Simulation Tool Development

1.
a. Develop a scale model car that shows the distance traveled in 1 s at speeds from 10 to 70 mph in increments of 10 mph. Use a scale of 1 in = 100 ft. Include a marker on each scale model car that shows the 160 ft distance that is illuminated by a car's headlights.
b. Develop a scale model car that shows the distance traveled in 1 s at speeds from 10 to 70 m/s in increments of 10 m/s. Use a scale of 1 cm = 10 m.

2. The stopping distance for a car is equal to the distance it travels during your reaction time (reaction distance) plus the distance it travels while the brakes are applied (braking distance). The typical deceleration of a car is 17 ft/s^2 and a typical reaction time is 1.5 s. Recall the equation for calculating stopping distance is $x = v^2/2a$, where v is the initial speed of the car, and the equation for calculating the distance traveled at constant speed is $x = vt$. Calculate the reaction distance, braking distance, and stopping distance for a car traveling at the following speeds.

a. 10 mph
b. 20 mph
c. 30 mph
d. 40 mph
e. 50 mph
f. 60 mph
g. 70 mph
h. Make a table summarizing the above data.
i. Make a plot summarizing the above data.
j. Calculate the braking time for the car for each of the cases a-g. Recall that for the case of constant acceleration, $t = \frac{v}{a}$,

where v is the initial speed and the deceleration is a. Generate a table and a graph for the reaction time, braking time, and total stopping time for each speed.
k. Generate a scale model car and map (or use car D and map A) to simulate these situations.

The stopping distance for a car is equal to the distance it travels during your reaction time (reaction distance) plus the distance it travels while the brakes are applied (braking distance). The typical deceleration (a) of a car is 17 ft/s^2 and a typical reaction time (t) is 1.5 s. Calculate the reaction distance (vt), braking distance ($v^2/(2a)$), and total stopping distance ($vt + v^2/(2a)$) for a car traveling at the following speeds (v).

(a) 10 mph
Reaction distance = speed x reaction time (recall that speed is a constant during the reaction time)
Reaction distance $= \frac{10\text{ mi}}{\text{h}} \times 1.5\text{ s} \times \frac{88\text{ft}}{\text{s}} \times \frac{\text{h}}{60\text{ mi}} = 22\text{ ft}$

{Recall that $\frac{88\text{ ft}}{\text{s}} = \frac{60\text{ mi}}{\text{h}}$ so $\frac{88\text{ ft}}{\text{s}} \times \frac{\text{h}}{60\text{ mi}} = 1$

This is a simple and useful conversion to remember. Or the student could use the previously found speed in ft/s as is done in the braking distance calculation below}

$$\text{Braking distance} = \frac{(\text{initial speed})^2}{2 \text{ x deceleration}}$$ (During this time, the deceleration is constant)

$$= \frac{14.7^2 \text{ ft}^2 \text{ x s}^2}{\text{s}^2 \text{ x } 2 \text{ x } 17\text{ft}} = 6.4 \text{ ft}$$

So stopping distance = reaction distance + braking distance = 22 ft + 6.4 ft = 28.4 ft.

(b) 20 mph

$$\text{Reaction distance} = \frac{20 \text{ mi}}{\text{h}} \text{ x } 1.5 \text{ s x } \frac{88\text{ft}}{\text{s}} \text{ x } \frac{\text{h}}{60 \text{ mi}} = 44 \text{ ft}$$

$$\text{Braking distance} = \frac{(\text{initial speed})^2}{2 \text{ x deceleration}}$$

$$= \frac{29.3^2 \text{ ft}^2 \text{ x s}^2}{\text{s}^2 \text{ x } 2 \text{ x } 17\text{ft}} = 25.2 \text{ ft}$$

So stopping distance = reaction distance + braking distance = 44 ft + 25.2 ft = 69.2 ft.

(c) 30 mph

$$\text{Reaction distance} = \frac{30 \text{ mi}}{\text{h}} \text{ x } 1.5 \text{ s x } \frac{88\text{ft}}{\text{s}} \text{ x } \frac{\text{h}}{60 \text{ mi}} = 66 \text{ ft}$$

$$\text{Braking distance} = \frac{(\text{initial speed})^2}{2 \text{ x deceleration}}$$

$$= \frac{44^2 \text{ ft}^2 \text{ x s}^2}{\text{s}^2 \text{ x } 2 \text{ x } 17\text{ft}} = 56.9 \text{ ft}$$

So stopping distance = reaction distance + braking distance = 66 ft + 56.9 ft = 122.9 ft.

(d) 40 mph

Reaction distance $= \frac{40 \text{ mi}}{\text{h}} \times 1.5 \text{ s} \times \frac{88\text{ft}}{\text{s}} \times \frac{\text{h}}{60 \text{ mi}} = 88 \text{ ft}$

Braking distance $= \frac{(\text{initial speed})^2}{2 \times \text{deceleration}}$

$$= \frac{58.7^2 \text{ ft}^2 \times \text{s}^2}{\text{s}^2 \times 2 \times 17\text{ft}} = 101.3 \text{ ft}$$

So stopping distance = reaction distance + braking distance = 88 ft + 101.3 ft = 189.3 ft.

(e) 50 mph

Reaction distance $= \frac{50 \text{ mi}}{\text{h}} \times 1.5 \text{ s} \times \frac{88\text{ft}}{\text{s}} \times \frac{\text{h}}{60 \text{ mi}} = 110 \text{ ft}$

Braking distance $= \frac{(\text{initial speed})^2}{2 \times \text{deceleration}}$

$$= \frac{73.3^2 \text{ ft}^2 \times \text{s}^2}{\text{s}^2 \times 2 \times 17\text{ft}} = 158 \text{ ft}$$

So stopping distance = reaction distance + braking distance = 110 ft + 158 ft = 268 ft.

(f) 60 mph

Reaction distance $= \frac{60 \text{ mi}}{\text{h}} \times 1.5 \text{ s} \times \frac{88\text{ft}}{\text{s}} \times \frac{\text{h}}{60 \text{ mi}} = 132 \text{ ft}$

Braking distance $= \frac{(\text{initial speed})^2}{2 \times \text{deceleration}}$

$$= \frac{88^2 \text{ ft}^2 \times \text{s}^2}{\text{s}^2 \times 2 \times 17\text{ft}} = 228 \text{ ft}$$

So stopping distance = reaction distance + braking distance = 132 ft + 228 ft = 360 ft.

(g) 70 mph

$$\text{Reaction distance} = \frac{70\ \text{mi}}{\text{h}} \times 1.5\ \text{s} \times \frac{88\text{ft}}{\text{s}} \times \frac{\text{h}}{60\ \text{mi}} = 154\ \text{ft}$$

$$\text{Braking distance} = \frac{(\text{initial speed})^2}{2 \times \text{deceleration}}$$

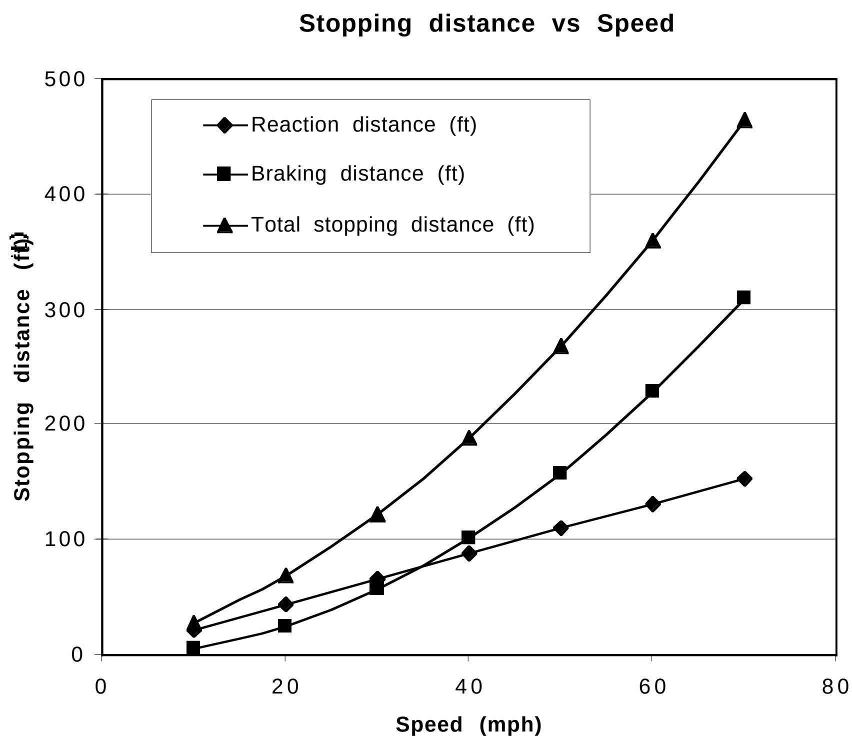
$$= \frac{102.7^2\ \text{ft}^2 \times \text{s}^2}{\text{s}^2 \times 2 \times 17\text{ft}} = 310\ \text{ft}$$

So stopping distance = reaction distance + braking distance = 154 ft + 310 ft = 464 ft.

(h)

Speed (mph)	Reaction distance (ft)	Braking distance (ft)	Total stopping distance (ft)
10	22	6.4	28.4
20	44	25.2	69.2
30	66	56.9	122.9
40	88	101.3	189.3
50	110	158	268
60	132	228	360
70	154	310	464

(i)



i.

10 mph = 14.7 $\frac{ft}{s}$ so braking time $t = \frac{v}{a} = \frac{14.7 \text{ ft}}{\text{s}} \frac{\text{s}^2}{17 \text{ ft}} = 0.9$ s

20 mph = 29.3 $\frac{ft}{s}$ so braking time $t = \frac{v}{a} = \frac{29.3 \text{ ft}}{\text{s}} \frac{\text{s}^2}{17 \text{ ft}} = 1.7$ s

30 mph = 44 $\frac{ft}{s}$ so braking time $t = \frac{v}{a} = \frac{44 \text{ ft}}{\text{s}} \frac{\text{s}^2}{17 \text{ ft}} = 2.6$ s

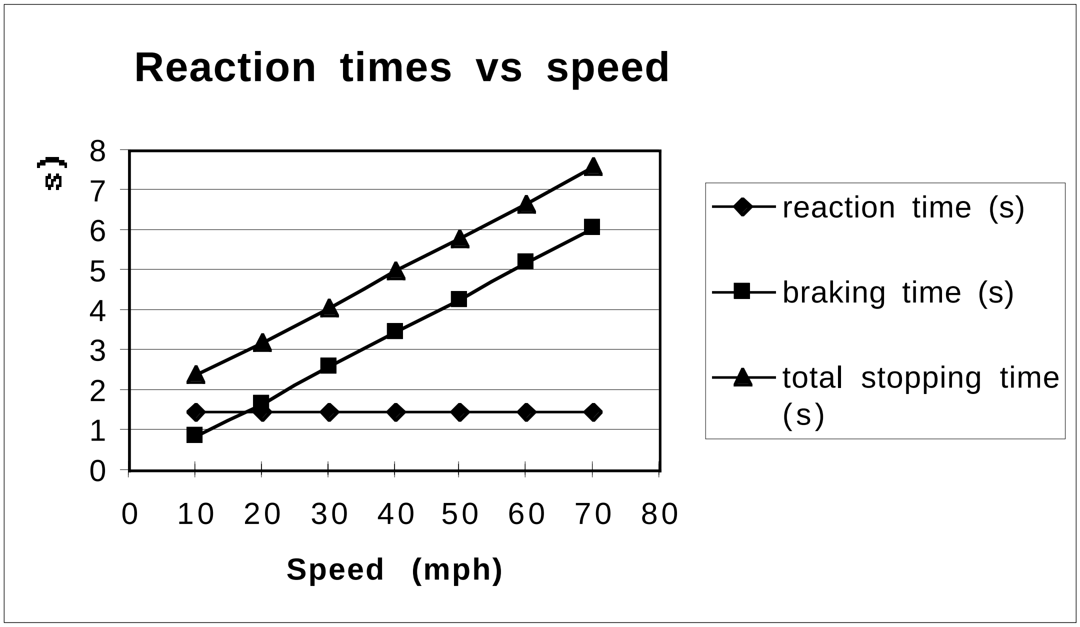
40 mph = 58.7 $\frac{ft}{s}$ so braking time $t = \frac{v}{a} = \frac{58.7 \text{ ft}}{\text{s}} \frac{\text{s}^2}{17 \text{ ft}} = 3.5$ s

50 mph = 73.3 $\frac{ft}{s}$ so braking time $t = \frac{v}{a} = \frac{73.3 \text{ ft}}{\text{s}} \frac{\text{s}^2}{17 \text{ ft}} = 4.3$ s

60 mph = 88 $\frac{ft}{s}$ so braking time $t = \frac{v}{a} = \frac{88 \text{ ft}}{\text{s}} \frac{\text{s}^2}{17 \text{ ft}} = 5.2$ s

70 mph = 103 $\frac{ft}{s}$ so braking time $t = \frac{v}{a} = \frac{103 \text{ ft}}{\text{s}} \frac{\text{s}^2}{17 \text{ ft}} = 6.1$ s

Speed (mph)	Reaction time (s)	Braking time (s)	Total stopping time (s)
10	1.5	.9	2.4
20	1.5	1.7	3.2
30	1.5	2.6	4.1
40	1.5	3.5	5.0
50	1.5	4.3	5.8
60	1.5	5.2	6.7
70	1.5	6.1	7.6



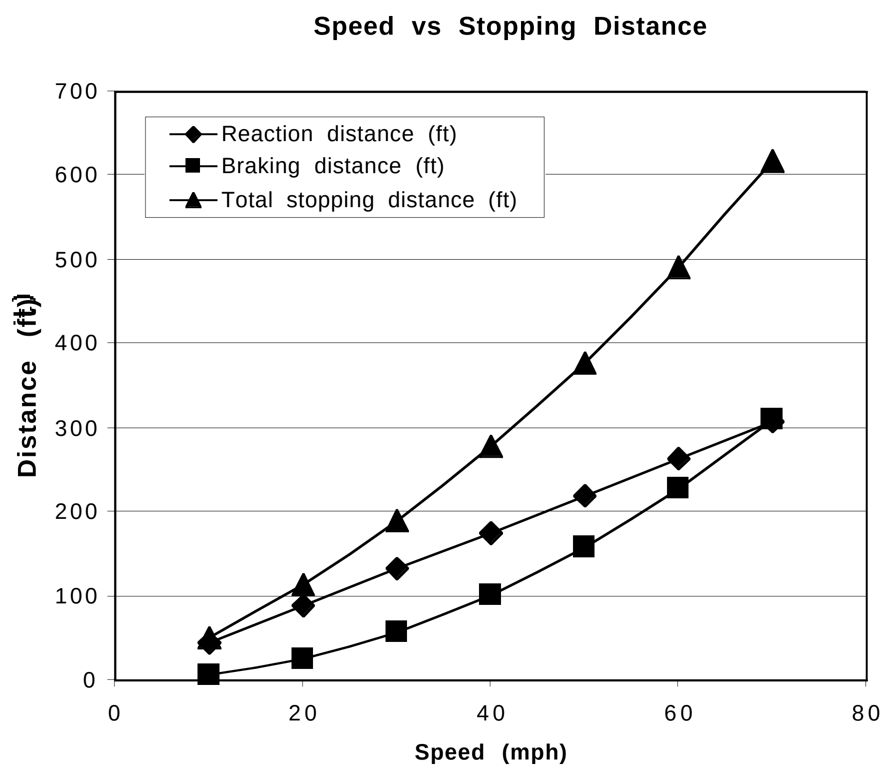
Develop a scale model car that shows the reaction distance, braking distance, and total stopping distance for speeds for 10 to 70 mph in increments of 10 mph. Include the reaction time, braking time, and total stopping time in the scale model car simulation tool. Also include a marker that shows the 160 ft distance that is illuminated by a car's headlights. Use the scale of 1 in = 100 ft.

3. Redo the calculations of problem 2 assuming that you are drunk and your reaction time is twice as long (3 s instead of 1.5 s).

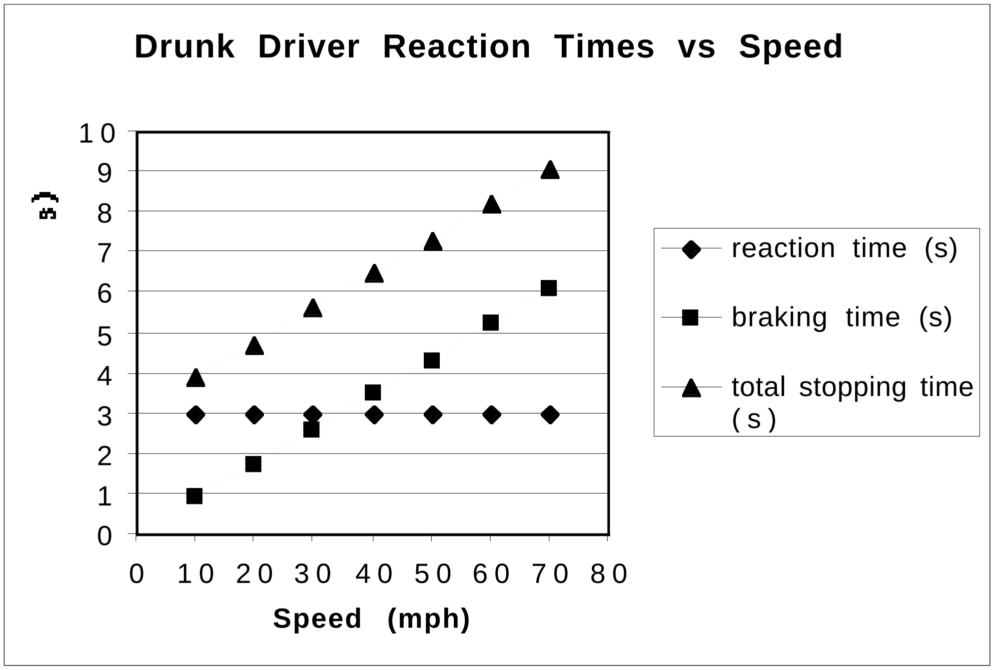
Generate a drunk driver scale model and map (or use car E and map A) to simulate these situations.

The reaction distance will be double the distances calculated in problem 5 because the reaction distance is directly proportional to the reaction time. The braking distance will remain the same because we are assuming it is not affected.

Speed (mph)	Reaction distance (ft)	Braking distance (ft)	Total stopping distance (ft)
10	44	6.4	50.4
20	88	25.2	113.2
30	132	56.9	188.9
40	176	101.3	277.3
50	220	158	378
60	264	228	492
70	308	310	618



Speed (mph)	Reaction time (s)	Braking time (s)	Total stopping time (s)
10	3.0	0.9	3.9
20	3.0	1.7	4.7
30	3.0	2.6	5.6
40	3.0	3.5	6.5
50	3.0	4.3	7.3
60	3.0	5.2	8.2
70	3.0	6.1	9.1



Develop a scale model car that shows the reaction distance, braking distance, and total stopping distance for speeds for 10 to 70 mph in increments of 10 mph. Include the reaction time, braking time, and total stopping time in the scale model car simulation tool. Also include a marker that shows the 160 ft distance that is illuminated by a car's headlights. Use the scale of 1 in = 100 ft.

4. Redo the calculations of problem 2 assuming that the road is wet. The deceleration of a car on a wet road is apparently 75-95% of the dry road value (see Appendix A) - assuming that there is no hydroplaning. So assume that the wet road deceleration is 13 ft/s^2 instead of the 17ft/s^2 that we have using for a dry road.

(a) 10 mph

Reaction distance = speed x reaction time (recall that speed is a constant during the reaction time)

$$\text{Reaction distance} = \frac{10 \text{ mi}}{\text{h}} \times 1.5 \text{ s} \times \frac{88\text{ft}}{\text{s}} \times \frac{\text{h}}{60 \text{ mi}} = 22 \text{ ft}$$

$$\text{Braking distance} = \frac{(\text{initial speed})^2}{2 \times \text{deceleration}}$$

$$= \frac{14.7^2 \text{ ft}^2 \times \text{s}^2}{\text{s}^2 \times 2 \times 13\text{ft}} = 8.3 \text{ ft}$$

So stopping distance = reaction distance + braking distance = 22 ft + 8.3 ft = 20.3 ft.

(b) 20 mph

$$\text{Reaction distance} = \frac{20 \text{ mi}}{\text{h}} \times 1.5 \text{ s} \times \frac{88\text{ft}}{\text{s}} \times \frac{\text{h}}{60 \text{ mi}} = 44 \text{ ft}$$

$$\text{Braking distance} = \frac{(\text{initial speed})^2}{2 \times \text{deceleration}}$$

$$= \frac{29.3^2 \text{ ft}^2 \times \text{s}^2}{\text{s}^2 \times 2 \times 13\text{ft}} = 33.0 \text{ ft}$$

So stopping distance = reaction distance + braking distance = 44 ft + 33.0 ft = 77.0 ft.

(c) 30 mph

$$\text{Reaction distance} = \frac{30 \text{ mi}}{\text{h}} \times 1.5 \text{ s} \times \frac{88\text{ft}}{\text{s}} \times \frac{\text{h}}{60 \text{ mi}} = 66 \text{ ft}$$

$$\text{Braking distance} = \frac{(\text{initial speed})^2}{2 \times \text{deceleration}}$$

$$= \frac{44^2 \text{ ft}^2 \times \text{s}^2}{\text{s}^2 \times 2 \times 13\text{ft}} = 74.5 \text{ ft}$$

So stopping distance = reaction distance + braking distance = 66 ft + 74.5 ft = 140.5 ft.

(d) 40 mph

Reaction distance $= \frac{40 \text{ mi}}{\text{h}} \times 1.5 \text{ s} \times \frac{88\text{ft}}{\text{s}} \times \frac{\text{h}}{60 \text{ mi}} = 88 \text{ ft}$

Braking distance $= \frac{(\text{initial speed})^2}{2 \times \text{deceleration}}$

$$= \frac{58.7^2 \text{ ft}^2 \times \text{s}^2}{\text{s}^2 \times 2 \times 13\text{ft}} = 132.5 \text{ ft}$$

So stopping distance = reaction distance + braking distance = 88 ft + 132.5 ft = 220.5 ft.

(e) 50 mph

Reaction distance $= \frac{50 \text{ mi}}{\text{h}} \times 1.5 \text{ s} \times \frac{88\text{ft}}{\text{s}} \times \frac{\text{h}}{60 \text{ mi}} = 110 \text{ ft}$

Braking distance $= \frac{(\text{initial speed})^2}{2 \times \text{deceleration}}$

$$= \frac{73.3^2 \text{ ft}^2 \times \text{s}^2}{\text{s}^2 \times 2 \times 13\text{ft}} = 206.6 \text{ ft}$$

So stopping distance = reaction distance + braking distance = 110 ft + 206.6 ft = 316.6 ft.

(f) 60 mph

Reaction distance $= \frac{60 \text{ mi}}{\text{h}} \times 1.5 \text{ s} \times \frac{88\text{ft}}{\text{s}} \times \frac{\text{h}}{60 \text{ mi}} = 132 \text{ ft}$

Braking distance $= \frac{(\text{initial speed})^2}{2 \times \text{deceleration}}$

$$= \frac{88^2 \text{ ft}^2 \times \text{s}^2}{\text{s}^2 \times 2 \times 13\text{ft}} = 297.8 \text{ ft}$$

So stopping distance = reaction distance + braking distance = 132 ft + 297.8 ft = 429.8 ft.

(g) 70 mph

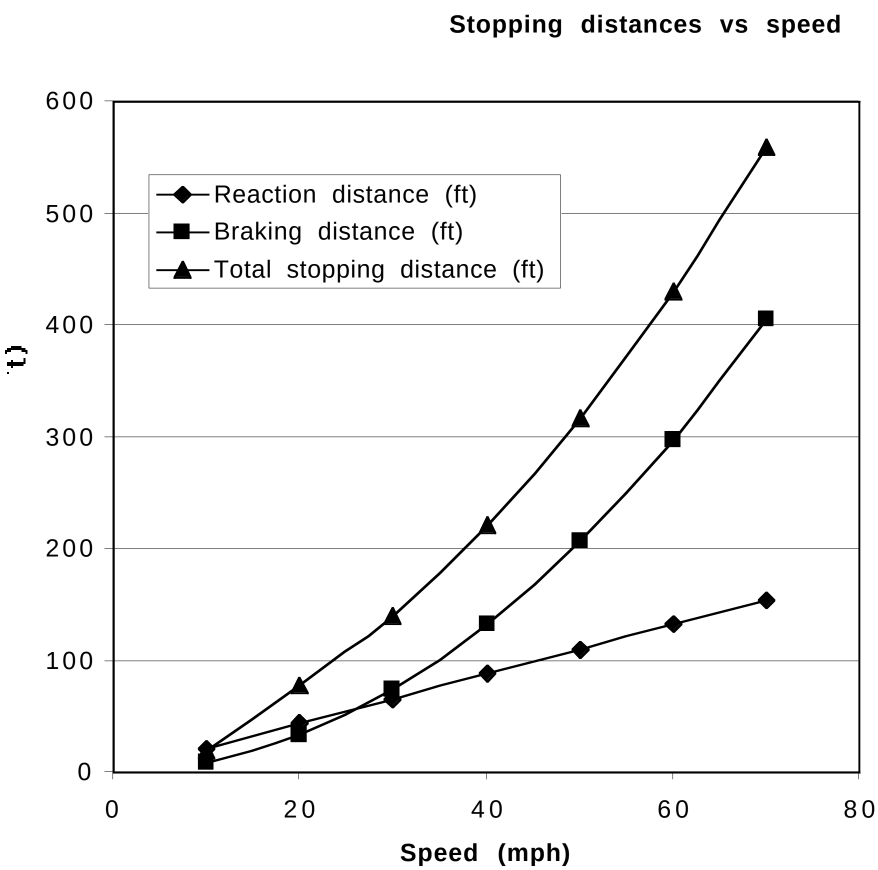
Reaction distance $= \frac{70 \text{ mi}}{\text{h}} \times 1.5 \text{ s} \times \frac{88\text{ft}}{\text{s}} \times \frac{\text{h}}{60 \text{ mi}} = 154 \text{ ft}$

Braking distance $= \frac{(\text{initial speed})^2}{2 \times \text{deceleration}}$

$$= \frac{102.7^2 \text{ ft}^2 \times \text{s}^2}{\text{s}^2 \times 2 \times 13\text{ft}} = 405.7 \text{ ft}$$

So stopping distance = reaction distance + braking distance = 154 ft + 405.7 ft = 559.7 ft.

Speed (mph)	Reaction distance (ft)	Braking distance (ft)	Total stopping distance (ft)
10	22	8.3	30.3
20	44	33	77
30	66	74.5	140.5
40	88	132.5	220.5
50	110	206.6	316.6
60	132	297.8	429.8
70	154	405.7	559.7



10 mph = 14.7 $\frac{ft}{s}$ so braking time $t = \frac{v}{a} = \frac{14.7\ ft}{s} \frac{s^2}{13\ ft} = 1.1\ s$

20 mph = 29.3 $\frac{ft}{s}$ so braking time $t = \frac{v}{a} = \frac{29.3\ ft}{s} \frac{s^2}{13\ ft} = 2.3\ s$

30 mph = 44 $\frac{ft}{s}$ so braking time $t = \frac{v}{a} = \frac{44\ ft}{s} \frac{s^2}{13\ ft} = 3.4\ s$

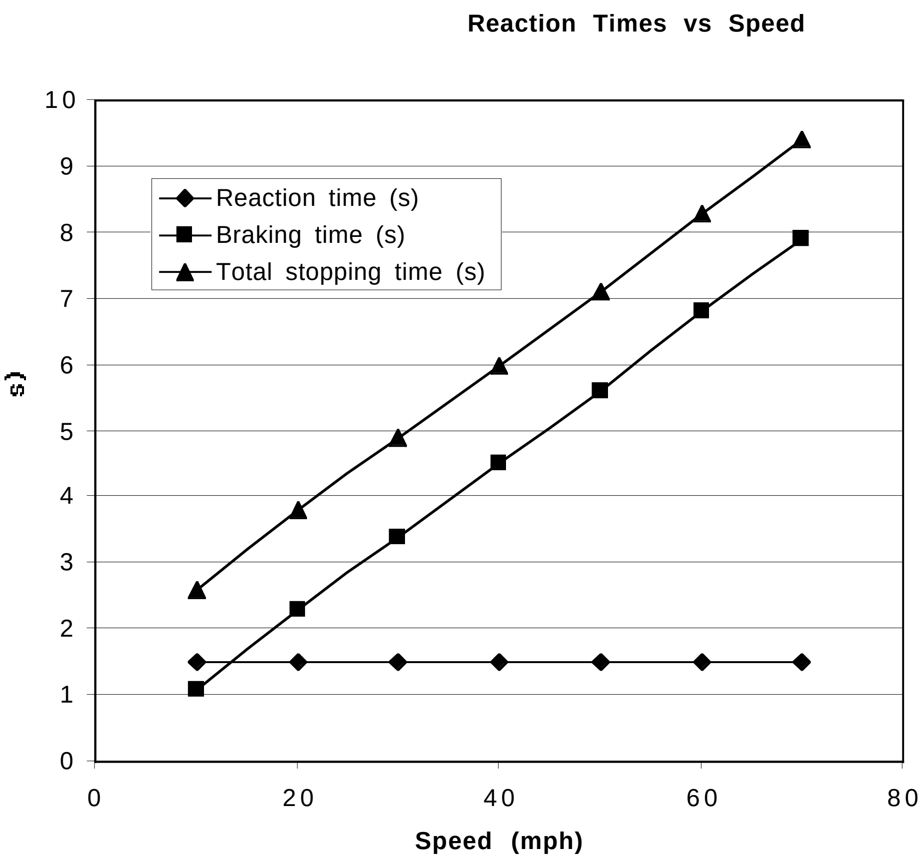
40 mph = 58.7 $\frac{ft}{s}$ so braking time $t = \frac{v}{a} = \frac{58.7\ ft}{s} \frac{s^2}{13\ ft} = 4.5\ s$

50 mph = 73.3 $\frac{ft}{s}$ so braking time $t = \frac{v}{a} = \frac{73.3\ ft}{s} \frac{s^2}{13\ ft} = 5.6\ s$

60 mph = 88 $\frac{ft}{s}$ so braking time $t = \frac{v}{a} = \frac{88\ ft}{s} \frac{s^2}{13\ ft} = 6.8\ s$

70 mph = 103 $\frac{ft}{s}$ so braking time $t = \frac{v}{a} = \frac{103\ ft}{s} \frac{s^2}{13\ ft} = 7.9\ s$

Speed (mph)	Reaction time (s)	Braking time (s)	Total stopping time (s)
10	1.5	1.1	2.6
20	1.5	2.3	3.8
30	1.5	3.4	4.9
40	1.5	4.5	6.0
50	1.5	5.6	7.1
60	1.5	6.8	8.3
70	1.5	7.9	9.4


Reaction Times vs Speed
10
9
8
7
6
5
4
3
2
1
0
s)
0
20
40
60
80
Speed (mph)
Reaction time (s)
Braking time (s)
Total stopping time (s)

5. Compare the total stopping distance and total reaction time for a driver on a dry road, a driver on a wet road and a drunk driver on a dry road. Use the results of the previous problems. Show the result in a table for speeds from 10 to 70 mph in increments of 10 mph. Plot the different stopping distances vs speed. What are the implications of these tabulated results for safe driving?

Speed (mph)	Dry Stopping Distance (ft)	Dry Stopping Time (s)	Wet Stopping Distance (ft)	Wet Stopping Time (s)	Drunk Stopping Distance (ft)	Drunk Stopping Time (s)
10	28	2.4	20	2.6	50	3.9
20	69	3.2	77	3.8	113	4.7
30	123	4.1	141	4.9	189	5.6
40	189	5.0	221	6.0	277	6.5
50	268	5.8	317	7.1	378	7.3
60	360	6.7	430	8.3	492	8.2
70	464	7.6	560	9.4	618	9.1

The stopping distances increase dramatically as the speed increases. The stopping distances for driving on wet roads and for drunk drivers are much greater than that for dry roads and sober drivers. The implications are: slow down when the roads are wet (drive about 10 mph slower than your typical speed) because the stopping distances are greater and don't drive if drunk.