1. A car has a wheelbase of 270 cm, and is traveling on level road. The center of gravity is 125 cm behind the front axle and 51 cm above ground level. The coefficient of rolling resistance is $f_r = 0.0136$, and the coefficient of road adhesion is $\mu = 0.85$. The aerodynamic drag is neglected.

   a) Calculate the maximum acceleration that the tire-ground contact support for a front and rear driven vehicle respectively.

   b) How long time does it take for the vehicle to accelerate from 0 to 100 km/h? Assume that the engine is able to supply the torque required for the acceleration calculated above.

   c) How does the result in a) change if the center of gravity is moved backward?

   d) How does the result in a) change if the center of gravity is moved upward?

2. Consider the same vehicle as in the previous exercise.

   a) Determine the distribution of the braking force between the front and rear tires so that the maximum forces are reached at the same time when braking.

   b) What is the maximum deceleration?

   c) How much do the maximum deceleration decrease if you only apply the front brakes?

3. A vehicle weighs 1400 kg and is running in a uphill slope of 5 degrees at a speed of 70 km/h.

   a) Calculate the stopping distance if the braking force is 12 kN and if the rolling and aerodynamic resistances are neglected.

   b) When do the expression for the stopping distance become negative? How should you interpret the result in such a case?

4. In this exercise we consider the brush model for a tire under the action of a driving torque and with the assumption that the normal pressure has a parabolic shape with zero pressure at both ends of the contact patch, instead of a uniformly distributed pressure.

   a) Sketch the curves corresponding to the ones in Figure 1.15 in the course book.

   b) What is the critical value of the slip?

c) Determine the normal pressure expressed in the normal force W, the contact length l_t, and the coordinate x.

d) Determine the relation between the length of the region where no sliding takes place l_c and the slip i.

e) Determine the relation between the force F_x and the length l_c.

f) What is the largest possible value for F_x and what are the corresponding values of the slip i?

g) Calculate the force F_x when $W = 5000$ N, $l_t = 12$ cm, $k_t = 15 \cdot 10^6$ N/m^2, $\mu_p = 0.85$, and $i = 5\%$.

5. You are driving a Volvo XC90 on a 90 km/h road (keeping the speed limit) and approach a 50 km/h speed-limit sign. The vehicle mass is 2100 kg, the drag coefficient is 0.33, the frontal area is 2.78 m^2, the road-tire friction coefficient is 0.95, the rolling resistance coefficient 0.0136, and the air density 1.2 kg/m^3. How close to the sign can you drive before applying the brakes, if the vehicle speed should have been reduced to 50 km/h when reaching the sign? (I.e. compute the shortest braking distance from 90 to 50 km/h.)

   a) Neglect air and rolling resistance.

   b) Take the air and rolling resistance into account.

6. A car weighs 1500 kg and has a wheelbase of 2.8 m. The center of gravity is located 1.3 m behind the front axle and 0.5 m above ground. The car brakes with a force of 6000 N and the braking force is equally distributed between the front and rear brakes. Use the brush model for calculating i_s at the front and rear tires respectively if $C_s = 80$ kN, $f_r = 0.014$, and $\mu = 0.8$. Assume that the normal pressure is uniformly distributed.

Answers

1. a) 3.80 m/s^2 and 4.53 m/s^2 respectively.

   b) 7.3 s and 6.1 s respectively.

   c) The maximum force decreases for a front-wheel-drive vehicle and increases for a rear-wheel vehicle.

   d) Same answer as c).

2. a) 30% rear and 70% front.

   b) 8.34 m/s^2

   c) The retardation decreases by 36% down to 5.40 m/s^2.

3. a) 20.1 m

   b) If the vehicle is traveling downhill and the braking force is small. The vehicle will not stop.

4. a) ...

   b) $i_c = 0$

   c) $6Wx(l_t - x)/l_t^3$

   d) $l_c = l_t - \frac{k_t l_t^3}{6\mu_p W} i$

   e) $F_x = \mu_p W(1 - (l_c/l_t)^3)$

   f) $\mu_p W$ and $i \geq 6\mu_p W/(k_t l_t^2)$

   g) $F_x = 3.4$ kN ($l_c = 6.9$ cm)

5. a) 23.2 m

   b) 22.9 m

6. 1.92% front and 2.14% rear.