Section 2.5 Physics of Tailgating

Reaction time includes the time taken for this processing plus the time for your foot to move to the brake. Typical reaction times are between 0.2 and 0.7 seconds.

Calculating Stopping Distance

Initially you are travelling along at some constant velocity before your foot hits the brake. The distance travelled during the reaction time is given by $d = v_1 t$ where v_1 is the initial velocity.

Calculating Stopping Distance if Cars have Identical Braking Capacity

Assume that two Lincoln Continentals are travelling along a highway at 97 km/h. The front car slams on its brakes. Determine the minimum distance that the second Lincoln should have been behind the first to avoid a rear end collision given that the driver's reaction time was 0.45 s and the maximum deceleration of the Lincoln is 9.0 m/s^2.

Front

$V_1 = 97\ km/h$
$= 26.9\ m/s$
$a = -9.0\ m/s^2$
$V_2 = 0$
$d = ?$

Second

$V_1 = 97\ km/h$
$a = -9.0\ m/s^2$
$V_2 = 0$

$t_r = 0.45\ s$

① distance it takes the 1st car to come to a stop.

$$d = \frac{V_2^2 - V_1^2}{2a} = \frac{0 - (26.9\ m/s)^2}{2(-9.0\ m/s^2)} = 40.2\ m$$

② 2nd car will also travel 40.2 m with the brakes on.

distance travelled while reacting:

$$d_r = V_1 t_r$$
$$= (26.9\ m/s)(0.45\ s)$$
$$= 12.1\ m$$

Note that 12 m of this distance is travelled before applying the brakes, and the other 41 m is required to stop. Thus a safe distance behind the first car would be at least 12 m.

The only factor affecting the required separation distance is the reaction time (when both cars are travelling at the same speed and have the same deceleration).

Calculating Stopping Distance if Cars have Different Braking Capacities

Two cars are travelling at 121 km/h with a separation ~~distance of 5 car lengths (approx. 24.38 m~~). Car A decelerates at 9.8 m/s^2 (a BMW), while car B decelerates at 7.5 m/s^2 (a Chevrolet Blazer).

A) If the driver of car B has a reaction time of 0.45 s, show that car B will in fact hit car A even at 5 car lengths away.

Car A
$V_1 = 121\,km/h = 33.61\,m/s$
$a = -9.8\,m/s^2$
$V_2 = 0\,m/s$
$d_B =$
(Braking distance)

Car B
Braking
$V_1 = 121\,km/h = 33.61\,m/s$
$a = -7.5\,m/s^2$
$V_2 = 0\,m/s$
$d_B =$

Reacting
$t_r = 0.45\,s$
$V_1 = 33.61\,m/s$
$d_r = ?$

Car A: $d_B = \dfrac{V_2^2 - V_1^2}{2a} = \dfrac{0 - (33.61\,m/s)^2}{2(-9.8\,m/s^2)} = 57.6\,m$

Car B: $d_B = \dfrac{V_2^2 - V_1^2}{2a} = \dfrac{0 - (33.61\,m/s)^2}{2(-7.5\,m/s^2)} = 75.3\,m$

$d_r = V_1 t = (33.61\,m/s)(0.45\,s) = 15.1\,m$

$d_{stopping} = 75.3\,m + 15.1\,m = 90.4\,m$

When Car A stops it will be $57.6\,m + 24.38\,m = 81.98\,m$ from where Car B started.

If car A comes to a complete stop it will still be hit by Car B b/c Car B needs 90.4 m to stop.

B) How fast will car B be going when it hits Car A?

Car B needs to stop in 81.98 m
While reacting Car B travels 15.1 m.
So Car B would have only been slowing down for a distance of $81.98\,m - 15.1\,m = 66.88\,m$ before hitting Car A.

$V_1 = 33.61\,m/s$
$V_2 = ?$
$a = -7.5\,m/s^2$
$d = 66.88\,m$

$V_2^2 = V_1^2 + 2ad$

$V_2^2 = (33.61\,m/s)^2 + 2(-7.5\,m/s^2)(66.88\,m)$

$V_2 = 11.2\,m/s$

$V_2 = \underline{40\,km/h}$

2. What is the stopping distance of a Toyota Celica ($a = -9.2\ m/s^2$) from 97 km/h where the driver has a reaction time of 0.55 s?

Test

Reacting

$V_1 = 97 km/h$

$V_1 = 26.9 m/s$

$t_r = 0.55 s$

$d_r = ?$

Braking

$V_1 = 26.9 m/s$

$V_2 = 0 m/s$

$a = -9.2 m/s^2$

$d_B = ?$

$$d_r = V_1 t_r = (26.9 m/s)(0.55 s) = 14.8 m$$

$$d_B = \frac{V_2^2 - V_1^2}{2a} = \frac{0 - (26.9 m/s)^2}{2(-9.2 m/s^2)} = 39.3 m$$

$$d_{stopping} = 14.8 m + 39.3 m = 54 m$$

3. A Chevrolet Blazer travelling at 97 km/h can stop in 48 m. Given that the actual stopping distance for a certain driver is 54 m, what was the driver's reaction time?

Reacting

$V_1 = 26.9 m/s$

$t_r = ?$

$d_r =$

Braking

$V_1 = 26.9 m/s$

$d_B = 48 m$

$V_2 = 0 m/s$

$d_{stopping} = 54 m$

$$d_r = 54 m - 48 m = 6 m$$

$$t_r = \frac{d}{V} = \frac{6 m}{26.9 m/s} = 0.22 s$$

4. A driver of a car going at 90.0 km/h suddenly sees the lights of a barrier 45 m ahead. If the driver applies the brakes and the average acceleration during braking is 10.0 m/s^2, determine the whether or not the car hits the barrier. The driver's reaction time is 0.75 s.

Reacting
$t_r = 0.75 s$
$V_1 = 90.0 km/h = 25 m/s$
$d_r = ?$

Braking
$V_1 = 90 km/h = 25 m/s$
$a = -10 m/s^2$
$V_2 = 0 m/s$
$d_B = ?$

$d_r = V_r t = (25 m/s)(0.75 s) = 18.75 m$

$d_B = \frac{V_2^2 - V_1^2}{2a} = \frac{0-(25 m/s)^2}{2(-10 m/s^2)} = 31.25 m$

$d_{stopping} = 18.75 m + 31.25 m = 50 m$

Since 50 m > 45 m, he will hit the barrier.

5. An automobile is travelling at 25 m/s on a country road when the driver suddenly notices a cow in the road 30.0 m ahead. The driver attempts to brake the automobile but the distance is too short. With what velocity would the car hit the cow if the car decelerated at 7.84 m/s^2 and the driver's reaction time was 0.75 s?

Reacting
$V_1 = 25 m/s$
$t_r = 0.75 s$

Braking
$V_1 = 25 m/s$
$a = -7.84 m/s^2$
$V_2 = ?$

$d_T = 30 m$

$d_r = V t_r = (25 m/s)(0.75 s) = 18.75 m$

$d_B = 30 m - 18.75 m = 11.25 m$

$V_2^2 = V_1^2 + 2ad$

$V_2^2 = (25 m/s)^2 + 2(-7.84 m/s^2)(11.25 m)$

$V_2 = 21 m/s$ (76 km/h)

Find Reaction time

Reacting
$V_1 = 70 km/h$
$t_r = ?$
d_r

Braking
$V_1 = 70 km/h$
$a = -10 m/s^2$
$V_2 = 0$

$d_T = 60 m$

① $d_B =$

② $d_r = d_T - d_B$

③ $t_r = \frac{d_r}{V}$