King Saud University
College of Engineering
Civil Engineering Department

CE 431: Highway Engineering
Tutorial Note 2: Chapter 5
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5.1 A driver in a vehicle traveling 40 mph shifts his eyes from right to left and focuses on a child about to dart across the street. Estimate the distance in feet the vehicle travels as the driver's eyes shift and fixate.

According to text, shift time is 0.15 – 0.33 sec and focus time is 0.10 – 0.30 sec

Therefore, the total time ranges from 0.25 to 0.63 sec

The corresponding distances are:

$$d = 0.25\,\text{sec} \times \frac{40mi}{hr} \times \frac{5280ft}{1mi} \times \frac{1hr}{3600sec} = 14.7ft$$

$$d = 0.63\,\text{sec} \times \frac{40mi}{hr} \times \frac{5280ft}{1mi} \times \frac{1hr}{3600sec} = 37ft$$

The vehicle travels a distance of 14.7 to 37.0 ft.

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5.2 A driver in a vehicle traveling 95 km/hr shifts his eyes from right to left and focuses on construction activities along the right shoulder. Estimate the distance in meters the vehicle travels as the driver's eyes shift and fixate.

According to text, shift time is 0.15 – 0.33 sec and focus time is 0.10 – 0.30 sec

Therefore, the total time ranges from 0.25 to 0.63 sec

The corresponding distances are:

$$d = 0.25\,\text{sec} \times \frac{95km}{hr} \times \frac{1000m}{km} \times \frac{1hr}{3600sec} = 6.6m$$

$$d = 0.63\,\text{sec} \times \frac{95km}{hr} \times \frac{1000m}{km} \times \frac{1hr}{3600sec} = 16.6m$$

The vehicle travels a distance of 6.6 to 16.6 m.

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5.3 In an intersection collision one of the vehicles leaves 160 ft of skid marks. A skid mark analysis indicates that the vehicle was traveling 50 mph at the onset of braking. Assuming an average driver (i.e. median brake-reaction time), estimate the distance from the point of impact to the vehicle position when the driver initially reacted.

$$Initial\ Speed = \frac{50mi}{hr} \times \frac{5280ft}{1mi} \times \frac{1hr}{3600sec} = 73.3\ ft/\ sec$$

Median brake reaction time for unexpected situations

$$= 1.35 \times 0.66\ sec = 0.89\ sec$$

Distance traveled during brake-reaction time

$$= 0.89\ \text{sec} \times \frac{73.3ft}{sec} = 65ft$$

Distance after brakes applied = 160 ft (per problem statement – length of skid marks)

Total distance = 65 + 160 = 225 ft

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5.4 In an intersection collision one of the vehicles leaves 30 m of skid marks. A skid mark analysis indicates that the vehicle was traveling 75 km/hr at the onset of braking. Assuming an average driver (i.e. median brake-reaction time), estimate the distance from the point of impact to the vehicle position when the driver initially reacted.

$$Initial\ Speed = \frac{75km}{hr} \times \frac{1000m}{km} \times \frac{1hr}{3600sec} = 20.8\ m/\ sec$$

Median brake reaction time for unexpected situations

$$= 1.35 \times 0.66\ sec = 0.89\ sec$$

Distance traveled during brake-reaction time

$$= 0.89\ \text{sec} \times \frac{20.8}{sec} = 18.5ft$$

Distance after brakes applied = 30 m (per problem statement – length of skid marks)

Total distance = 18.5 + 30 = 48.5 m

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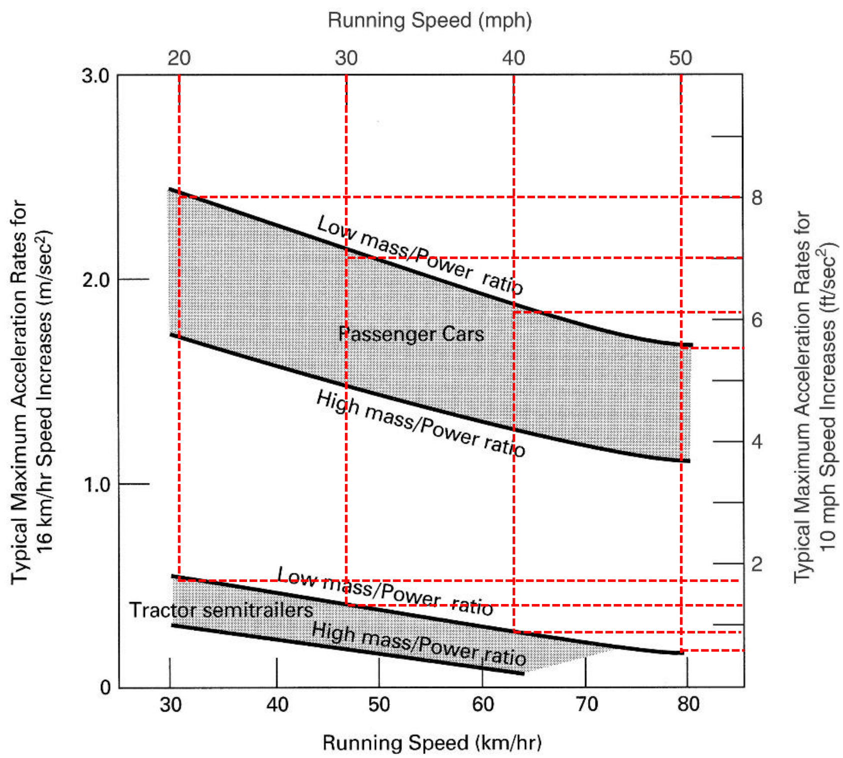
5.5 On the basis of Figure 5 – 7 prepare a table showing the typical maximum acceleration rates in mph/sec for a low mass/power ratio at 20, 30, 40, and 50 mph.



For 20, 30, 40, 50 mph values, read acceleration values, ft/sec2, from Figure 5-7. To determine values in mph/sec, multiply graph acceleration values by:

$$\frac{1ft}{sec^2} \times \frac{3600\ sec}{1hr} \times \frac{1mi}{5280ft} = 0.682$$

The following table results:

Running Speed	Acceleration			
	Tractor Semitrailers		Passenger Cars	
mph	ft/sec^2	mph/sec	ft/sec^2	mph/sec
20	1.6	1.1	8.0	5.5
30	1.3	0.9	7.0	4.8
40	0.9	0.6	6.1	4.2
50	0.6	0.4	5.6	3.8

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5.6 Estimate the horsepower required to accelerate a 2,500-lb vehicle traveling 30 mph up a 5.0 percent grade at a rate of 6 ft/sec^2. The vehicle has a frontal cross-section area of 20 ft^2. The roadway has straight alignment and a badly broken and patched asphalt surface. Assume the drag coefficient = 0.3.

Vehicle weight = 2500 lb. speed = 30 mph, grade = +5%, acceleration rate = 6 ft/sec^2,

Frontal cross-sectional area = 20 ft^2, drag coefficient = 0.3

- Inertial Resistance by equation 5-1,

  $$F_i = \frac{w}{g} \times a = \frac{2500}{32.2} \times 6 = 465.8\ lb$$

- Grade Resistance by equation 5-2: two alternatives:
  1. To find the angle of incline in degrees, calculate as follows:

  $$\tan\theta = \frac{5}{100} \rightarrow \theta = 2.86^{\circ}$$

  $$F_g = m \times g \times \sin\theta = \frac{2500}{32.2} \times 32.2 \times \sin 2.86 = 124.8\ lb$$

  2. For even the steepest highway gradient in practice, $\sin\theta = \tan\theta$ so,

  $$F_g = \frac{w \times G}{100} = \frac{2500 \times 5}{100} = 125\ lb$$

- Rolling Resistance per Table 5-2:

  $$F_r = R_r(lb/ton) \times w(ton)$$

  $$F_r = 34 lb/ton \times 2500 lb \times \frac{1 ton}{2000 lb} = 42.5 lb$$

- Curve Resistance is not needed (value of zero) since the road is straight.
- Air Resistance by Equation 5-5:

  Assume air density = 0.002385

  $$F_a = 0.5 \times C_D \times A \times (\rho \times v^2)$$

  $$F_a = 0.5 \times 0.3 \times 20 \times \left(0.002385 \times \left[\frac{30 mi}{hr} \times \frac{5280 ft}{1 mi} \times \frac{1 hr}{3600 sec}\right]^2\right) = 13.9 lb$$

➔ Power Requirements by Equation 5-6a:

$$P = \frac{R \times v}{550} hp$$

$$P = \frac{(465.8 + 124.8 + 42.5 + 13.9) \times \left(\frac{30 mi}{hr} \times \frac{5280 ft}{1 mi} \times \frac{1 hr}{3600 sec}\right)}{550} = 51.8\ hp$$

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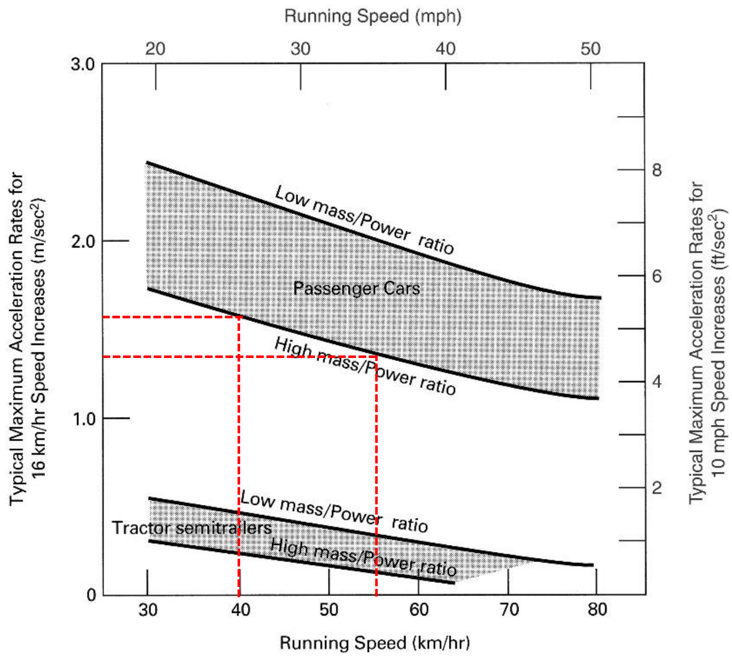
5.7 A high power/mass ratio passenger car enters an acceleration lane at 40 km/hr and merges into a traffic lane at 70 km/hr. Estimate the desired length of the acceleration lane.

Apply Equation 5-9 three times to determine the distances traveled from 40-56 and 56-70km/hr.

Use the acceleration values from Figure 5-7.



Speed Range		Acceleration
Km/hr	m/sec	m/sec^2
40 – 56	11.1 – 15.6	1.50
56 – 70	15.6 – 19.4	1.30

By equation 5-9,

$$v_f^2 = v_0^2 + 2ad$$

$$d = \frac{v_f^2 - v_0^2}{2a}$$

$$d_1 = \frac{15.6^2 - 11.1^2}{2 \times 1.5} = 40\ m$$

$$d_2 = \frac{19.4^2 - 15.6^2}{2 \times 1.3} = 51.2\ m$$

Total distance traveled = 40 + 51.2 = 91.2 m

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