to determine the slope-reduced measured distance to calculate height. An attachable magnifier can be used when measuring diameters in situations that require maximum measurement resolution.

INSTRUMENTS FOR MEASUREMENT OF TREE HEIGHT

As height is an important parameter for volume estimation, preparation of volume tables and determination of site index. Therefore, in this experiment, different instruments used to record height of the trees in different situation are explained.

Abney's Level: It measures the height of a tree as well as in making contours in hilly terrains (Fig.10 a). This instrument consists of different parts- 1). An eye piece; 2). 2-3 hollow tubes which can be inserted into one another; 3). Far end with horizontal wire; 4). Vernier scale and a magnifying glass; 5). A leveler with a bubble inside; 6). Mirror which shows the bubble of leveler; 7). Screw for rapid and fine adjustment of leveler.	
Brandis Hypsometer: It measures angle between observer and the object (Fig. 10 b). It has two main parts- a). hollow tube for looking the object and b). wheel on which scale depicting angles is marked. On the upper part of the wheel a stopper is provided. When the stopper is pressed, it allows the move freely under the influence of gravity and when released, it makes the scale stationary at that position. When instrument is kept at horizontal position, scale gives zero reading. The scale has marking up to 60 on both sides of zero mark.	
Haga Altimeter: It looks like a pistol having a protruding handle, a peep hole and a object hole (Fig. 10 c). A stop button and a release button for controlling needle are provided. Needle moves freely on gravity. It has 5 scales (15m, 20m, 25m, 30m and % scale) which are marked on a bar. One scale at a time can be read. For selecting rest of the scale a knob need to be moved clock wise or anti-clock wise. The 15m scale is marked up to 26m on left side of zero and up to 6m on right side of zero mark. 20m scale up to 35m and 6m, 25m scale up to 45m and 10m, 30m scale up to 52m and 12m, per cent scale up to 150 % and 40 % on left and right side of zero mark respectively. 15m, 20m, 25m and 30m scale gives height of tree in meters and per cent scale gives height as per cent of the distance.	
Ravi Multimeter: It is provided with two different scales 20m and 30m. In addition, it has per cent scale, degree scale and scale for correcting sloping distance (Fig. 10 d). All these scales are visible simultaneously. On the observer side, it has a grove to handle the instrument while taking the observation. A peep hole and an object hole are provided. A stop button is present at the far end and release button on front of the instrument. It also has an aperture to measure basal area and a leveler for measuring crop height.	
Ravi Altimeter: It is similar to that of **Ravi multimeter** in operation, where altimeter has less function than multimeter. It measures only height on leveled and sloping ground (Fig. 10 e). Thus, it has the same five scales and method of using is also same. Only difference is that it is not provided with mirror, leveler, aperture and turning knob.	
Spiegel Relaskope: This is a small instrument and it contains a drum pendulum with graduations (measuring bands) precisely mounted on roller bearings and is fitted inside the sturdy metal case (Fig. 10 f). The detail of this instrument is described in the experiment 4. To find out the height of the tree from 20m, 25m or 30m distance from the tree, 20m scale is the first scale in Spiegel Relaskope from left hand side. After leaving the band 1 and four narrow bands, 25m and 30m height measuring scale are located. These scales are used for height measurement of trees.	
Clinometer/ Silva Ranger Compass: It is the finest hand compass available for professional use (Fig. 10 g). It is finely crafted to withstand rigors associated with the outdoor professions. It is a rugged, durable piece of equipment that, with proper care, will remain dependable and accurate. The Silva Ranger compasses are practical instruments for measuring angles of inclination. The long side of the compass coincides with the slope of the terrain.	

Electronic Clinometer (HEC) It is a small, helpful instrument for professional measurements of heights and angles (Fig. 10 h). Heights can be measured from any distance and position, which makes this instrument especially useful in adverse conditions. **Functions:** Select function by pressing the button. **1-DIST** for Distance setup and height measuring (m/ft) **2- HGT** for Height Measuring (m/ft) **DEG** for Angle measuring (%/º)	
Vertex Laser Hypsometer: This instrument uses laser technology to calculate distance and a high quality tilt sensor to measure angles (Fig. 10 I). The laser method can be used with or without the use of the tilt sensor and vice versa. The laser method allows long distance measuring and a quick presentation of measuring results. Data on heights, distances and angles can be transferred through a built-in Infrared transmitter or by Bluetooth to a PC or HHC, for storage and further processing. For transfer of results, a serial IR receiver for the external device is available as an optional accessory to the instrument. The Laser emits invisible, eye safe infrared energy pulses that reflect off the selected target back to its optical receiver. The laser is classified as Class 1 and as Class 3 a. By measuring the time, it takes for each pulse to it takes for each pulse to travel from the rangefinder, to the target and back with sophisticated precision charge circuitry, the instrument instantly calculates distances. The maximum range of the laser measuring method depends on the target"s reflectivity, its colour, surface, finish, shape and size	

TREE HEIGHT MEASUREMENT BY ABNEY'S LEVEL

Materials required: 1. Tape 2. Abney's level

Procedure: In order to use the instrument, the observer stands away from the tree at a place where the top and base of tree are visible. This make the instrument inclined and the bubble is not seen in the mirror. Therefore, while sighting the top, the screw is rotated to bring the spirit level in the horizontal position. As the sprit level approaches horizontal position, the bubble appears on the edge of mirror. The spirit level is continued to move slowly to the position when the bubble image is bisected by the line of horizontal wire on the mirror and the other half the tree is seen touching the horizontal wire. At this position, the index arm reads the angle of elevation to the top of the tree on the circular arc. Similarly, the angle of depression to the base of the tree is also read.

The height of the tree can be determined by using tangent or sine method: If AB = Height of tree, ED/EB = Horizontal distance, EF = Eye height, α = Angle of elevation and β = Angle of depression Then height of trees can be calculated according to their condition of presence: I- Tangent Method- If Conditions are like

1. On level ground: AB =ED Tan α + EF
2. On sloping ground, where the top of the tree is above the eye level and base below it:
   AB = EB Cos β (Tan α + Tan β)
3. On sloping ground, where the top and base of the tree are present above the eye level:
   AB = EB Cos β (Tan α - Tan β)
4. On sloping ground, where the top and base of the tree are present below the eye level:
   AB = EB Cos β (Tan β- Tan α)

TREE HEIGHT MEASUREMENT BY RAVI ALTIMETER

Materials required: 1. Tape, 2. Ravi altimeter

Procedure: This is an instrument made up of metal. There was a hole to hold the instrument. An eye piece is avail to sight the object. A pointer is controlled by two livers. This pointer gave the height of tree. To free the pointer, side liver is pressed and to fix the pointer, the front liver is pressed. First a point was selected where both base and top of the tree was clearly visible and the distance was measured. Then, the instrument was hold by thumbs and released the pointer by pressing side liver. The top of the tree was sighted through eye piece. When top of the tree was viewed by pressing the front liver, the pointer was fixed and the height of the tree was read on per cent (%) of height scale. Then, base of the tree was sighted and reading on per cent (%) of height scale was noted. Later, the total height of the tree was found by adding both the heights. The height is also determined by taking observer distance at 20m or 30m from the tree. In both cases, similar process is adopted, but height readings of the tree is noted directly from 20m or 30m scale on Ravi altimeter depending upon observer distance from the tree. This scale is depends upon the height of the tree and observer distance.

FARM FACTORS

The form of trees varies among trees according to their presence *i.e.* open or dense forest conditions. Similarly, it also varies with age of trees from juvenile to mature stage.

Materials required: 1. Measurement Tape, 2. Tree Caliper and 3. Dendrometer

Procedure: The form of trees can be studied by comparison of standard form ratios which is of two types *viz.* form factor and form ratio.

I. **Form Factor:** It refers to the ratio of the volume of a tree or its part to the volume of a cylinder having the same length and cross section as the tree. (Or it is ratio between the volume of a tree to the product to the basal area and height)

Form factor (F) $= \frac{V}{Sh}$

Where, V= Volume of tree; S = Basal Area and h = Height of tree

Classification of form factor

Artificial form factor (Breast height form factor): Basal area is measured at breast height (BH) and the volume refers to the whole tree both above and below the point of measurement of BH.
Absolute form factor: Basal area is measured at any convenient height but volume and height of the tree are above the point of the measurement (Ratio between the volume of the tree above the point of diameter or basal area measurement with the cylinder which has the same basal area and whose height is equal to the height of the tree above that point).

Normal (tree) form factor: Basal area is measured at a constant proportion of the total height of the tree. *E.g.,* 1/10th, 1/20th, etc. (average of these measurement will give the basal area) of the total height and the volume and height are calculated and measured respectively for the whole tree above ground level.

Form Quotient: (Developed by A. Schiffel)

F.Q $= \frac{Mid-diameter}{DBH}$ **or** $= \frac{Mid-girth}{GBH}$

Form Quotient is the ratio between the mid diameter and DBH or ratio between the mid- girth and GBH.

Classification of form quotient

Normal form quotient: Ratio of mid- diameter or mid –girth of a tree to its diameter or girth at breast height, respectively.

Absolute form quotient: Ratio of diameter or girth of a stem at one half of its height above the breast height to the diameter or girth at breast height, respectively.
As per availability of instrument, the form quotients of trees are determined. For this, measure the mid-diameter and diameter of a stem at one half of its height above the breast height with the help of dendrometer. Later, measure DBH of tree using callipers.

VOLUME ESTIMATION

Material required: 1. Ravi altimeter, 2. Calliper, 3. Tape, 4. Pentaprism or Dendrometer (as per availibility)

Procedure: Volume of standing trees can be measured by different methods such as Ocular, Partly ocular and partly measurement, by direct and indirect measurement, by volume tables
For getting relatively more accuracy, the last two methods *i.e.*-direct measurement and volume tables methods are used.
Direct measurement method

First method- In this method, generally, the diameter of tree(s) decreasing from ground level to top (called as tapering). So the shape of the tree bole is in the form of a cone. The volume of the tree up to commercial bole height is calculated. For example, the volume of tree can be calculated by assuming tree shape as conical. In the direct measurement method, commercial bole height is measured by Ravi altimeter and DBH (diameter at breast height) by caliper and used in the volume estimation by assuming tree in the conical form. Again, if the stem or trunk of a tree is in cylindrical shape up to commercial or merchantable bole height, then DBH and commercial bole height to be measured as per above mentioned procedure. In case of estimation of volume of entire tree, the same procedure is followed by measuring total height and DBH. In all the above cases, appropriate formula can be used for determination of volume.

by General formula- **If the tree is in conical shape**

$V = S \times H/3$
$= (\pi D^2/4) \times H/3$
$= \pi D^2 H/12$

Where, V= Volume of tree (m^3); S= Basal Area of tree (*i.e.* $S = \pi D^2/4$ & unit is m^2); H= Commercial bole height or height of tree (m).

If the tree is in cylindrical shape

$V = S \times H$ where V= Volume of tree (m^3); S= Basal Area of tree (*i.e.* $S = \pi D^2/4$ &

$= (\pi D^2/4) \times H$ unit is m^2) and H= Commercial bole height or height of tree (m)

MEASUREMENT OF LOGS

Materials required: 1. Caliper, 2. Measurement Tape

Procedure: Measure the length of log by Tape and then measure the diameters at different points like at any point, mid-point, thick end and thin end of log by Caliper as per the requirement.

The volume of log can be determined according to the form of log *i.e.* either cylindrical or taper. After getting the above mentioned parameters, the volume can be determined by using different formulae.

ESTIMATION OF VOLUME

Materials required: 1. Caliper, 2. Measurement Tape and 3. Bark Gauge

Procedure: Measure the length of log by Tape and then measure the diameters at different points like at any point, mid-point, thick end and thin end of log by Caliper as per the requirement. At mid-point, measure the bark thickness of the log with the help of Bark Gauge. After getting the bark thickness, convert the diameter over bark (DOB) into diameter under bark (DUB) by using the formula:

DUB= DOB –2T (T= Bark thickness) Then, convert the DUB into GUB by using formula

GUB= π x DUB

The volume of log can be determined according to the form of log *i.e.* either cylindrical or taper. After getting the above mentioned parameters, the volume can be determined by using different formulae:

Volume calculation of logs of cylindrical form (under bark)

General formula (Measure the diameter at any point of log) $V = S \times L$

Where, S= Basal Area; L= Length of log

Quarter Girth formula (Measure the diameter at middle of log) $V = (G/4)^2 \times L$

Where, G= Girth at mid-point of log; L= Length of log

Volume calculation of logs of taper form (under bark)

Smalian"s formula, (Measure the diameter at thick end and thin end of log) $V = (S_1 + S_2)/2 \times L$

Where, S_1 = Basal Area of thick end cross section; S_2 = Basal Area of thin end cross section and L = Length of log

Huber"s formula (Measure the diameter at middle of log) $V = Sm \times L$

Where, Sm = Basal Area at middle of log and L = Length of log

Newton"s formula (Measure the diameter at thick end, middle and thin end of log) $V = (S_1 + 4\,Sm + S_2)/6 \times L$

Where, S_1 = Basal Area of thick end cross section; S_2 = Basal Area of thin end cross section; Sm = Basal Area at mid-point and L = Length of log

Quarter Girth formula (Measure the diameter at middle of log) $V = (G/4)^2 \times L$

Where, G= Girth at mid-point of log and L= Length of log

DETERMINATION OF AGE

Materials required: 1. Increment borer, 2. Measurement Tape, 3. Sterilized wood or wax

Procedure: Generally coring is done at the beast height to determine age of a tree. Firstly, the borer is held firm in the handle. After clamping the borer on the handle, the instrument is screwed in a radial (clock wise) direction into the tree at right angles to its axis to the desired depth after removing the bark. So, a cylindrical column of wood enters the hollow borer and is served from the tree from all four sides at breast height. After this the wedge is inserted between the column of wood and the inner wall of borer with its toothed edge towards the former. Then the wedge is screwed backward one or two turns to break the base of the column from the tree. The instrument is then screwed back (anti clock wise) further to take it out and when it is out of the tree, the core is pushed out gently by brass rod into the cradle for counting of rings. After this keep the cores of wood in the cradles for air dry. After drying, rub down the wood core by different grits of sand paper for better visibility of annual rings to naked eyes. Then each annual ring is cross matched from all four core samples by counting to avoid any false ring or missed ring. The total number of annual rings gives the age of a tree. It is also advisable to seal the bore by sterilized wood or wax to prevent subsequent damage to the tree.

STUMP ANALYSIS

Material required: 1. Measurement Tape, 2. Pin and 3. Pencil

Procedure: For stump analysis, sound stumps of trees having rotation size or over are selected. Care should be taken that stump should not have excessively suppressed or extreme closeness rings. The stumps should be of the average trees so that they can serve as representatives of the crop. Give cross- cut to selected stumps for clear visibility of annual rings. Stump height and under bark girth of each stump then measured and recorded.

If old stumps are not available, trees are specially selected and felled. The trees should be of the rotation size and over and should be representative of the site quality. They should be of the typical shape and development and avoid the suppressed, markedly dominated and abnormal or malformed. After selection, the DBH is measured and recorded then the tree is felled. As felling cut is seldom smooth and horizontal, hence the stump is cross-cut by a saw to remove a disc leaving smooth and horizontal cross-section.

By counting the annual rings on the stump give the age of the tree above stump height. During this counting avoid the false or incomplete rings. Incase presence of a greater number of false or incomplete rings, four radii angularly as far as possible with length not appreciably longer than the calculated average are marked on the stump with pencil. If rings are not clearly visible, the surface is moistened with water or chiseled along the marked radius. On each radius, decades (10 rings) are counted from pith outwards and a pin inserted at each decade, leaving incomplete decade (odd rings) on the outer periphery. Incomplete or false rings are not counted. To ensure this, pins are fixed at each decade independently on all the four radii and then checked to see that all the 4 pins of the same decade lie on the same continuous ring.

Again the time taken by tree to reach the stump height can be determined by cutting the seedlings of the same species in the ground level which is equal in height to the height of stump and age can be found out by counting the annual rings (the number of years for a young tree to reach stump height varies from 1 year for sprouts of broadleaved species to 20 years for coniferous seedlings growing on dry sites). Other way raises seedling of same species up to the stump height and add the same time taken to attain the stump height to total calculated rings by adding the age of tree above stump height and below stump height the total age can be determined.