A Brief Review of FE Exam Subjects

In Surveying and Transportation,
Afternoon Session in Civil Engineering,
Using Sample Problems and Supplemental Material

By

Robert S. Foyle, P.E.
Institute for Transportation Research and Education
NC State University

May 2010

References:

1. FE Reference Handbook, NCEES, Fall 2009
2. FE Civil Sample Questions and Solutions, NCEES, 2010
4. Surveying and Transportation – FE Exam Review Notes, by R. S. Foyle, P.E., and J. E. Hummer, Ph.D., P.E., Institute for Transportation Research and Education, NC State University, December 2008
FE Exam Subjects
Afternoon Session in Civil Engineering

SURVEYING (6-7 problems)
A. Angles, distances, and trigonometry
B. Area computations
C. Closure
D. Coordinate systems (e.g., GPS, state plane)
E. Curves (vertical and horizontal)
F. Earthwork and volume computations
G. Leveling (e.g., differential, elevations, percent grades)

TRANSPORTATION (7 problems)
A. Streets and highways
   1. Geometric design
   2. Pavement design
   3. Intersection design
B. Traffic analysis and control
   1. Safety
   2. Capacity
   3. Traffic flow
   4. Traffic control devices
1. A slope distance and zenith angle of 123.456 m and 102°54'00", respectively, are measured using a total station. The horizontal distance (m) is most nearly:

(A) 123.335
(B) 123.298
(C) 120.511
(D) 120.340

2. The arc definition of the Degree of Curve (D) is defined as the:

(A) central angle subtended by 100 ft of arc
(B) central angle subtended by 50 ft of chord
(C) central angle subtended by 50 ft of arc
(D) total arc length of the curve in stations divided by the total central angle in degrees
CIVIL SAMPLE QUESTIONS

3. The area inside the quadrilateral PC, PI, PT, and O below equals 83,164 m². The shaded area (m²) between the circular curve and the tangents is most nearly:

(A) 2,879
(B) 3,577
(C) 5,407
(D) 8,286
CIVIL SAMPLE QUESTIONS

4. The cross-sectional areas to be excavated (cut) at certain sections of a road project are as follows:

<table>
<thead>
<tr>
<th>Station</th>
<th>Area (ft²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3+00</td>
<td>247</td>
</tr>
<tr>
<td>4+00</td>
<td>269</td>
</tr>
<tr>
<td>4+35</td>
<td>322</td>
</tr>
<tr>
<td>5+00</td>
<td>395</td>
</tr>
<tr>
<td>5+65</td>
<td>418</td>
</tr>
<tr>
<td>6+00</td>
<td>293</td>
</tr>
<tr>
<td>7+00</td>
<td>168</td>
</tr>
</tbody>
</table>

Using the prismoidal method, the earth to be excavated (yd³) between Sections 4+35 and 5+65 is most nearly:

(A) 1,460  
(B) 1,840  
(C) 1,860  
(D) 1,900

5. A 12-in.-diameter concrete sanitary sewer \( (n = 0.013, \text{constant with depth}) \) flows half full and is constructed on a grade of 0.5%. The flow velocity (ft/sec) in this sewer is most nearly:

(A) 1.6  
(B) 2.0  
(C) 3.2  
(D) 32.4
Example – Area by Trapezoidal Rule and Simpson’s 1/3 Rule

- From Kavanagh, *Surveying with Construction Applications*

Solution – Trapezoidal Rule:

\[
Area = w \left[ \frac{h_1 + h_n}{2} + h_2 + h_3 + \ldots + h_{n-1} \right]
\]

\[
Area = 15.0 \left[ \frac{26.1 + 20.0}{2} + 35.2 + 34.8 + 41.8 + 45.1 + 40.5 + 30.3 + 25.0 \right] + \frac{(8.1)(26.1)}{2} + \frac{(20.0)(11.1)}{2}
\]

\[
Area = 15.0 \times 275.75 + 105.71 + 111.00
\]

\[
Area = \frac{4136.25 + 105.71 + 111.00}{43560} = 0.09993 \text{ ac}
\]

Solution – Simpson’s 1/3 Rule:

\[
Area = w \left[ h_1 + 2 \left( \sum_{k=3,5,\ldots}^{n-2} h_k \right) + 4 \left( \sum_{k=2,4,\ldots}^{n-1} h_k \right) + h_n \right] / 3
\]

\[
Area = 15.0 \left[ 26.1 + 2(34.8 + 45.1 + 30.3) + 4(35.2 + 41.8 + 40.5 + 25.0) + 20.0 \right] / 3 + 105.71 + 111.00
\]

\[
Area = 15.0 \times 836.50 / 3 + 105.71 + 111.00
\]

\[
Area = \frac{4182.50 + 105.71 + 111.00}{43560} = 0.10099 \text{ ac}
\]
I. Surveying

A. Angles, Distances, and Trigonometry

Angles and Directions

- Bearing—angle from north or south, i.e., N 50° W
- Azimuth—angle from north, clockwise, i.e., 310° degrees
- Interior angles of closed traverse; sum = (n − 2)180°
- Deflection angle—how much angle to turn to keep following the alignment

Latitude—north (+) or south (-) component of line (p. 164 in FE Handbook)
- \[ \text{Latitude} = \text{distance} \times \cos (\text{bearing } \angle) \]
- Signs matter!

Departure—east (+) or west (-) component of line
- \[ \text{Departure} = \text{distance} \times \sin (\text{bearing } \angle) \]

Distance = \( \sqrt{\text{(latitude)}^2 + \text{(departure)}^2} \)

Bearing \( \angle = \tan^{-1}\left(\frac{\text{departure}}{\text{latitude}}\right) \)

Typically use degrees, minutes, and seconds
- Get used to converting to and from decimals of degrees

Precision—record on drawings to nearest second
- Keep 5 decimal places when calculating with degrees
Example – Traverse Error

Given the following preliminary survey information, compute the error of closure, the accuracy of the survey, and the corrected bearing and length for course AB. All distances are in feet.

<table>
<thead>
<tr>
<th>Course</th>
<th>Bearing</th>
<th>Length</th>
<th>Latitude Y, N-S</th>
<th>Departure X, E-W</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB</td>
<td>S 44°32’11” W</td>
<td>200.02’</td>
<td>−142.58</td>
<td>−140.29</td>
</tr>
<tr>
<td>BC</td>
<td>N 49°09’58” W</td>
<td>368.48’</td>
<td>+240.94</td>
<td>−278.79</td>
</tr>
<tr>
<td>CD</td>
<td>N 28°29’34” E</td>
<td>196.90’</td>
<td>+173.05</td>
<td>+93.93</td>
</tr>
<tr>
<td>DA</td>
<td>S 50°08’38” E</td>
<td>423.64’</td>
<td>−271.49</td>
<td>+325.21</td>
</tr>
<tr>
<td>Sum</td>
<td>---------------</td>
<td>1189.04’</td>
<td>−0.08</td>
<td>+0.06</td>
</tr>
</tbody>
</table>

Solution:

Perimeter: $\sum$ lengths = 1189.04’

Sum of latitudes: −0.08’

Sum of departures: +0.06’

Error of closure: $\sqrt{(-0.08)^2 + (0.06)^2} = 0.10’$

Survey accuracy: $\frac{0.10}{1189.04} = \frac{1}{x}$  \[ x = \frac{1189.04}{0.10} \approx 11890 \]

Latitude correction for AB: $+0.08 \left( \frac{200.02}{1189.04} \right) = +0.01$

Departure correction for AB: $-0.06 \left( \frac{200.02}{1189.04} \right) = -0.01$
Example – Leveling

- From Kavanagh, *Surveying With Construction Applications*
- BM elevation = 161.273 m
- Level location 1: BS to BM = 2.868 m and FS to TP = 0.982 m
- Level location 2: BS to TP = 1.977 m and FS to Point Q = 0.540 m
- In table form:

<table>
<thead>
<tr>
<th>Station</th>
<th>BS, m</th>
<th>HI, m</th>
<th>FS, m</th>
<th>Elevation, m</th>
</tr>
</thead>
<tbody>
<tr>
<td>BM</td>
<td>2.868</td>
<td>164.141</td>
<td></td>
<td>161.273</td>
</tr>
<tr>
<td>TP</td>
<td>1.977</td>
<td>165.136</td>
<td>0.982</td>
<td>163.159</td>
</tr>
<tr>
<td>Point Q</td>
<td></td>
<td></td>
<td>0.540</td>
<td>164.596</td>
</tr>
</tbody>
</table>

- What is the elevation of Point Q?

Location 1:  
- HI = 161.273 + 2.868 = 164.141 m  
- El. TP = 164.141 - 0.982 = 163.159 m  

Location 2:  
- HI = 163.159 + 1.977 = 165.136 m  
- El. Q = 165.136 - 0.540 = 164.596 m
CIVIL SAMPLE QUESTIONS

17. Which of the following is a prominent operating characteristic of cloverleaf interchanges?

(A) There are no unusual signing challenges.
(B) Traffic exits before additional traffic enters.
(C) There are low speeds on the loop ramps.
(D) There is no weaving traffic between exiting and entering traffic.

18. A person is driving a car on a road that has a gravel surface. A deer suddenly leaps into the road. The road is on a 10% downgrade, and the car is traveling at 50 mph when the deer appears. The driver’s reaction time is 1.5 sec, and the coefficient of friction on the gravel surface is 0.65. The coefficient of friction, \( f = \frac{\text{deceleration rate, } a}{32.2 \text{ ft/sec}^2} \)

The total distance (ft) required to stop is most nearly:

(A) 153 
(B) 222 
(C) 242 
(D) 262
19. A freeway lane has a volume of 1,400 vehicles/hr and an average vehicle speed of 45 mph. The time spacing (sec) between vehicles (center to center) is most nearly:

(A) 2.6
(B) 5.2
(C) 15
(D) 31

20. A street underpass has a sag vertical curve. The following data apply:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of vertical curve</td>
<td>6.00 stations</td>
</tr>
<tr>
<td>Entering profile grade, $g_1$</td>
<td>$-1.5%$</td>
</tr>
<tr>
<td>Exiting profile grade, $g_2$</td>
<td>$+2.5%$</td>
</tr>
<tr>
<td>PVI station</td>
<td>32+00</td>
</tr>
<tr>
<td>PVI elevation</td>
<td>250.00</td>
</tr>
</tbody>
</table>

A drainage inlet must be designed to carry away the stormwater flow at the low point of the vertical curve. The station of the center of the inlet is most nearly:

(A) 29+75
(B) 31+25
(C) 32+75
(D) 34+25
Density and Speed

- The upper left curve is between density and speed. Greenshields assumed that this relationship was linear.
- The speed at which density is zero is called the free flow speed, \( v_f \) (or \( S_f \)). An assumption of 60 mph is common and useful.
- The density at which the speed is zero is called the jam density, \( k_j \) (or \( D_j \)). An assumption of 150 vpm is common and useful. Average vehicle spacing would be 5280 ft/mi / 150 veh/mi = 35 ft/veh, which is about right.
- The equation for the speed/density line would then look like:

\[
v = \left( \frac{-v_f}{k_j} \right) k + v_f = \left( \frac{-60}{150} \right) k + 60 = -0.4k + 60
\]
Problem 22 – Traffic Flow
Assume a linear relationship between speed and density, a jam density of 140 vpm, and a free flow speed of 70 mph for a freeway.

(1) What is the capacity of the road?
   a) 2300 vph
   b) 2350 vph
   c) 2400 vph
   d) 2450 vph

(2) At a volume of 1700 vph, under capacity, the average speed is most nearly:
   a) 56 mph
   b) 54 mph
   c) 52 mph
   d) 50 mph

(3) At a volume of 1700 vph, under capacity, what is the density?
   a) 30.3 vpm
   b) 31.3 vpm
   c) 32.3 vpm
   d) 33.3 vpm
Problem 23 – Traffic Control Devices

Several citizens have called the traffic engineering department complaining about how hazardous an intersection is and suggesting that a traffic signal should be installed. You are investigating the intersection and have collected the following traffic volumes and lane configurations.

Is the peak hour warrant met for this intersection?

a) Yes, plan for installation of a signal
b) Yes, but investigate other relevant warrants
c) No, signal not warranted
d) No, but investigate other relevant warrants

*Note: 150 vph applies as the lower threshold volume for a minor street approach with two or more lanes and 100 vph applies as the lower threshold volume for a minor street approach with one lane.