Practical 6: The theodolite, an instrument for measuring angles

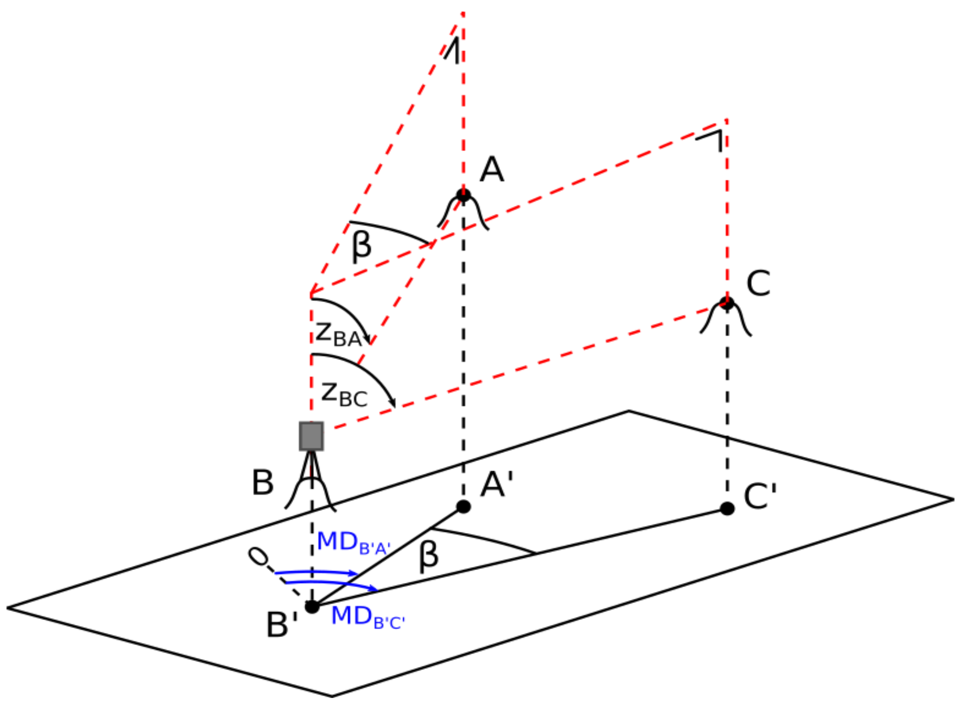
Horizontal and vertical angles

The theodolite is an instrument constructed to measure angles in a horizontal and a vertical plane. In order to be able to do this, a horizontal (HZ) circle and a vertical (V) circle are located inside the instrument. Both circles are graduated and the scales on them go from 0° to 360°.

If we properly set up the theodolite on point B (see the figure below), the extension of the standing axis of the instrument will go through the point. If the instrument is properly levelled, the standing axis is vertical. The HZ circle inside the instrument is located in a plane that is perpendicular to the standing axis and after properly setting up the instrument, it can be used to measure horizontal angles.

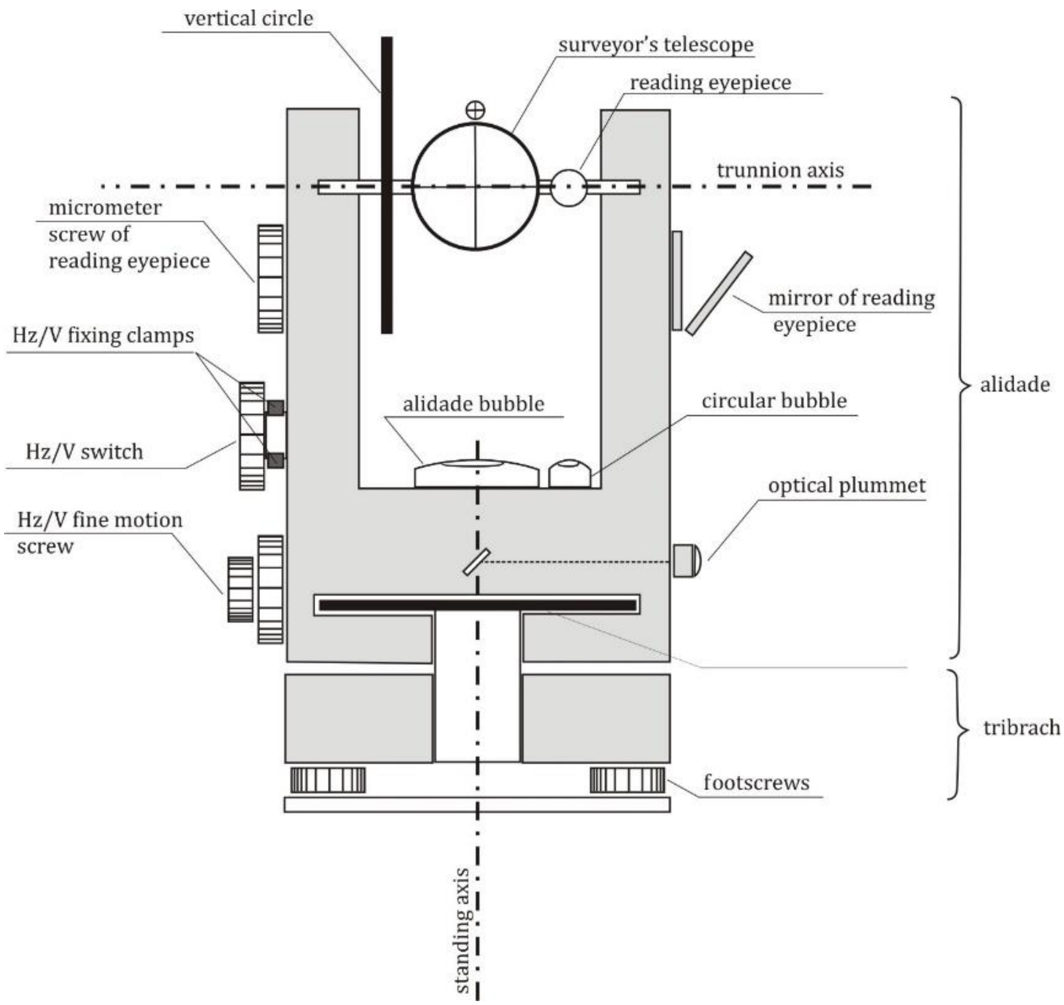
The HZ circle of the theodolite is fixed if the instrument is fixed on a tripod and doesn't move during measurements. However, the alidade of the theodolite can rotate around the circle and the horizontal rotation angle of the telescope can be measured. If we sight point A from point B, the reading corresponds to the horizontal angle measured clockwise between the 0° mark of the HZ circle and the line of sight connecting points B and B. If we now sight point C, the same kind of horizontal angle can be measured, but now between the 0° mark of the HZ circle and the line of sight between points B and C. These angles are called the mean direction (MD) and are interpreted in the horizontal plane. If we project the points onto a horizontal plane using vertical lines, we get points A', B' and C'. The MD between B' and A' is denoted $MD_{B'A'}$ and the MD between B' and C' is denoted $MD_{B'C'}$. We can compute the deflection angle (the angle ∠A'B'C' = β on the horizontal plane) by subtracting the mean direction corresponding to the right leg of the angle (that is, $MD_{B'C'}$) from the mean direction of the left leg (that is, MD_{AC}).

The vertical angle that is measured using the theodolite is the smaller angle between the standing axis of the instrument and the line of sight determined by the telescope and it is called the zenith angle (z). If the line of sight is exactly horizontal, the zenith angle measured is 90°.



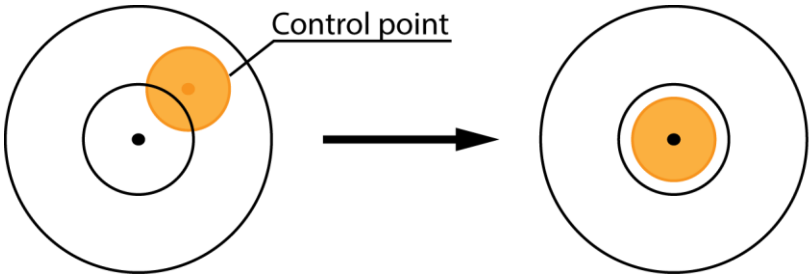
Mean direction and zenith angle measured using the theodolite.

Structure of the theodolite

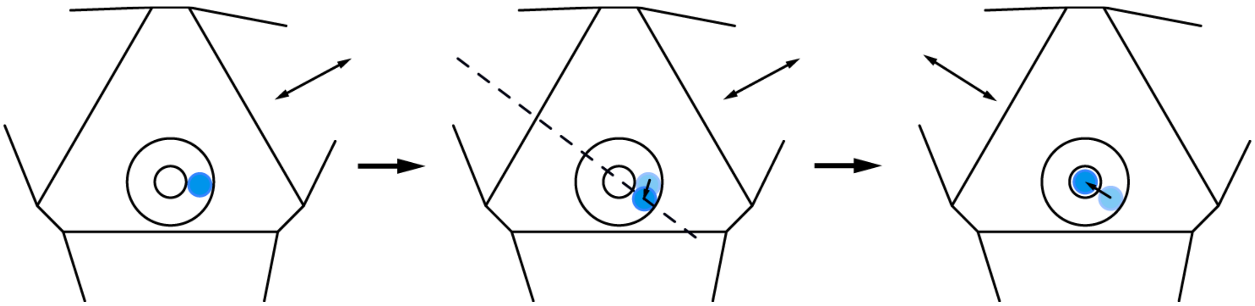


Steps of setting up the theodolite on a station

1. Set up the tripod above the control point, making sure that the head of the tripod is approximately horizontal.
2. Fix the instrument on the tripod with the central fixing screw.
3. Using the optical plummet and the footscrews, sight the control point on the ground. (The standing axis now goes through the control point, but it is not vertical yet.)
   - 3.1. The focusing of the diaphragm (where the aiming circles are located) is done by rotating the optical plummet.
   - 3.2. The focusing of the image of the control point is done by pushing/pulling the optical plummet.

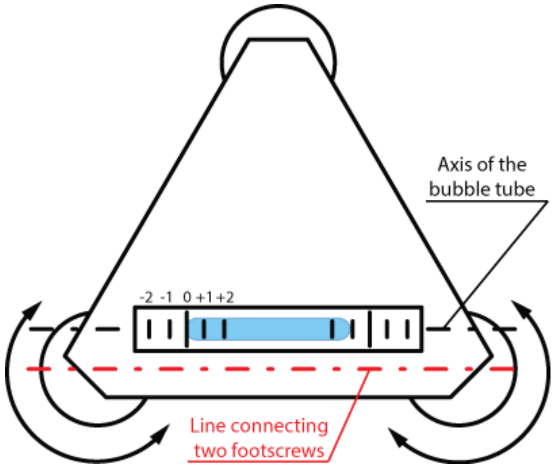


4. Level the circular bubble by adjusting the length of the legs of the tripod. Lengthen or shorten one leg until the line formed by the center of the circular bubble and the bubble's current position is parallel with the extension of one of the legs. Use this leg to finish setting the bubble into the middle.

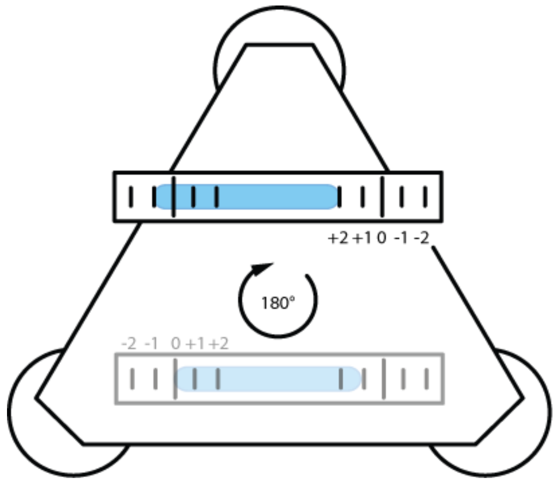


5. Find the normal point of the bubble tube and move the bubble to the normal point.

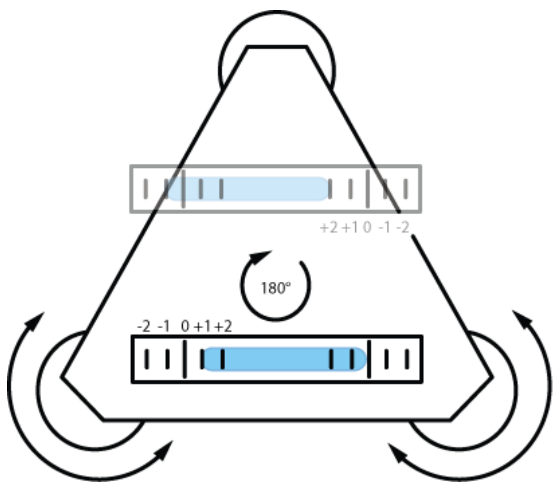
   5.1. Set the instrument into the I. principal position, when the axis of the bubble tube is parallel with two chosen footscrews. By rotating these two footscrews at the simultaneously and in the opposite direction move the left edge of the bubble to one of the marks on the bubble tube. In the example below, the left edge of the bubble is moved to the 0 mark.



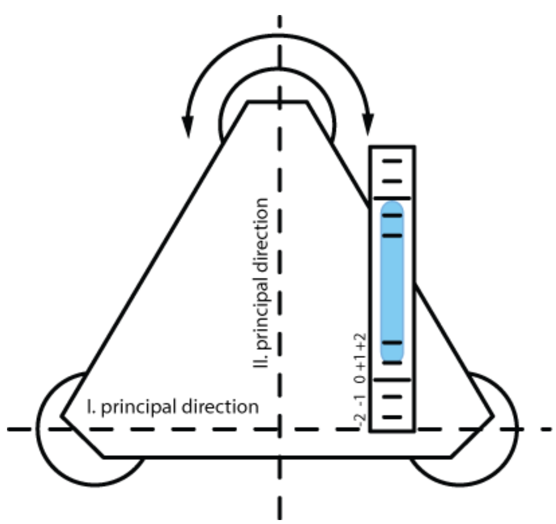
   5.2. Turn the instrument 180°. Check how much the bubble moved from its position. Keep in mind, that in the rotated position the previously left edge of the bubble becomes the right edge. The normal point is the average of the two positions. In the example below, after rotating the alidade with the bubble tube, the left edge of the bubble settles on the +2 mark. The average of 0 and +2 is +1, so the bubble tube's normal point is where the left edge of the bubble rests on the +1 mark.



5.3. Turn the instrument back to the starting position and move the bubble to the normal point by simultaneously rotating the two footscrews in the opposite direction.



5.4. Turn the instrument to the II. principal position, which is perpendicular to the I. principal position. Move the bubble to the normal point using only the third screw.



5.5. Slowly turn the instrument around in a circle. The bubble should always rest on the normal point.

6. Using the optical plummet, check whether the standing axis still goes through the control point. If it does, the setting up is complete. In case the standing axis moved off the control point, loosen the central fixing screw a bit (do not remove it completely!) and while looking through the optical plummet, slide the instrument onto the control point, without twisting it. Afterwards, slowly rotate the instrument and check whether the bubble in the bubble tube still rests on the normal point in any position. If it doesn't, repeat all the steps from 5.3.