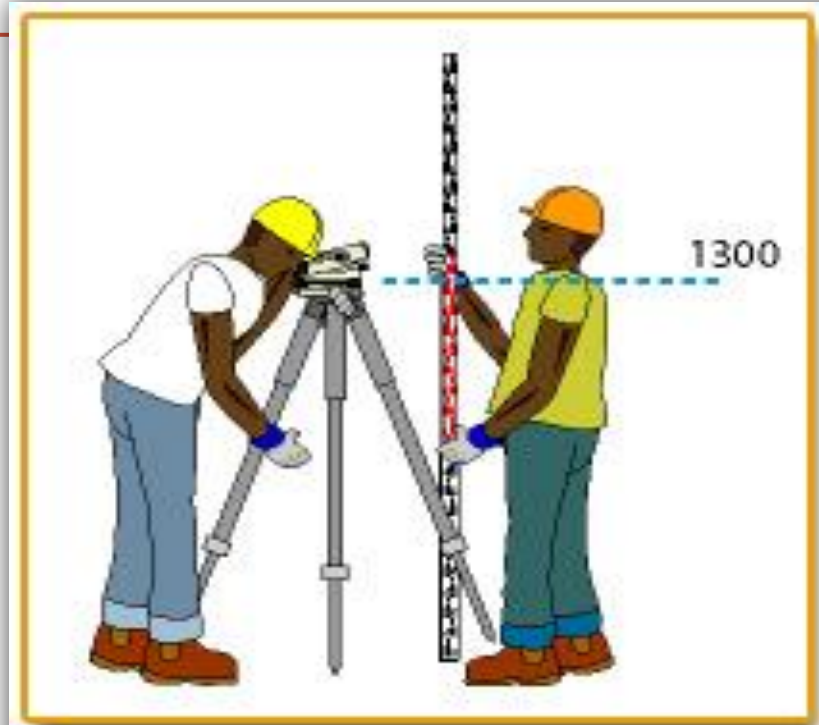


# LEVELING

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# Leveling:

- Leveling is an art of determining relative height of different points on the surface of earth.
- It deals with the measurement in vertical plane.

OR

- Leveling is an operation in surveying performed to determine the difference in levels of two points. By this operation the height of a point from a datum, known as elevation, is determined.

# Important Terms:

## Level Surface:

- Level surface is any surface parallel to mean spheroidal surface of earth. E.g. surface of water in still lake.

OR

- A level surface or level line is one at which all points is normal to the direction of the force of gravity as defined by a freely suspended plumb-bob.

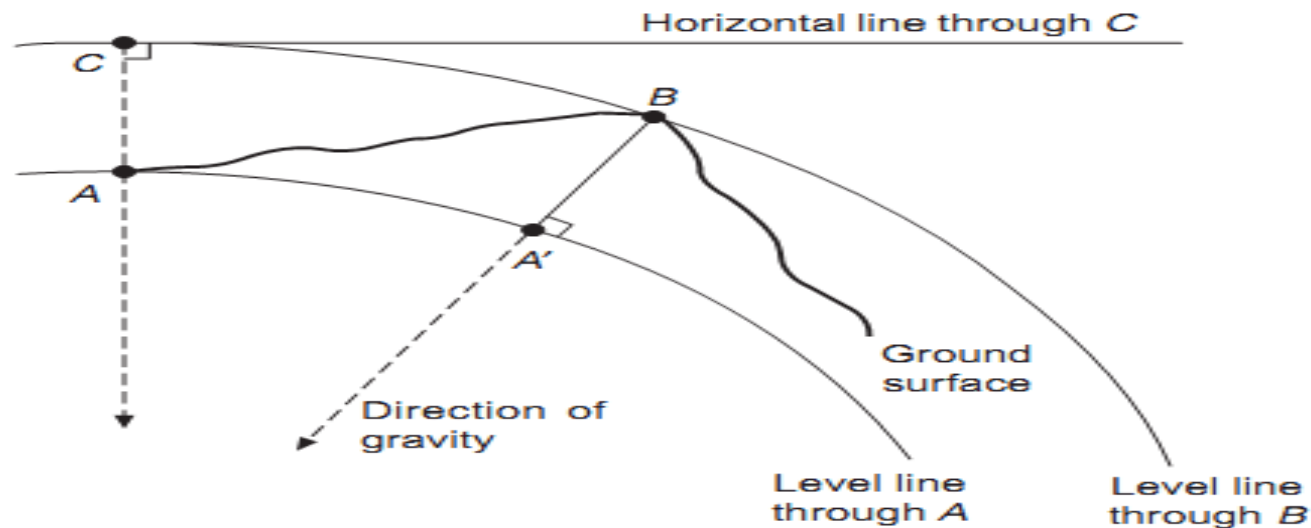


Fig. 4.1

## Important Terms

### **Level Line:**

- Any line lying on a level surface is called level line.

### **Horizontal Plane:**

- Horizontal plane through a point is a plane tangential to level surface passing through that point.
- It is perpendicular to the direction of gravity (vertical plane).

### **Horizontal Line:**

- Any line lying in the horizontal plane is horizontal line.
- It is a straight line tangential to level line.

### **Vertical Plane:**

- A plane is called vertical if it contains vertical lines.

## Important Terms

### Vertical Line:

- A vertical line at a point is a line normal to the level surface through that point. E.g. Plumb line (direction of gravity)

### Vertical Angle:

- It is angle between the two lines intersecting in a vertical plane.

### Datum:

- A datum is any reference surface to which the elevations of points are referred. The most commonly used datum is that of mean sea level (MSL).
- In Pakistan, the datum adopted is the mean sea level (MSL) at Karachi.

## Important Terms

### **Bench mark (BM):**

- It is a permanent fixed reference point of known elevation and position.

### **Reduced level (RL):**

- The RL of a point is its height above or below a reference datum. It is also called as Elevation.

### **Line of Collimation:**

- Line joining the point of intersection of cross hairs to the optical center of object glass and its continuation is called the line of collimation. It is also called as line of sight.

## Important Terms

### **Back Sight (BS):**

- It is the staff reading taken at the point of known elevation (such as BM). It is also the first staff reading after setting the instrument.

### **Fore Sight (FS):**

- It is the reading at a point after which the instrument is shifted to another point. So it is the last reading at a setting.

### **Intermediate Sight (IS):**

- Any reading taken between BS and FS reading is called Intermediate Sight (IS).

# Equipment:

- The equipment used in the levelling process comprises **optical levels** and **graduated staffs**.
- Basically, the optical level consists of a telescope fitted with a spirit bubble to ensure long horizontal sights onto the vertically held graduated staff.
- Different type of levels includes:

- A. Tilting Level
- B. Automatic Level
- C. Digital Level





# Differential or Spirit Leveling:

- Differential leveling or spirit leveling is the most accurate simple direct method of determining the difference of level between two points using an instrument known as level with a leveling staff.
- A level establishes a horizontal line of sight.
- Leveling staff measures the difference in the level of the line of sight and the point over which the leveling staff is held.

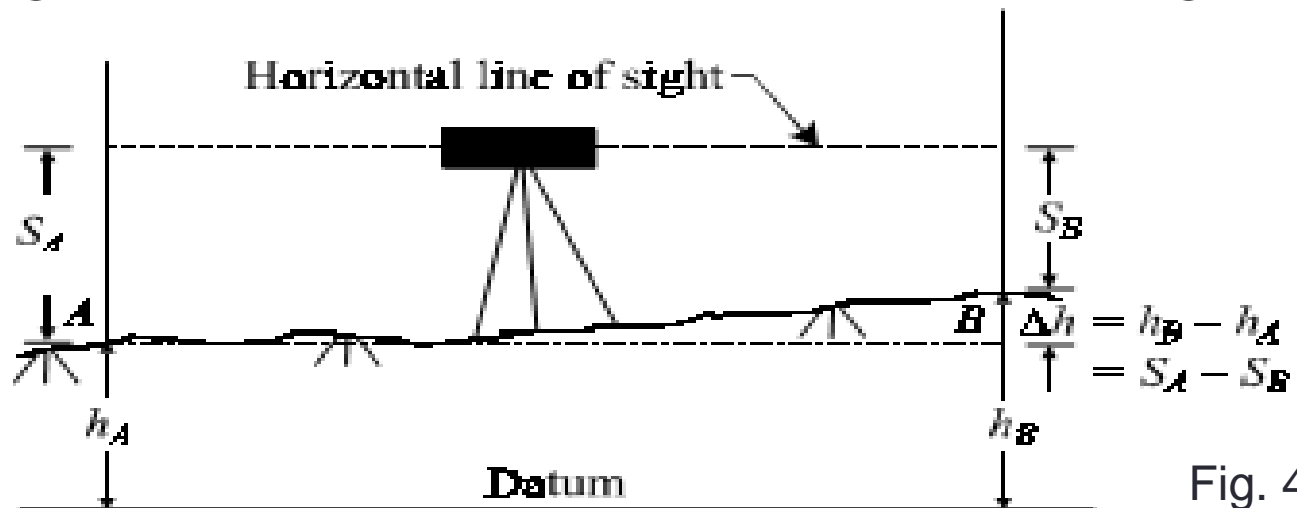


Fig. 4.2

## Differential or Spirit Leveling

- Fig. 4.2 shows the principle of determining the difference in level  $\Delta h$  between two points A and B, and thus the elevation of one of them can be determined if the elevation of the other one is known.
- $S_A$  and  $S_B$  are the staff readings at A and B, respectively, and  $h_A$  and  $h_B$  are their respective elevations.
- From the figure, we find that:
  1. if  $S_B < S_A$ , the point B is higher than point A.
  2. if  $S_B > S_A$ , the point B is lower than point A.
  3. to determine the difference of level, the elevation of ground point at which the level is set up, is not required.

# Booking and Reducing of Levels:

- Before discussing the booking and methods of reducing levels, the following terms associated with differential leveling must be understood.
- **Station:** A station is the point where the leveling staff is held. (Points A, a, b, B, c, and C in Fig. 4.3).
- **Height of instrument (H.I.) or height of collimation:** For any set up of the level, the elevation of the line of sight is the height of instrument. ( $H.I. = h_A + S_A$  in Fig. 4.2).
- **Back sight (B.S.):** It is the first reading taken on the staff after setting up the level usually to determine the height of instrument. It is usually made to some form of a bench mark (B.M.) or to the points whose elevations have already been determined. When the instrument position has to be changed, the first sight taken in the next section is also a back sight. (Staff readings S1 and S5 in Fig. 4.3).

# Important Terms

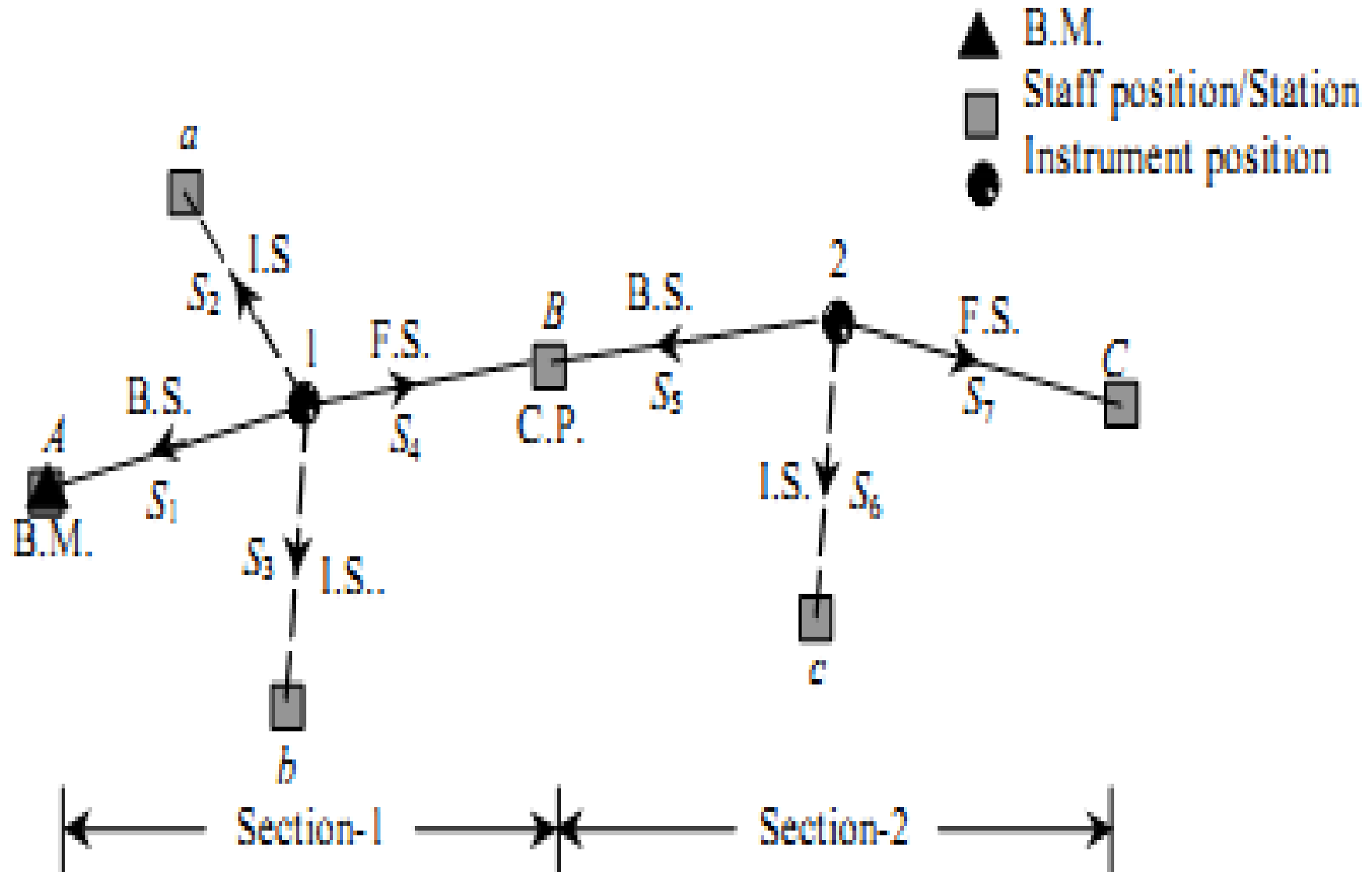


Fig. 4.3

## Important Terms

- **Fore sight (F.S.):** It is the last reading from an instrument position on to a staff held at a point. It is thus the last reading taken within a section of levels before shifting the instrument to the next section, and also the last reading taken over the whole series of levels. (Staff readings S4 and S7 in Fig. 4.3).
- **Change point (C.P.) or turning point:** A change point or turning point is the point where both the fore sight and back sight are made on a staff held at that point. A change point is required before moving the level from one section to another section. By taking the fore sight the elevation of the change point is determined and by taking the back sight the height of instrument is determined. The change points relate the various sections by making fore sight and back sight at the same point. (Point B in Fig. 4.3).

## Important Terms

- **Intermediate sight (I.S.):** The term 'intermediate sight' covers all sightings and consequent staff readings made between back sight and fore sight within each section. Thus, intermediate sight station is neither the change point nor the last point. (Points a, b, and c in Fig. 4.5).
- **Reduced level (R.L.):** Reduced level of a point is its height or depth above or below the assumed datum. It is the elevation of the point.
- **Rise and fall:** The difference of level between two consecutive points indicates a rise or a fall between the two points. In Fig. 4.2, if  $(S_A - S_B)$  is positive, it is a rise and if negative, it is a fall. Rise and fall are determined for the points lying within a section.

## Important Terms

- **Section:** A section comprises of one back sight, one fore sight and all the intermediate sights taken from one instrument set up within that section. Thus the number of sections is equal to the number of set ups of the instrument. (From A to B for instrument position 1 is section-1 and from B to C for instrument position 2 is section-2 in Fig. 4.3).

# Rise & Fall Method:

- In the rise and fall method, the rises and the falls are found out for the points lying within each section.
- Adding or subtracting the rise or fall to or from the reduced level of the backward station obtains the level for a forward station.
- In Table 4.1,  $r$  and  $f$  indicate the rise and the fall, respectively, assumed between the consecutive points.



**Table 4.1**

Station	B.S.	I.S.	F.S.	Rise	Fall	R.L.	Remarks	
<i>A</i>	$S_1$					$h_A$	B.M. = $h_a$	Section-1
<i>a</i>		$S_2$		$r_1 =$ $S_1 - S_2$		$h_a = h_A + r_1$		
<i>b</i>		$S_3$			$f_1 = S_2 - S_3$	$h_b = h_a - f_1$		
<i>B</i>	$S_5$		$S_4$		$f_2 = S_3 - S_4$	$h_B = h_b - f_2$	C.P.	Section-2
<i>c</i>		$S_6$			$f_3 = S_5 - S_6$	$h_c = h_B - f_3$		
<i>C</i>			$S_7$	$r_2 =$ $S_6 - S_7$		$H_C = h_c + r_2$		
	$\Sigma$ B.S.		$\Sigma$ F.S.	$\Sigma$ Rise	$\Sigma$ Fall			

Check:

$$\Sigma \text{ B.S.} - \Sigma \text{ F.S.} = \Sigma \text{ Rise} - \Sigma \text{ Fall} = \text{Last R.L.} - \text{First R.L.}$$

# Checks

- For the rise and fall method

$$\Sigma \text{B.S.} - \Sigma \text{F.S.} = \Sigma \text{Rise} - \Sigma \text{Fall} = \text{Last R.L.} - \text{First R.L.}$$

# Height of Collimation method

- In this system, the R.L. of plane of collimation (H.I) is found out for every set-up of the level and then the reduced levels of the points are worked out with the respective plane of collimation as described below.

1) Determine the R.L. of plane of collimation for the first set up of the level by adding B.S. to the R.L. of B.M. i.e( R.L of plane of collimation= R.L. of B.M.+B.S.)

2) Obtained the R.L. of the intermediate points and first change point by subtracting the staff readings (I.S. and F.S. from the R.L. of plane of collimation (H.I). (R.L. of a point=R.L of plane of collimation H.I.-I.S or F.S)

3) When the instrument is shifted and set up at new position a new plane of collimation is determined by addition of B.S. to the R.L of change point. Thus the levels from two set-ups of the instruments can be correlated by means of B.S. and F.S. taken on C.P.

4) Find out the R.L.s of the successive points and the second C.P. by subtracting their staff readings from this plane of collimation R.L.

5) Repeat the procedure until all the R.Ls are worked out.

**Observation table:-**

Station	Reading			R.L. of plane collimation (H.I)	Reduced Level	Remarks
	B.S	I.S	F.S			

**Arithmetical check:** The difference between the sum of the back sights and the sum of the fore sights should be equal to the difference between the last and first reduced levels.

$$\text{i.e } \sum \text{B.S} - \sum \text{F.S.} = \text{LAST R.L} - \text{FIRST R.L}$$

# Problem-01:

- Following consecutive readings were taken with a level and staff rod:
  - 2.5 ft at A, 3.35, 4.75, 6.38, 8.91, 1.21, 3.76, 5.98 , 3.11, 6.74 and 7.75 at B.
  - The instrument was shifted after 5<sup>th</sup> and 8<sup>th</sup> reading. If the reduced level of A = (300+ Reg. No) ft.
  - Find the reduced level of B and also apply usual checks.

# Problem-02:

- Following consecutive readings were taken with a level and staff rod:
  - 8.75 at A, 6.50, 4.21, 5.65, 1.12, 3.75, 5.50, 9.21, 7.32, 5.81, 6.65 on B.
  - Instrument was shifted after 4<sup>th</sup> and 7<sup>th</sup> reading.
  - Find the RL of staff points and difference of RL between change points.
  - Given that reduced level of A is  $(500 + \text{Reg.No})$  ft, also apply usual checks.

# Assignment

- Solve Problem 01 and 02 by Rise and Fall method.
- Solve Problem 01 and 02 by Height of Instrument method.