1. Given the following data for a highway curve to the right: $\Delta = 33^\circ 30' 00''$, $R = 1455.00'$, $T = 437.91$, $L = 850.72$, $LC = 838.65$, $D = 03^\circ 56' 16''$ and the following table of deflections and chords:

<table>
<thead>
<tr>
<th>Station</th>
<th>Deflection</th>
<th>Sub-chord</th>
<th>Chord</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC 46 + 76.29</td>
<td>00° 00' 00''</td>
<td>0.00'</td>
<td>0.00'</td>
</tr>
<tr>
<td>47 + 00</td>
<td>00° 28' 01''</td>
<td>23.71</td>
<td>23.71</td>
</tr>
<tr>
<td>48 + 00</td>
<td>02° 26' 09''</td>
<td>99.98</td>
<td>123.67</td>
</tr>
<tr>
<td>49 + 00</td>
<td>04° 24' 17''</td>
<td>99.98</td>
<td>223.49</td>
</tr>
<tr>
<td>50 + 00</td>
<td>06° 22' 25''</td>
<td>99.98</td>
<td>323.04</td>
</tr>
<tr>
<td>51 + 00</td>
<td>08° 20' 33''</td>
<td>99.98</td>
<td>422.21</td>
</tr>
<tr>
<td>52 + 00</td>
<td>10° 18' 44''</td>
<td>99.98</td>
<td>520.88</td>
</tr>
<tr>
<td>53 + 00</td>
<td>12° 16' 49''</td>
<td>99.98</td>
<td>618.94</td>
</tr>
<tr>
<td>54 + 00</td>
<td>14° 14' 58''</td>
<td>99.98</td>
<td>716.28</td>
</tr>
<tr>
<td>55 + 00</td>
<td>16° 13' 06''</td>
<td>99.98</td>
<td>812.76</td>
</tr>
<tr>
<td>PT 55 + 27.01</td>
<td>16° 45' 00''</td>
<td>27.01</td>
<td>838.65</td>
</tr>
</tbody>
</table>

There are stakes in the ground at the PC, PI, and PT. In all questions relating to angles set or sighted, you must specify telescope position.

A. There are no obstructions to prevent setting out stakes from the PC as far as station 53 + 00 with your electronic total station. How will you set a stake at station 53 + 00? Be specific in terms of angle set for the back sight, where the back sight is, and angle set for pointing at 53 + 00. Also, what distance you will measure to 53 + 00 and where you will measure this distance from?

B. You are trying to set a stake at station 54 + 00 and can see through some tree leaves well enough to see a plumb bob string, but cannot get enough reflectance from a prism to your total station to measure a distance along the sight line. You have a three-person field crew. How will you set a stake at station 54 + 00? Be specific in terms of angle set for the back sight, where the back sight is, and angle set for pointing at 54 + 00. Also, what distance you will measure to 54 + 00 and where you will measure this distance from?

C. You have been able to stake out stations from the PC as far as 49 + 00, but must now move your total station to station 49 + 00 to stake out the rest of the curve. How will you stake out station 50 + 00? Be specific in terms of angle set for the back sight, where the back sight is, and angle set for pointing at 50 + 00. Also, what distance you will measure to 50 + 00 and where you will measure this distance from?

D. Assume that Station 49 + 00 is the low point of a curve and consequently catch basins are to be installed at this station. While you are set at this station (from C., above), you will stake out the position of the catch basins. The pavement is to be 30 feet wide. How will you do this? Be specific in terms of angle set for the back sight, where the back sight is, and angle set for pointing toward the catch basin locations. Also, what distance you will measure to the catch basin locations, and where you will measure this distance from?

E. From station 49 + 00, you are able to stake out stations as far as 51 + 00, but not beyond 51 + 00. How will you stake out station 52 + 00? Be specific in terms of angle set for the back sight, where the back sight is, and angle set for pointing at 52 + 00. Also, what distance you will measure to 52 + 00 and where you will measure this distance from?
F. Continuing from 1.E., above, how will you stake out 53 + 00 and 54 + 00? Backsight information will be the same as in 1.E. What are the angles set and distances measured for 53 + 00 and 54 + 00?

G. Sketch the curve, and indicate by a small triangle symbol on the sketch each of the stations you set the instrument to accomplish items A through F, above.

1.A. Total Station @ PC. - Sight 00° 00' 00', telescope inverted, back along tangent line OR Sight 00° 00' 00', telescope normal, on PI. Now set 12° 16' 49" RIGHT, and with telescope in the normal position, instrument is pointed along the line of the chord from the PC to station 53 + 00. Measure 618.94' along this line from the instrument to a prism and set a stake at 53 + 00.

1.B. Total Station @ PC. - Sight 00° 00' 00', telescope inverted, back along tangent line OR Sight 00° 00' 00', telescope normal, on PI. Set 14° 14' 58" RIGHT, and with telescope in the normal position, instrument is pointed along the line of the chord from the PC to station 54 + 00. Measure 99.98' from 53 + 00 and swing this distance slowly along an arc until the end of the tape intersects the 14° 14' 58" RIGHT sight line from the PC. Set a stake at this point for station 54 + 00. ALTERNATIVELY, you may move the instrument up to station 53 + 00 and continue staking the curve from there, using a process similar to that described in 1.C., below.

1.C. Total Station @ 49 + 00. - Sight 00° 00' 00', telescope inverted on the PC. Now place the telescope in the normal position, set 06° 22' 25" RIGHT and measure 99.98' along that line from the instrument to set a stake at 50 + 00.

1.D. Total Station @ 49 + 00. - Set 04° 24' 17" LEFT, telescope normal, on the PC. Now set 09° 00' 00" RIGHT and with the telescope normal, measure along that line 15' to set the outer catch basin. Then invert the telescope and measure 15' along that line to set the inner catch basin. Alternatively, for the inner catch basin, you may set 09° 00' 00" LEFT or 27° 00' 00" RIGHT, telescope normal. An alternative method is to sight 00° 00' 00', telescope normal, on the PC, then set 94° 24' 17" RIGHT, telescope normal, and measure along that line 15' to set the outer catch basin.

1.E. Total Station @ 51 + 00. - Sight 04° 24' 17" RIGHT, telescope inverted, on 49 + 00. Invert the telescope to the normal position, set 10° 18' 44" RIGHT and measure 99.98', along that line, from the instrument, to set a stake at 52 + 00.

1.F. After same sighting as in 1.E., above, invert the telescope to the normal position, set 12° 16' 49" RIGHT and measure 2RsinD = 199.84' to 53 + 00. Then, with the telescope still in the normal position, set 14° 14' 58" RIGHT and measure 2Rsin(3D/2) = 299.46' to 54 + 00.
2. Report all curve data $\Delta$, $R$, $D$, $L$, $T$, $LC$, PC Station, PT Station, and a table of deflection angles, chords, and sub-chords to lay out curves to the left in half station intervals for either A or B below. In both cases, PI station is 11 + 08.84.

A. \[ D = 18^\circ 00' 00" \quad \Delta = 42^\circ 15' 20" \]

B. \[ R = 580.00' \quad \Delta = 19^\circ 56' 50" \]

SKETCH THE CURVE YOU CHOSE AND LABEL ALL ELEMENTS OF THE CURVE.

A. \[
\frac{D}{100} = \frac{18^\circ 00' 00"}{18} = 234.75 \quad \text{AND} \quad \frac{\Delta}{18} = \frac{42^\circ 15' 20"}{18} = 234.75
\]

\[
T = 318.31 \tan \frac{42^\circ 15' 20"}{2} = 123.00 \quad \text{LC} = 2(318.31) \tan \frac{42^\circ 15' 20"}{2} = 229.47
\]

PC Station = 1108.84 - 123.00 = 985.84

PT Station = 985.84 + 234.75 = 1220.59

$\phi$ for 1' = $\frac{D}{200} = \frac{18}{200} = 0.0900'$ = 00\textdegree\textquotesingle\textquotesingle\textquotesingle\textquotesingle\textquotesingle\textquotesingle\textquotesingle 18"

$\phi$ for 14.16' = 01\textdegree\textquotesingle\textquotesingle\textquotesingle\textquotesingle\textquotesingle\textquotesingle\textquotesingle 27"

$\phi$ for 50' = 04\textdegree\textquotesingle\textquotesingle\textquotesingle\textquotesingle\textquotesingle\textquotesingle\textquotesingle 00"

$\phi$ for 20.59' = 01\textdegree\textquotesingle\textquotesingle\textquotesingle\textquotesingle\textquotesingle\textquotesingle\textquotesingle 51"

<table>
<thead>
<tr>
<th>STATION</th>
<th>DEFLECTION</th>
<th>CHORD</th>
<th>SUBCHORD</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC 985.84</td>
<td>00\textdegree\textquotesingle\textquotesingle\textquotesingle\textquotesingle\textquotesingle\textquotesingle 00&quot;</td>
<td>0.00'</td>
<td>0.00'</td>
</tr>
<tr>
<td>10+00</td>
<td>01\textdegree\textquotesingle\textquotesingle\textquotesingle\textquotesingle\textquotesingle\textquotesingle 16' 28&quot;</td>
<td>14.16</td>
<td>14.16</td>
</tr>
<tr>
<td>10+50</td>
<td>04\textdegree\textquotesingle\textquotesingle\textquotesingle\textquotesingle\textquotesingle\textquotesingle 30&quot;</td>
<td>64.05</td>
<td>49.94</td>
</tr>
<tr>
<td>11+00</td>
<td>06\textdegree\textquotesingle\textquotesingle\textquotesingle\textquotesingle\textquotesingle\textquotesingle 46' 28&quot;</td>
<td>113.55</td>
<td>49.94</td>
</tr>
<tr>
<td>11+50</td>
<td>09\textdegree\textquotesingle\textquotesingle\textquotesingle\textquotesingle\textquotesingle\textquotesingle 30&quot;</td>
<td>162.34</td>
<td>49.94</td>
</tr>
<tr>
<td>12+00</td>
<td>12\textdegree\textquotesingle\textquotesingle\textquotesingle\textquotesingle\textquotesingle\textquotesingle 16' 28&quot;</td>
<td>210.14</td>
<td>49.94</td>
</tr>
<tr>
<td>12+20.59</td>
<td>21\textdegree\textquotesingle\textquotesingle\textquotesingle\textquotesingle\textquotesingle\textquotesingle 07' 39&quot;</td>
<td>229.47</td>
<td>20.59</td>
</tr>
</tbody>
</table>

\[
\frac{42^\circ 15' 20"}{2} = 21^\circ 07' 40"
\]
2. Report all curve data $\Delta, R, D, L, T, LC, PC$ Station, $PT_m$ Station, and a table of deflection angles, chords, and sub-chords to lay out curves to the left in half station intervals for either A or B below. In both cases, PI station is $11 + 08.84$.

A. $D = 18^\circ 00' 00''$ and $\Delta = 42^\circ 15' 20''$

B. $R = 580.00'$ and $\Delta = 19^\circ 56' 50''$

**SKETCH THE CURVE YOU CHOSE AND LABEL ALL ELEMENTS OF THE CURVE.**

\[ \Delta = 19^\circ 56' 50'' \quad L = \frac{100 (19^\circ 56' 50'')}{90^\circ 52' 43''} = 201.92 \quad \frac{5729.58}{580.00} = 9.8786 = 09^\circ 52' 43'' \]

\[ LC = 2(580)(\tan \frac{19^\circ 56' 50''}{2}) = 200.91 \]

PC data = $110.84 - 101.99 = 10 + 06.85$

PT data = $100.85 + 201.92 = 12 + 08.77$

$\phi$ for 1' = $\frac{D}{200} = \frac{09^\circ 52' 43''}{200} = 0.049393^\circ = 00^\circ 02' 15''$

$\phi$ for 43.15' = $2.1313^\circ = 02^\circ 07' 15''$

$\phi$ for 50' = $2.4696^\circ = 02^\circ 28' 11''$

$\phi$ for 8.77' = $0.4332^\circ = 00^\circ 25' 59''$

<table>
<thead>
<tr>
<th>STATION</th>
<th>DEFLECTION</th>
<th>CHORD</th>
<th>SUBCHORD</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC</td>
<td>10+06.85</td>
<td>00^\circ 00' 00''</td>
<td>0.00'</td>
</tr>
<tr>
<td></td>
<td>10+50</td>
<td>02^\circ 07' 53''</td>
<td>43.14</td>
</tr>
<tr>
<td></td>
<td>11+00</td>
<td>04^\circ 36' 04''</td>
<td>93.05</td>
</tr>
<tr>
<td></td>
<td>11+50</td>
<td>07^\circ 04' 15''</td>
<td>142.79</td>
</tr>
<tr>
<td></td>
<td>12+00</td>
<td>09^\circ 32' 26''</td>
<td>192.27</td>
</tr>
<tr>
<td></td>
<td>12+08.77</td>
<td>09^\circ 58' 25''</td>
<td>200.91</td>
</tr>
</tbody>
</table>

$T = \frac{19^\circ 56' 50''}{2} = 09^\circ 58' 25''$
Sketches for Problem 2

(2A)

P.T. 12 + 20.59
R = 118.31
Δ = 42° 15' 20"

P.C. 9 + 85.84

L = 25 + 76.41
T = 123.00

P.I. 11 + 08.34

(2B)

P.T. 12 + 08.77
R = 380.00
Δ = 19° 56' 50"

P.C. 10 + 06.85

L = 200.31
T = 104.99

P.I. 11 + 08.84
3. You are working on the upgrading of a geodetic control network and go to station 1718 to observe new angles and distances. There has been a recent lumbering operation near 1718 and you have trouble finding the station. You can observe angles $\alpha$ and $\beta$ from point 1 on the same hilltop as 1718. What distance will you measure from 1 to try to find 1718, AND what angle or azimuth will you set off to try to find 1718?

Known coordinates:

<table>
<thead>
<tr>
<th></th>
<th>X</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>1216</td>
<td>714,471.49</td>
<td>322,823.88</td>
</tr>
<tr>
<td>4968</td>
<td>729,896.98</td>
<td>336,671.50</td>
</tr>
<tr>
<td>1715</td>
<td>734,144.11</td>
<td>323,164.30</td>
</tr>
<tr>
<td>1718</td>
<td>732,383.27</td>
<td>345,015.73</td>
</tr>
</tbody>
</table>

Known azimuths and distances:

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1216 - 4968</td>
<td>48° 05' 07&quot;</td>
<td>20,729.26</td>
<td></td>
</tr>
<tr>
<td>4968 - 1715</td>
<td>162° 32' 42&quot;</td>
<td>14,159.19</td>
<td></td>
</tr>
<tr>
<td>1216 - 1715</td>
<td>89° 00' 31&quot;</td>
<td>19,675.57</td>
<td></td>
</tr>
</tbody>
</table>

Measurements taken (average values given): $\alpha = 21° 13' 13''$ and $\beta = 22° 18' 35''$
3. Solution

Compute R from azimuth:

\[
\begin{align*}
162^\circ 32' 42'' & \quad - 48^\circ 05' 07'' \\
114^\circ 27' 35'' &= R' \\
+ 180^\circ & \\
294^\circ 27' 35'' &= R
\end{align*}
\]

Compute J

In quadrilateral 1715 - 4968 - 1216 - 1,

\[
y + x = 360^\circ - 294^\circ 27' 35'' - 21^\circ 13' 13'' - 22^\circ 18' 35''
\]

\[
y + x = 22^\circ 00' 37'' = J
\]

Compute H

\[
H = \frac{26,729.26 \ \text{min} \ 21^\circ 13' 13''}{14,153.19 \ \text{min} \ 22^\circ 18' 35''} = 1.395912
\]
3. Solution - continued

\[ \tan y = \sin 22^\circ 00'37'' \]
\[ \frac{1.395912 + \cos 22^\circ 00'37''}{1.395912 + \cos 22^\circ 00'37''} = 0.161329 \]
\[ y = 9.164530^\circ = 09^\circ 09'52'' \]

Compute \( x \)

\[ y + x = 90^\circ \]
\[ x = 90^\circ - y = 22^\circ 00'37'' - 09^\circ 09'52'' = 12^\circ 50'45'' \]

Quick check of quadrilateral angle

\[ \gamma = 09^\circ 09'52'' \]
\[ \theta = 43^\circ 31'48'' \]
\[ \alpha = 12^\circ 50'45'' \]
\[ \tau = 294^\circ 27'35'' \]
\[ \frac{360^\circ 00'00''}{3} = R \]

Now work with \( \triangle \) triangles to find distances

\[ 1216 - 1, \ 4968 - 1, \ add \ 1715 - 1 \]

\[ 09^\circ 09'52'' \]
\[ 22^\circ 18'35'' \]
\[ 20.729.26 \]
\[ 4968 \]

\[ 09^\circ 09'52'' \]
\[ 22^\circ 18'35'' \]
\[ 31^\circ 28'27'' \]
\[ 179^\circ 55'40'' \]
\[ 148^\circ 31'33'' \]
3. Solution - continued

sin law solutions of 2 triangles

Triangle on Left

\[
\frac{1216-1}{\sin 148^\circ 31' 33''} = \frac{4968-1}{\sin 09^\circ 09' 52''} = \frac{20,729.26}{\sin 22^\circ 18' 35''}
\]

\[
1216-1 = 28,510.70 \quad \odot \quad 4968-1 = 8,697.14 \quad \odot
\]

Triangle on Right

\[
\frac{1715-1}{\sin 145^\circ 56' 02''} = \frac{4968-1}{\sin 125^0 45' 26''} = \frac{14,159.18}{\sin 21^\circ 13' 15''}
\]

\[
1715-1 = 21,912.29 \quad \odot \quad 4968-1 = 8,697.14 \quad \checkmark
\]

Compute directions of lines 1216-1, 4968-1, and 1715-1

\[
\begin{align*}
4968 - 1715 & \quad 162^\circ 32' 42'' \\
\quad + 180^\circ & \quad \quad \quad 196^\circ 36' 40'' \\
1715 - 4968 & \quad 342^\circ 32' 42'' \\
\quad + 12^\circ 50' 45'' & \quad \quad \quad 218^\circ 18' 35'' \\
1715 - 1 & \quad 355^\circ 23' 27'' \\
\quad - 180^\circ & \quad \quad \quad 218^\circ 18' 35'' \\
1 - 1715 & \quad 175^\circ 23' 27'' \\
\quad + 21^\circ 13' 13'' & \quad \quad \quad 196^\circ 36' 40'' \\
1 - 4968 & \quad 196^\circ 36' 40'' \\
\quad - 180^\circ & \quad \quad \quad 218^\circ 18' 35'' \\
4968 - 1 & \quad 16^\circ 36' 40'' \\
\quad + 145^\circ 56' 02'' & \quad \quad \quad 376^\circ 36' 40'' \\
4968 - 1715 & \quad 162^\circ 32' 42'' \\
\quad - 180^\circ & \quad \quad \quad 376^\circ 36' 40'' \\
4968 - 1 & \quad 16^\circ 36' 40'' \\
\quad \checkmark & \quad \quad \quad 360^\circ
\end{align*}
\]

Check Triangle by coordinates (and establish coordinates of point 1)

<table>
<thead>
<tr>
<th>AZIMUTH</th>
<th>DISTANCE</th>
<th>LATITUDE</th>
<th>DEPARTURE</th>
<th>COORDINATES</th>
<th>NORTH</th>
<th>EAST</th>
<th>POINT</th>
</tr>
</thead>
<tbody>
<tr>
<td>355^\circ 23' 27''</td>
<td>21,912.29</td>
<td>21,841.43</td>
<td>-1,760.84</td>
<td></td>
<td>345,265.73</td>
<td>732,383.27</td>
<td>I</td>
</tr>
<tr>
<td>196^\circ 36' 40''</td>
<td>8,697.14</td>
<td>-8,334.18</td>
<td>-2,486.29</td>
<td></td>
<td>336,671.54</td>
<td>729,892.99</td>
<td>4968</td>
</tr>
<tr>
<td>218^\circ 56' 15''</td>
<td>28,510.70</td>
<td>-22,181.75</td>
<td>-17,911.78</td>
<td></td>
<td>322,623.98</td>
<td>714,471.54</td>
<td>1216</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td>98</td>
<td>49</td>
<td></td>
</tr>
</tbody>
</table>
3. Solution - continued

Find direction and distance needed to try to find
station 1718

\[
\begin{align*}
1718 & & y = 345,015.73 & & x = 732,383.27 \\
1 & & 345,015.73 & & 732,383.27 \\
10.00 & & 0.00 & & 0.00
\end{align*}
\]

from 1 to 1718 is directly north (azimuth is
00°00'00") and 10.00' is the distance
between 1 and 1718.