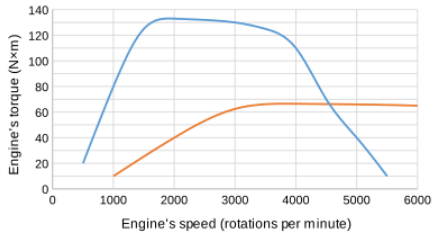
3. GEAR SHIFT

i) The acceleration of the car is proportional to the torque applied to the wheels. Therefore we should keep the torque onto the wheels as big as possible, and shift gears when the torque applied onto the wheels in the second gear is bigger than the one obtained in the first gear. At the same car's speed, the engine's speed is (14:1):(7:1) = 2 times bigger in the first gear than in the second gear. Correspondingly, at the same engine's speed, the torque onto the wheels is two times smaller in the second gear than in the first gear. Therefore we can draw another graph where the engine's torque is twice as small and the engine's speed is two times bigger. The intersection of those graphs is the point where the gear should be changed.



From the graph we read that at that moment in the first gear, the engine's torque is $\tau_e = 66.5\,\mathrm{N}\cdot\mathrm{m}$ and the engine's speed is $\omega_e = 4550\,\mathrm{rpm}$. The wheels' angular speed is then $\omega_w = \frac{1}{14}\omega_e$ and the car's speed is $v = \frac{1}{2}\omega_w d = \frac{1}{28}\omega_e d$. Let's convert $1\,\mathrm{rpm} = 120\pi\,\mathrm{rad/h}$ and $d = 6\times10^{-4}\,\mathrm{km}$. Thus, $v \approx 37\,\mathrm{km/h}$.

ii) At the optimum point, the acceleration before and after gear change is the same. From Newton's second law, it equals $a = F/m = \frac{2\tau_w}{md}$, where the net torque applied to the wheels is $\tau_w = 14\tau_e$. Hence, $a = \frac{28\tau_e}{md} \approx 2.2\,\mathrm{m/s^2}$.