NCEES adopted the following code updates for the October 2018 PE Civil Transportation exam:


Please use these updates for the corresponding pages in your copy of *PE Civil Practice Problems*, Sixteenth Edition (CEPP16).


PCI: PCI Design Handbook: Precast and Prestressed Concrete, Seventh ed., 2010. Precast/Prestressed Concrete Institute, Chicago, IL.

TRANSPORTATION DESIGN STANDARDS


From part (d), the total travel time between stations at 80 mph is

\[ t_{a1} + t_{\text{max}} + t_{a2} = 21.3 \text{ sec} + 21.0 \text{ sec} + 26.7 \text{ sec} = 69 \text{ sec} \]

At 100 mph,

\[ t_{a1} = \frac{S_{\text{max}} - S_0}{a_1} = \frac{\left( 100 \frac{\text{mi}}{\text{hr}} - 0 \frac{\text{mi}}{\text{hr}} \right) \left( 5280 \frac{\text{ft}}{\text{mi}} \right)}{\left( 5.5 \frac{\text{ft}}{\text{sec}^2} \right) \left( 3600 \frac{\text{sec}}{\text{hr}} \right)} = 26.7 \text{ sec} \]

\[ t_{\text{max}} = \frac{d_{\text{max}}}{S_{\text{max}}} = \frac{(880 \text{ ft}) \left( 3600 \frac{\text{sec}}{\text{hr}} \right)}{\left( 100 \frac{\text{mi}}{\text{hr}} \right) \left( 5280 \frac{\text{ft}}{\text{mi}} \right)} = 6 \text{ sec} \]

\[ t_{a2} = \frac{S_0 - S_{\text{max}}}{a_2} = \frac{\left( 0 \frac{\text{mi}}{\text{hr}} - 100 \frac{\text{mi}}{\text{hr}} \right) \left( 5280 \frac{\text{ft}}{\text{mi}} \right)}{\left( -4.4 \frac{\text{ft}}{\text{sec}^2} \right) \left( 3600 \frac{\text{sec}}{\text{hr}} \right)} = 33.3 \text{ sec} \]

\[ t_{a1} + t_{\text{max}} + t_{a2} = 26.7 \text{ sec} + 6 \text{ sec} + 33.3 \text{ sec} = 66 \text{ sec} \]

The time that is saved at 100 mph maximum speed versus 80 mph maximum speed is 69 sec — 66 sec = 3 sec.

2. Refer to HCM p. 15-6 or p. 15-28. The capacity of a two-lane highway is 1700 pcph in each direction. The maximum capacity for the combined (i.e., both ways) capacity is 3200 pcph. This is considered the saturation volume; or LOS E.

The answer is (C).

3. (a) No information is given about the field-measured traffic speeds. Therefore, according to HCM p. 15-15, the design speed of the highway is an acceptable estimator of base free-flow speed (BFFS). Use Eq. 73.21. From HCM Exh. 15-7, and Exh. 15-8, the adjustment factors for lane and shoulder width and for access points in both directions are 3.0 mph and 5.0 mph, respectively.

\[ FFS = BFFS - f_{LS} - f_A \]

\[ = 60 \frac{\text{mi}}{\text{hr}} - 3.0 \frac{\text{mi}}{\text{hr}} - 5.0 \frac{\text{mi}}{\text{hr}} \]

\[ = 52.0 \frac{\text{mi}}{\text{hr}} \]

The answer is (A).

(b) From HCM p. 15-17, when the demand is expressed as an hourly volume, it must be divided by the peak hour factor (PHF). For one-direction travel, the volume, \( V_i \), is 1600 vph/2 = 800 vph. The demand flow rate for ATS in each direction, \( v_{i,ATS} \), is

\[ v_{i,ATS} = \frac{V_i}{\text{PHF}} = \frac{800 \text{ vph}}{0.95} = 842.10 \text{ vph} \] [use 800 vph]

Use HCM Eq. 15-3 to find the one-direction demand flow rate, with adjustments for grade and heavy vehicles. From HCM Exh. 15-9, the grade adjustment factor for rolling terrain, \( f_{g,ATS} \), is 0.99.

The heavy vehicle adjustment for ATS, \( f_{HV,ATS} \), is found from Eq. 73.16. From HCM Exh. 15-11, the passenger car equivalent for trucks, \( E_T \), is 1.4. The passenger car equivalent for RVs, \( E_R \), is 0 since there are no RVs in the traffic stream.

\[ f_{HV,ATS} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)} \]

\[ = 1 + (0.14)(1.4 - 1) + (0)(0 - 1) \]

\[ = 0.947 \]

Adjusting the demand flow rate for ATS, the demand flow rate in one direction is

\[ v_{i,ATS} = \frac{V_i}{(PHF)f_{g,ATS}f_{HV,ATS}} = \frac{800 \text{ vph}}{(0.95)(0.99)(0.947)} \]

\[ = 898 \text{ pcph} \] (900 pcph)

The answer is (D).
(c) Use Eq. 73.24. From HCM Exh. 15-15, the adjustment factor for the percentage of no-passing zones in the analysis direction, \( f_{np,ATS} \), is 0.9. Since the traffic distribution is 50% in each direction, use 898 pcph for both the analysis and the opposing directions of travel.

\[
\text{ATS}_d = \text{FFS} - 0.0076(v_{d,ATS} + v_{o,ATS}) - f_{np,ATS}
\]

\[
= 52.0 \frac{\text{mi}}{\text{hr}} - (0.0076)(898 \text{ pcph} + 898 \text{ pcph}) - 0.9
\]

\[
= 37.45 \frac{\text{mi}}{\text{hr}} (37 \text{ mph})
\]

The answer is (A).

(d) The demand flow rate for PTSF is found from Eq. 73.23. From HCM Exh. 15-16, the PTSF grade adjustment factor, \( f_{g,PTSF} \), is 1.0. From HCM Exh. 15-18, the PTSF passenger car equivalent for trucks, \( E_T \), for level and rolling terrain is 1.0.

\[
f_{HV,PTSF} = \frac{1}{1 + P_r(E_T - 1) + P_d(E_R - 1)}
\]

\[
= \frac{1}{1 + (0.14)(1.0 - 1) + (0)(0 - 1)}
\]

\[
= 1.00
\]

From HCM Exh. 15-16, the PTSF grade adjustment factor, \( f_{g,PTSF} \), is 1.0. From Eq. 73.23,

\[
v_{i,PTSF} = \frac{V_i}{(PHF)f_{g,PTSF}f_{HV,PTSF}}
\]

\[
= \frac{800 \text{ vph}}{(0.95)(1.00)(1.00)}
\]

\[
= 842 \text{ pcpf} (840 \text{ pcpf})
\]

The answer is (C).

(e) Find the base percent time spent following (BPTSF) in the analysis direction using Eq. 73.25. Constants \( a \) and \( b \) are found from HCM Exh. 15-20, and the no-passing-zone adjustment factor, \( f_{np,PTSF} \), is found by interpolation from HCM Exh. 15-21.

\[
\text{BPTSF}_d = (1 - e^{(a + b \times 0.9) \times 100})
\]

\[
= (1 - e^{((-0.0046)(842 \times 0.9)) \times 100})
\]

\[
= 71.3\%
\]

From Eq. 73.26, the percent time spent following is

\[
\text{PTSF}_d = \text{BPTSF}_d + f_{np,PTSF}\left(\frac{v_{d,PTSF}}{v_{d,PTSF} + v_{o,PTSF}}\right)
\]

\[
= 71.3\% + (21.0)(\frac{42 \text{ pcph}}{842 \text{ pcph} + 842 \text{ pcph}})
\]

\[
= 81.8\% (82\%)
\]

The answer is (C).

(f) LOS is found using HCM Exh. 15-3. For Class I two-lane highways, both ATS and PTSF apply, and the lower value determines the applicable LOS. The ATS was found in part (c) to be 37.45 mph. The PTSF was found in part (e) to be 81.8%. Both of these values correlate to an LOS \( E \) for the highway segment.

The answer is (C).

4. (a) Spot speed is an instantaneous value at a particular point and is not a function of the number of vehicles on the highway. Use space mean speed.

\[
29 \text{ mph} = \left(29 \frac{\text{ mi}}{\text{ hr}}\right) \left(\frac{5280 \text{ ft}}{3600 \text{ sec}}\right) = 42.53 \text{ ft/sec}
\]

From Eq. 73.12,

\[
\text{headway}_{sec/veh} = \frac{\text{spacing}_{ft/veh}}{\text{space mean speed}_{ft/sec}}
\]

\[
= \frac{80 \text{ ft}}{42.53 \text{ ft/sec}}
\]

\[
= 1.88 \text{ sec/veh (1.9 sec/veh)}
\]

The answer is (A).

(b) density = \( \frac{5280 \text{ ft}}{80 \text{ ft/veh}} = 66 \text{ veh/mi (66 vpm)} \)

The answer is (B).
(c) From Eq. 73.13,

\[ v_{vph} = \frac{3600 \text{ sec}}{\text{hr}} \times \frac{\text{sec}}{\text{veh}} = \frac{3600 \text{ sec}}{1.88 \text{ sec/veh}} \]

\[ = 1914 \text{ veh/hr} \quad (1900 \text{ vph}) \]

The answer is (C).

(d) From HCM p. 15-6, the maximum stable capacity is 3200–3400 pcph (two directions). Use 3200 pcph.

The answer is (B).

(e) Only volume has units of time. Density is a function of the number of cars in a given distance, but has nothing to do with speed. The cars could be stopped and still have a high density.

Capacity based on volume is more accurate.

The answer is (D).

(f) From HCM p. 12-8

\[ 2400 \text{ passenger cars/hr} \quad (2400 \text{ pcph}) \]

Since capacity occurs at the highest density, the free-flow speed has little effect on the maximum capacity.

The answer is (B).

5. (a) Since the lost time includes the amber time, the effective green time is the actual green time.

Determine the relevant adjustment factors for the right turn lane group. As drawn, the right lane is an exclusive turn lane. The right lane is the lane group, and the number of lanes in the lane group is 1.

**Lane width [HCM Exh. 18-13]:**

\[ f_w = 1.0 \]

**Heavy vehicles [HCM Eq. 18-6]:**

\[ P_{HV} = %\text{trucks} = 4\% \]

\[ f_{HV} = \frac{100}{100 + P_{HV}(E_{RT} - 1)} = \frac{100}{100 + (4\%)(2 - 1)} = 0.962 \]

\[ f_{HVg} = \frac{100 - 0.78(4\%)(0.31)(0\%)^2}{100} \]

\[ = 0.969 \]

**Type of area [HCM p. 18-37]:** There is no required adjustment due to the type of area, so \( f_a = 1.0 \).

**Lane utilization [HCM p. 18-38]:**

Because the lane group has one exclusive lane,

\( f_{LU} = 1.0 \)

**Left turns [HCM p. 18-38]:**

Since there are no left turns in the lane group, \( f_{LT} = 1.0 \).

**Right turns [HCM p. 18-38]:**

The right turn adjustment factor is

\[ f_{RT} = \frac{1}{E_R} = \frac{1}{1.18} = 0.847 \]

There is no required adjustment for work zone presence at the intersection, so \( f_{WZ} = 1.0 \).

There is no required adjustment for downstream lane blockage, so \( f_{MS} = 1.0 \).

There is no required adjustment for sustained spillback, so \( f_{SP} = 1.0 \).
Pedestrian bicycle blockage [HCM p. 18-38]:
There is negligible bicycle and pedestrian traffic, so the factors will not affect the adjusted saturation flow rate.

\[ f_{Lpb} = f_{Rpb} = 1.0 \]

From HCM Exh. 18-28, for a non-metropolitan area, the base saturation flow rate is 1750 vph/ln. The saturation flow rate is given by HCM Eq. 18-5.

\[ s = s_{bw} f_{P} f_{Lpb} f_{LRT} f_{T} f_{Rpb} f_{w} f_{m} f_{p} \]

\[ = \left( 1750 \frac{\text{vph}}{\text{lane}} \right) (1.0)(0.962)(1.0)(0.84)(1.0) \times (1.0)(1.0)(0.847)(1.0)(1.0)(1.0)(1.0) \]

\[ = 1197 \frac{\text{vph}}{\text{ln}} \ (1200 \frac{\text{vph}}{\text{ln}}) \]

The answer is (B).

(b) The right turn lane group on First Street has an adjusted capacity of 1197 vph/ln. The lane group capacity [HCM Eq. 18-15] is

\[ c = N s \frac{g}{C} \]

\[ = (1) \left( 1197 \frac{\text{vph}}{\text{ln}} \right) \left( \frac{27 \text{ sec}}{60 \text{ sec}} \right) \]

\[ = 538 \frac{\text{vph}}{\text{ln}} \ (540 \frac{\text{vph}}{\text{ln}}) \]

The answer is (B).

(c) Maximum delay for level of service E is 80 sec [HCM Exh. 18-4]. The answer is (D).

(d) Use Eq. 73.5 and solve for the demand flow rate, \( v_p \), to find the volume-capacity ratio for the lane group.

\[ v_p = \frac{v}{PHF} = \frac{620 \frac{\text{vph}}{\text{ln}}}{0.85} = 729 \frac{\text{vph}}{\text{ln}} \]

\[ \frac{729 \frac{\text{vph}}{\text{ln}}}{538 \frac{\text{vph}}{\text{ln}}} = 1.35 \ (1.3) \]

The First Street approach is oversaturated, and the operation will be unsatisfactory.

The answer is (D).

(e) With \( v_p \) at capacity, \( v_p = c \).

\[ v = c(PHF) = \left( 538 \frac{\text{vph}}{\text{ln}} \right)(0.85) \]

\[ = 457 \frac{\text{vph}}{\text{ln}} (460 \frac{\text{vph}}{\text{ln}}) \]

The answer is (A).

(f) The level of service is found by the intersection approach delay, found by HCM Eq. 18-19, \( d_1 \) is given by HCM Eq. 18-20, where \( X \) is limited to 1.0, per the HCM, \( d_2 \) is given by HCM Eq. 18-45 for all values of \( X \), \( d_3 = 0 \) since there is no initial queue (i.e., no residual delay).

\[ d = d_1 + d_2 + d_3 \]

\[ = \frac{0.50}{C} \frac{(1 - \frac{g}{C})^2}{1 - \left(\frac{g}{C}\right)} \frac{(1 - P) f_{PA}}{1 - \left(\frac{g}{C}\right)} + 900 T \left( X - 1 + \sqrt{\left( X - 1 \right)^2 + \frac{8kX}{cT}} \right) + 0 \]

\[ = (0.50)(60 \text{ sec}) \frac{\left(1 - \frac{27 \text{ sec}}{60 \text{ sec}}\right)^2}{1 - (1.0) \frac{27 \text{ sec}}{60 \text{ sec}}} \times \left( 1 - \frac{27 \text{ sec}}{60 \text{ sec}} \right) \]

\[ \times \left( 1 - \frac{27 \text{ sec}}{60 \text{ sec}} \right) (1.0) \left( 1.1 - 1 \right) \]

\[ + (900)(0.25) \left( \left(1.1 - 1\right)^2 + \frac{(1.1 - 1)^2}{(8)(0.50)(1.1)(1.1)} \right) \]

\[ + (538)(0.25) \left(1.35 \ (1.3) \right) \]

\[ + 0 \]

\[ = 85.5 \text{ sec} \]

From HCM Exh. 18-1, the level of service is F.

The answer is (D).

6. (a) Although the geometric design of the intersection is specified, no information about any aspect of intersection performance is given. All warrants are theoretically applicable in this instance.

The answer is (D).

(b) All aspects of intersection performance should be evaluated. Work through the warrants in forward order.

The answer is (C).