8 TOTAL STATION INSTRUMENTS; ANGLE OBSERVATIONS

Asterisks (*) indicate problems that have partial answers given in Appendix G.

8.1 Why should a total station be carried in its case when moving to and from the field.

From Section 8.5, paragraph 5: "The instrument should NEVER be transported on the tripod since this causes stress to the tripod head, tribrach, and instrument base."

8.2 Define the axis of sight, horizontal axis, and vertical axis in a total station and describe their relationship to each other.

From Section 8.2, paragraph 2: The (1) *axis of sight* defines the vertical plane, (2) *horizontal axis* is the axis about which the telescope revolves, and the (3) *vertical axis* is the axis about which the telescope can also be rotated in any azimuth.

Relationships:

1. The vertical axis should be perpendicular to the horizontal axis.
2. The axis of the line of sight should be perpendicular to the horizontal axis.

8.3 What are the primary sources of random instrumental error in a total station.

Random instrumental errors are:

1. From Section 8.21: Ability to resolve the reading for the horizontal and vertical circles, which is stated as the DIN 18723 accuracy of the instrument.
2. From Section 8.20.1: Ability of the operator and/or electronic sensor to level the instrument.
3. Ability to center instrument and target over a point.
4. From Section 6.22: Ability to resolve the slope distance, which is given as a constant error and a scalar error (ppm).

8.4 Describe the procedure for properly focusing the optics of a total station.

From Section 81.4, subsection 1: To properly focus the telescope, parallax must be removed. Parallax is the apparent motion of an object caused by a movement in the position of the observer's eye. The existence of parallax can be observed by quickly shifting one's eye position slightly and watching for movement of the object in relation to the cross-hairs. Careful adjustment of the eyepiece and objective lens will result in a sharp image of both the object and the reticle with no visible parallax.

8.5 Describe the procedure for properly focusing an optical plummet.

From Section 81.4, subsection 1: To properly focus the telescope, parallax must be removed. Parallax is the apparent motion of an object caused by a movement in the position of the observer's eye. The existence of parallax can be observed by quickly shifting one's eye position slightly and watching for movement of the object in relation to the cross-hairs. Careful adjustment of the eyepiece and objective lens will result in a sharp image of both the object and the reticle with no visible parallax.

8.6 What is the purpose of the jog/shuttle mechanism on a servo-driven total station?

From Section 8.4.4: This device actuates internal servo-drive motors that rotate the telescope about its horizontal and vertical axes.

8.7 Why is it important not to sight the EDM reflector when turning an angle?

If the reflector is not perfectly aligned with the line of sight, the reflector will offset the line of sight resulting in an error in the direction observed.

8.8 What are the functions of the stator and rotor in a total station?

From Section 8.4, subsection 2: "The rotor (lower circle) contains a pattern of equally divided alternate dark lines and light spaces. The stator (upper circle) contains a slit-shaped pattern which has the same pitch as that of the rotor circle."

8.9 What is meant by an angular position?

From Section 8.10, paragraph 2: "A set of readings around the horizon in both the direct and reverse modes constitutes a so-called *position.*"

8.10 What is the purpose of the horizontal tangent screw on a total station?

From 8.4, subsection 2: "The horizontal motion, which also contains a lock and tangent screw, controls this rotation. Rotation can be prevented by clamping the lock. To sight a point, the lock is released and the telescope rotated in azimuth to the approximate direction desired, and the lock clamped again. Then the horizontal tangent screw enables a fine adjustment to be made in the direction of pointing."

8.11 Why is it important to maintain long sight distances when measuring angles?

The error in an direction observation is dependent on the size of the target sighted and controlled by the formula, $\theta = S/R$. By keeping the size of the target, S, small and the length of the sight, R, long, the error in the angle θ can be minimized.

8.12 Determine the angles subtended for the following conditions:

(a)* a 1-cm diameter pipe sighted by total station from 100 m.

<u>21"</u>; $\frac{0.010}{100}206{,}264.8 \approx 20.6''$

(b) a 1/8-in. stake sighted by total station from 400 ft.

7"; $\frac{\frac{\frac{1}{8}}{12}}{400} * 206{,}264.8''/rad = 7.2''$

(c) a 1/4-in. diameter chaining pin observed by total station from 200 ft.

22"; $\frac{\frac{1}{4}}{12*200} 206{,}264.8 = 21.5''$

8.13 What is the error in an observed direction for the situations noted?

(a) setting a total station 5 mm to the side of a tack on a 50-m sight.

21"; $\frac{0.005}{50} 206{,}264.8 = 20.6''$

(b) lining in the edge (instead of center) of an 1/4-in. diameter chaining pin at 100 ft.

22"; $\frac{1/4 \big/ (12 \times 2)}{100} \approx 21.5''$

(c) sighting the edge (instead of center) of a 1-cm diameter range pole 200 m.

5"; $\frac{0.01}{200} 206{,}264.8 = 5.2''$

(d) sighting the top of a 6-ft range pole that is $3'$ off-level on a 200-ft sight.

5.4"; $6\left(\frac{180}{206264.8}\right) = 0.0052;\ \frac{0.0052}{200} 206264.8 = 5.4''$

8.14* Intervening terrain obstructs the line of sight so only the top of a 6-ft long pole can be seen on a 250-ft sight. If the range pole is out of plumb and leaning sideways 0.025-ft per vertical foot what maximum angular error results?

$S = 0.025(6) = 0.15 \text{ ft}$

124"; $\frac{0.15}{250} 206{,}264.8 \approx 123.8''$

8.15 Same as Problem 8.14, except that it is a 2-m pole that is out of plumb and leaning sideways 1 cm per meter on a 200 m sight.

21"; $S = 0.01(2) = 0.020 \text{ m};\ \frac{0.02}{200} 206{,}264.8 \approx 20.6''$

8.16 Discuss the advantages of a robotic total station instrument.

From Section 8.6: "The computer retrieves the direction to the point from storage or computes it and activates a servomotor to turn the telescope to that direction within a few seconds. This feature is particularly useful for construction stakeout, but it is also convenient in control surveying when multiple observations are made in observing angles. In this instance, final precise pointing is done manually."

In essence, it speeds the field operations.

8.17 What instrumental errors are compensated by averaging an equal number of observations with the telescope direct and reversed?

From Section 8.20.1, paragraphs 2 and 3: Averaging an equal number of direct and reversed observations compensates for the instrumental errors of (1) vertical axis not perpendicular to the horizontal axis and the (2) axis of the line of sight not perpendicular to the horizontal axis.

8.18 Describe how a total station can be leveled when the leveling bubble is out of adjustment.

From Section 8.19.1: "If the level vial is out of adjustment, it can be adjusted by bringing the bubble *halfway back* to the centered position by turning the screw. Repeat the test until the bubble remains centered during a complete revolution of the telescope."

8.19 An interior angle x and its explement y were turned to close the horizon. Each angle was observed once direct and once reversed using the repetition method. Starting with an initial backsight setting of $0°00'00''$ for each angle, the readings after the first and second turnings of angle x were $50°38'48''$ and $50°38'52''$ and the readings after the first and second turnings of angle y were $309°21'06''$ and $309°21'04''$. Calculate each angle and the horizon misclosure.

<u>50°38'50", 309°21'05", 5"</u>;

$x = 50°38' + \frac{48+52}{2} = 50°38'50''$ **;** $y = 309°21' + \frac{6+4}{2} = 309°21'05''$;

misclosure $= 360° - (50°38'50'' + 309°21'05'') = 5''$

8.20* A zenith angle is measured as $84°13'56''$ in the reversed position. What is the equivalent zenith angle in the direct position?

<u>275°46'04"</u> = 360° – 84°13'56"

8.21 What is the average zenith angle given the following direct and reversed readings

Direct: $87°45'04'', 87°45'12'', 87°45'08''$
Reversed: $272°14'50'', 272°14'48'', 272°14'52''$

<u>87°45'09"</u>

$\sum z_D = 263°15'24''$; $\sum z_R = 816°44'30''$;

By Equation (8.3): $\frac{263°15'24''}{3} + \frac{3(360)-(263°15'24''+816°44'30'')}{2(3)} = 87°45'09''$

In Figure 8.9(c), direct and reversed directions observed with a total station instrument from A to points B, C, and D are listed in Problems 8.23 and 8.24. Determine the values of the three angles, and the horizon misclosure.

8.22 Direct: $0°00'00'', 26°29'21'', 92°57'44'', 0°00'04''$

Reverse: $0°00'00'', 26°29'17'', 92°57'46'', 0°00'02''$

26°29'19"; 66°28'26"; 267°02'18"; misclosure = 3"

8.23 Direct: $0°00'00'', 106°52'06'', 191°38'43'', 359°59'58''$

Reverse: $0°00'00'', 106°52'04'', 191°38'41'', 0°00'00''$

106°52'05"; 84°46'37"; 168°21'17"; misclosure = −3"

8.24* The angles at point *X* were observed with a total station instrument. Based on 4 readings, the standard deviation of the angle was $\pm 5.6''$. If the same procedure is used in observing each angle within a six-sided polygon, what is the estimated standard deviation of closure at a 95% level of probability?

±27"; $1.9599(5.6)\sqrt{6} = 26.9''$

8.25 The line of sight of a total station is out of adjustment by $10''$.

(a) In prolonging a line by plunging the telescope between backsight and foresight, but not double centering, what angular error is introduced?

20"; 2(10")

(b) What off-line linear error results on a foresight of 200 m?

19.4 mm; 200tan(20") = 0.0194 m

8.26 A line PQ is prolonged to point R by double centering. Two foresight points R' and R'' are set. What angular error would be introduced in a single plunging based on the following lengths of QR and $R'R''$ respectively?

(a)* 650.50 ft and 0.35 ft.

56"; $\tan^{-1}\left(\frac{0.35/2}{650.05}\right) = 55.5''$

(b) 312.600 m and 42 mm.

13.9"; $\tan^{-1}\frac{0.042/2}{312.600} = 13.9''$

8.27 Explain why the "principal of reversion" is important in angle measurement.

From Section 8.15 and 8.20.1: The principle of reversion is applied when angles are measured in both the direct and reversed positions. The procedure negates the effect of the horizontal axis not being perpendicular to the vertical axis. It is also used in detecting a maladjusted level and in prolonging a line of sight.

8.28* A total station with a $20''/\text{div.}$ level bubble is one divisions out of level on a point with an altitude angle of $38°15'44''$. What is the error in the horizontal pointing?

<u>16"</u>; By Equation (8.4): E_H = (20")tan($38°15'44''$) = 15.8"

8.29 What is the equivalent altitude angle for a zenith angle of 93°02'06"?

<u>−3°02'06"</u>

8.30 What is the equivalent altitude angle for a zenith angle of 276°42'36"?

<u>6°42'36"</u>

8.31 What error in horizontal angles is consistent with the following linear precisions?

(a) 1/5000, 1/20,000, 1/50,000, and 1/100,000

<u>41", 10.3", 4.1", 2.1"</u>

(b) 1/3000, 1/15,000, 1/30,000, and 1/80,000

<u>69", 13.8", 6.9", 2.6"</u>

8.32 Why is it important to check if the shoes on a tripod are tight?

If the shoes are not tight, an unstable setup will result.

8.33 Describe the procedure to adjust an optical plummet on a total station.

From Section 8.19.4: "To adjust a plummet contained in the alidade, set the instrument over a fine point and aim the line of sight exactly at it by turning the leveling screws. Carefully adjust for any existing parallax. Rotate the instrument 180° in azimuth. If the plummet reticle moves off the point, bring it *halfway* back by means of the adjusting screws provided. These screws are similar to those shown in Figure 8.19. As with any adjustment, repeat the test to check the adjustment and correct if necessary.

For the second case where the optical plummet is part of the tribrach, carefully lay the instrument, with the tribrach attached, on its side (horizontally) on a stable base such as a bench or desk, and clamp it securely. Fasten a sheet of paper on a vertical wall at least six feet away, such that it is in the field of view of the optical plummet's telescope. With the horizontal lock clamped, mark the position of the optical plummet's line of sight on the paper. Release the horizontal lock and rotate the tribrach 180°. If the reticle of the optical plummet moves off the point, bring it *halfway* back by means of the adjusting screws. Center the reticle on the point again with the leveling screws, and repeat the test."

8.34 List the procedures for "wiggling-in" a point.

See Section 8.16

8.35 A zenith angle was read twice direct giving values of 88°22'54" and 88°22'56" and twice reversed yielding readings of 272°37'20" and 272°37'22". What is the mean zenith angle? What is the indexing error?

By Equation 8.3: **<u>88°22'47"; indexing error = −8″</u>**

8.36 A zenith angle was read twice direct giving values of 96°32'24" and 96°32'28" and twice reverse yielding readings of and What is the mean zenith angle? What is the indexing error?

By Equation 8.3: **<u>96°32'32"; indexing error = 6″</u>**

8.37 A total station has a DIN 18723 specified accuracy of ±3″. What is the estimated precision of an angle observed with 2 repetitions?

By Equation (8.5): **<u>±4.2"</u>**; $E = \frac{2(3")}{\sqrt{2}} = \pm 4.2"$

8.38 A total station has a DIN 18723 specified accuracy of ±1″. What is the estimated precision of an angle observed with 8 repetitions?

By Equation (8.5): **<u>±0.7"</u>**; $E = \frac{2(1")}{\sqrt{8}} = \pm 0.7"$