Chapter 13: Tunneling Surveys
Sample Quiz

**Multiple Choice Questions**
Circle the most appropriate answers to the following questions.

1. Which of the following survey projects will require the use of three-dimensional computational model?
   a. Positioning and orientation of nuclear accelerator relative to earth’s center of mass
   b. Establishment of geodetic control for a very long tunnel.
   c. Deformation monitoring survey of a concrete dam.
   d. Establishment of primary control for construction of a bridge

2. With regard to Daniel Johnson dam project in Quebec, which of the following would not be considered as an important geodetic challenge?
   a. establishing permanent high-precision network around the dam site
   b. monitoring the variation of water levels in the reservoir
   c. performing precise monitoring survey of the dam during its loading and unloading
   d. precisely positioning the dam and its other facilities

3. With regard to the conventional triangulation method used in establishing the survey control for the Daniel Johnson dam project in Quebec, which of the following will not be most efficient today?
   a. triangulation with electronic theodolites and EDM equipment
   b. triangulation with DKM3 precision theodolites and invar tapes
   c. trilateration with total station equipment
   d. GPS surveys

4. With regard to Transportation Tunnelling surveys at Rogers Pass, BC, which of the following would not be considered as an important geodetic challenge?
   a. determining the effects of the large changes in the deflection of the vertical
   b. determining the effects of atmospheric refraction in the tunnel traverses
   c. controlling the tunnelling project so that the specified lateral breakthrough is not exceeded
   d. determining the orthometric heights at the entrances of the tunnel

5. Which of the following were used in establishing the special-order levelling control for the transportation tunnelling project at Rogers Pass, BC?
   a. Zeiss NI-1 precision level with invar rods
   b. Digital (electronic) levels with bar code rods
   c. GPS surveys with suitable geoid model
   d. Trigonometric levelling with total station equipment
6. With regard to tunnelling surveys for the Superconducting Super Collider (SSC) project in Texas, which of the following were considered as important geodetic challenges (multiple choices allowed)?
   a. following strict alignment guidelines for relative positioning of a large number of magnets
   b. not giving time for the checking of the survey closures before installing and aligning the magnets
   c. predicting the influence of atmospheric refraction
   d. all of the above

7. With regard to tunnelling surveys for the Superconducting Super Collider (SSC) project in Texas, which of the following were considered as important geodetic challenges (multiple choices allowed)?
   a. predicting uncertainties in the deflection of the vertical
   b. controlling the calibration errors of survey instruments
   c. accurately transferring orientation underground through vertical shafts
   d. all of the above

8. Which of the following is false with regard to the geodetic aspects of the tunnelling surveys for the Superconducting Super Collider (SSC) project in Texas?
   a. surface horizontal control network was based mainly on GPS surveys
   b. surface vertical control network was based on special-order geodetic levelling procedure
   c. underground networks were occasionally controlled using gyro attachment MOM GiB-11
   d. underground control network surveys were established based on total station traverse and precision levelling procedures.

9. Which of the following was not used in transferring orientation through vertical shafts in the Superconducting Super Collider (SSC) project in Texas?
   a. Leica precision optical plummets
   b. Total station TC2002 equipment with suitable Taylor-Hobson targets
   c. Precision levels with invar rods and suitable Taylor-Hobson targets
   d. GYROMAT 2000 equipment

10. Which of the following tunnelling survey methods will be affected more by refraction?
    a. zig-zag traverse in the tunnel
    b. traverse run close to the wall of the tunnel
    c. traverse involving azimuth measurements with gyrotheodolite
    d. straight traverse run along the center-line of the tunnel
11. Which of the following is not one of the important reasons of error analysis of tunnelling surveys?
   a. calculating breakthrough error in lateral direction of tunnel
   b. calculating breakthrough error in longitudinal direction of tunnel
   c. calculating breakthrough error in vertical direction of tunnel
   d. calculating refraction error in tunnelling surveys

12. Which of the following is much more important in error analysis of tunnelling surveys?
   a. breakthrough error in lateral direction of tunnel
   b. breakthrough error in longitudinal direction of tunnel
   c. breakthrough error in vertical direction of tunnel
   d. refraction error in tunnelling surveys

13. Which of the following is usually false about horizontal atmospheric refraction?
   a. refraction deflects line of sight away from warmer surface
   b. there is no refraction if there is no temperature changes in the direction perpendicular to the line of sight
   c. there is no refraction if the temperature gradient is zero along the line of sight
   d. if temperature gradient is constant across the line of sight, the line of sight will conform to a circular path

14. Which of the following is not likely to be true about the process of orienting underground survey?
   a. it gives horizontal position of at least a point underground in the surface system
   b. it gives the elevation of at least a point underground in the surface system
   c. it gives the azimuth of at least a line underground
   d. it gives the positions of the underground points relative to one another

15. Which of the following is not directly used in computing the relative horizontal positional error ellipse in breakthrough analysis of tunnel surveys?
   a. azimuth of the tunnel axis at the breakthrough point
   b. coordinates of the breakthrough points
   c. angle between the lateral breakthrough error direction and the semi-major axis of the standard relative error ellipse
   d. cofactor matrix of the coordinate differences of the breakthrough points

16. Which of the following can be considered as one of the main sources of gross error during tunnelling surveys?
   a. pointing error
   b. centering error
   c. rock deformation
   d. instrumental error
17. Which of the following can be considered as the main source of error while extending the horizontal control underground via an inclined shaft?
   a. rock deformation
   b. atmospheric refraction
   c. instrumental error
   d. effect of high temperature

18. Which of the following tunnelling survey methods is most unlikely?
   a. zig-zag traverse in the tunnel
   b. braced traverse in the tunnel
   c. traverse involving azimuth measurements with gyrotheodolite
   d. straight traverse run along the center-line of the tunnel

19. Which of the following is false about tunnelling surveys?
   a. purpose of error analysis of tunnelling surveys is to calculate the breakthrough errors of the tunnel axis
   b. use of precision gyrotheodolite in tunnelling survey will not contribute to accuracy of tunnel axis alignment
   c. suitable survey technique for tunnel axis alignment is open traverse in zigzag form
   d. Precise surface control network is required as part of the tunnelling surveys

Discussion and Calculation Questions
Answer the following.

1. Interpret the usual design tolerance for leveling with regard to leveling for the tunneling project by answering the following:
   (a) How will you interpret any value supplied as tolerance for this job?
   (b) Given the overall error expected for this project, how will you distribute the error to different aspects of the project?

2. Answer the following with regard to the ground surface surveys for tunneling projects:
   (a) Describe the measurement scheme for the surface network with regard to the order of job and survey technique.
   (b) Describe the measurement scheme with regard to benchmark types and their important locations.

3. Answer the following with regard to the initial design of underground network surveys for tunneling projects:
   (a) Describe the measurement scheme for establishing the primary control with regard to the order of job and survey technique.
   (b) Describe the measurement scheme for establishing the primary control with regard to benchmark types and their locations.
4. Describe (with regard to surface network surveys for tunneling projects) how to determine error contributions due only to the proposed surface measurements with regard to the following:
   (a) Quantity to be fixed in the least squares adjustment.
   (b) The quantities to be assigned values and the type of values assigned for the adjustment.
   (c) One specific quantity to be determined and used later in the breakthrough analysis.

5. Describe (with regard to underground network surveys for tunneling projects) how to determine error contributions due only to the proposed underground measurements with regard to the following:
   (a) Quantity to be fixed in the least squares adjustment method.
   (b) The quantities to be assigned values and the type of values assigned for the adjustment.
   (c) One specific quantity to be determined and used later in the breakthrough analysis.

6. Answer the following with regard to the overall simulation of the tunneling surveys.
   (a) Give a formula for the expected total vertical breakthrough error, stating the confidence level for the error.
   (b) What is the next move after determining the total expected vertical breakthrough error in (a)?

7. Explain how the diagonal elements in Equation (13.18) are different from those in Equation (13.3) with regard to the two breakthrough points P’ and P”.

8. If the semi-major axis value of 95% relative error ellipse of the breakthrough points is 25 cm, what is the equivalent value of relative standard relative ellipse?

9. If the surface contribution (Es) to horizontal breakthrough in Eqn. (13.14) is determined from the relative error ellipse with a = 2 cm, b = 1 cm, azimuth of semi-major axis as 90º with the azimuth of the tunnel as 90º, what is Es?

10. If the underground contribution (Eu) to horizontal breakthrough in Eqn. (13.14) is determined from the relative error ellipse with a = 2.5 cm, b = 1.5 cm, azimuth of semi-major axis as 180º with the azimuth of the tunnel as 90º, what is Eu?

11. Explain why Equation (13.3) is not directly relevant to vertical breakthrough error analysis.

12. Explain where 1.96 comes from in Equations (13.25) and (13.26) and why 2.448 is used in Equations (13.10) and (13.11).

13. If the term “relative error ellipses” is associated with horizontal breakthrough error analysis, what is the equivalent term for vertical breakthrough error analysis?

14. A flat hanging traverse is to be measured with uniform sight lengths of 110 m ± 2 mm. There are two “fixed” stations, “A” and “B”, plus six traverse stations, “P1” to “P6” so that “B” and “P1” to “P5” would be occupied while “A” and “P6” would be sighted. The order of the stations is A, B, P1, P2, …P6. All are at practically the same elevation. The included horizontal angles [values near 180º] of the traverse are to be measured with standard deviation of ±5” at each of the 6 occupied stations. Explain the dominant component of the random positional uncertainty at the end point of the traverse, “P6”, and suggest a value and orientation of the uncertainty.
In a tunneling survey, the temperature of the tunnel wall was found to be 30.2°C and at about 1 m away from the wall perpendicular to a traverse line of sight, the temperature was 30.1°C. The average temperature in the tunnel was 30.2°C and the atmospheric pressure was 1000 mb. A straight traverse of 5 traverse legs with angle $\theta = 180^\circ$ at each station is measured. Assuming the gradient of temperature persists over the whole length of traverse and each traverse leg is 100 m, answer the following.

a. If only angle will be measured at each of the traverse stations, by how much (in millimeters) will the last point of the traverse be deflected due to the effect of refraction?

b. If the traverse would be measured with gyro-theodolite at each station, by how much (in millimeters) will the last point of the traverse be deflected due to the effect of refraction?