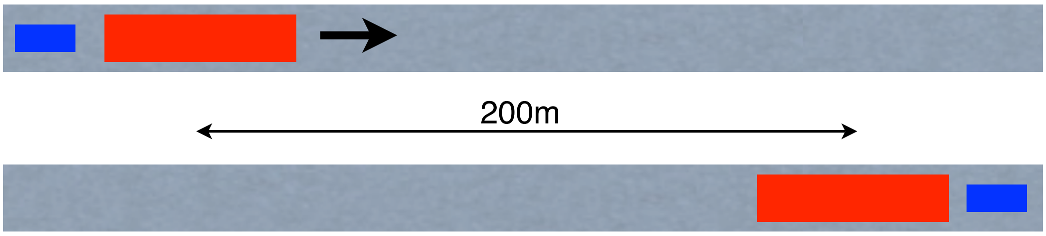
Overtaking a truck

(an extension of Example 10.17 in the textbook)

Your 1500 kg car is behind a truck travelling at 90 km h^{-1} (= 25 m s^{-1}). You have a distance d = 200m to overtake it. What engine power do you need?



Assume you start 20m behind the centre of the truck and finish 20m in front of it.

The truck is moving at speed v so the time it takes to cover the distance d is

$$\Delta t = d / v = 200 / 25 = 8\text{s}$$

You need to travel a distance

$$\Delta x = d + 40\text{m}$$

in Δt s with constant acceleration starting from speed v. Using the motion equations (eq. 2.12)

$$\Delta x = v \, \Delta t + \tfrac{1}{2} a \, (\Delta t)^2$$

so

$$d + 40 = v \, . \, (d/v) + \tfrac{1}{2} a \, (d/v)^2$$

$$\tfrac{1}{2} a \, (d/v)^2 = 40$$

so the required acceleration is

$$a = 80 \, (v/d)^2$$

$$= 80 \text{ x } (25/200) = 1.25 \text{ ms}^{-2}$$

From Newton's laws, the net force on the car is

$$F = ma = 1500\text{x}1.25 = 1875 \text{ N}$$

so the work done by this force accelerating the car over 240m is

$$W = Fd = 1875 \text{ x } 240 \text{ m} = 450 \text{ kW}$$

The power required is

$$P = W / t = 450/8 = 56 \text{ kW}$$

c.f. typical small car has engine power of ~ 50 kW, with ~10–15 kW needed to maintain speed at 90 km h^{-1}.

Note that if d is a bit longer, say 250m, then

$$\Delta t = d / v = 10\text{s}$$

$$a = 80 \, (v/d)^2 = 0.8 \text{ ms}^{-2}$$

$$W = ma \text{ x } d = 1500 \text{ x } 0.8 \text{ x } 290 \text{ m} = 350 \text{ kW}$$

so

$$P = W / t = 350/10 = 35 \text{ kW}$$

so a 25% increase in distance leads to a 38% drop in required power.