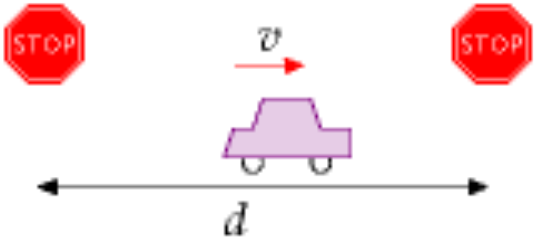
Exercice 1

Addendum

Power to move a car

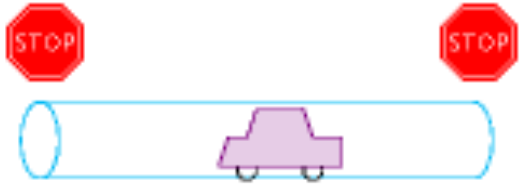
- Energy to accelerate = energy put in braking

$$\frac{E_{kin}}{time\ btw\ brakes} = \frac{0.5 m_{car} v^2}{d/v} = \frac{m_{car} v^3}{2d}$$



- Energy to move in a tube of air

$$\frac{1}{2} m_{air} v^2 = \frac{1}{2} \rho A_{eff} v t v^2 = \frac{1}{2} \rho c_{drag} A_{car} t v^3$$



- Power to move the car:

$$\frac{m_{car} v^3}{2d} + \frac{\rho c_{drag} A_{car} v^3}{2}$$

braking power air drag power

- braking > drag if $m_{car} > \rho c A d$

$= m_{air(tube)}$

- A=2 m^2, c_d = 0.3, m_{car} = 1630kg, ρ=1.29 → d = 2.1 km

- city-driving (d btw stops < 2 km): brake-dominant

→save energy by lower m_{car}, lower v, regenerative braking

- long-distance driving (d>> 2 km): drag-dominant

→save energy by lower c_d, lower A_{car}, lower v

- Power of engine:
  - ε = 25%
  - v = 30 m/s (108 km/h)

  → P = 84 kW

$$P = \frac{\frac{m_{car} v^3}{2d} + \frac{\rho c_{drag} A_{car} v^3}{2}}{\varepsilon_{transmission}}$$

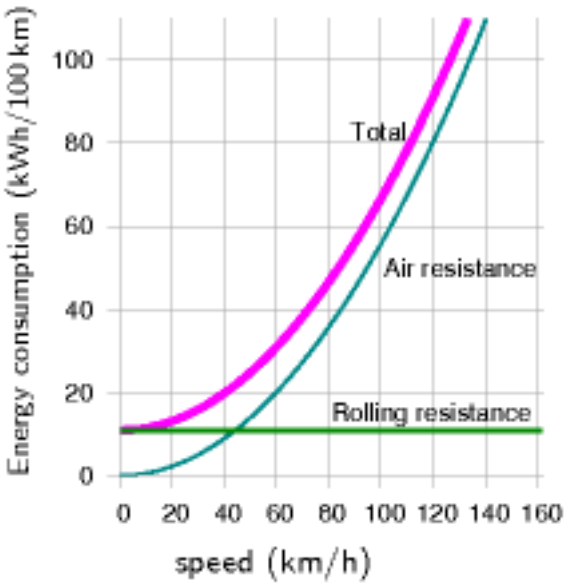
Rolling resistance

wheel	c_{roll}
car rubber tyre on road	0.010
bike tyre on road	0.005
steel on rail (train)	0.002

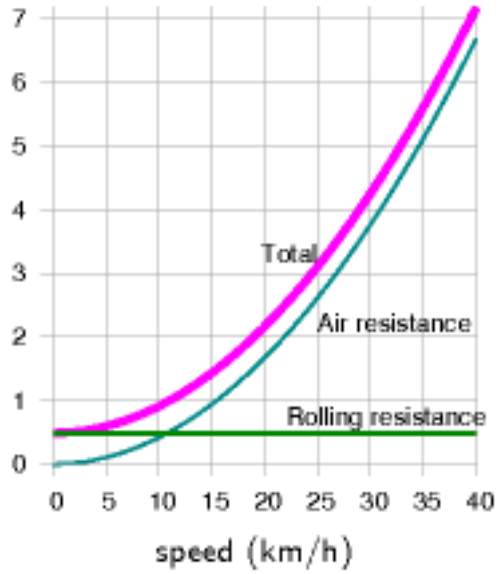
- = m_{car} * c_{roll}
- for c_r = 0.01, F=100 N for m_{car} = 1000 kg
- = like pushing the car up a slope of 1/100
- for v = 30 m/s (108 km/h), P = F*v = 3 kW
- with ε = 25%, this becomes 12 kW

Car vs bike vs train

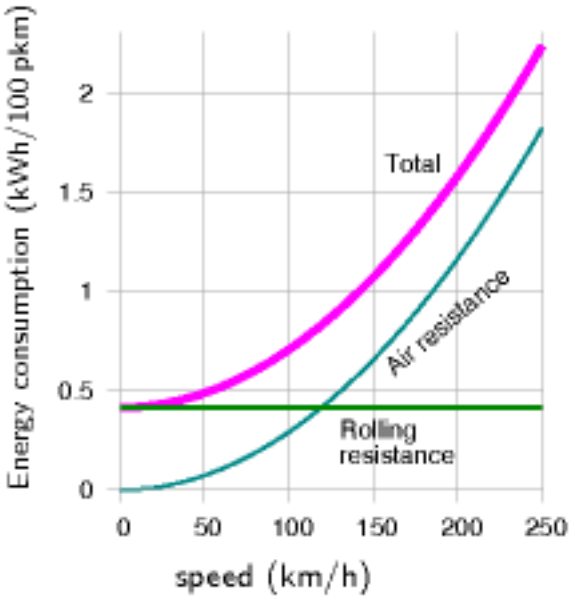
Car
m=1000 kg
$\varepsilon = 0.25$
$c_dA = 1\ m^2$
$c_r = 0.01$



Bike
m=90 kg
$\varepsilon = 0.25$
$c_dA = 0.75\ m^2$
$c_r = 0.005$



Train (8 wagons)
M=400'000 kg
$\varepsilon = 0.9$
$c_dA = 11\ m^2$
$c_r = 0.002$



Battery cars

m=740 kg, without batteries
ε = 0.85 (charging / discharging)
$c_dA = 0.8\ m^2$
$c_r = 0.01$
v=15 m/s (50 km/h)
d = 500 m
(with 50% regenerative braking)

Allow for 500 kg battery:
difficult with Pb-acid (40 Wh/kg)
→ range < 200 km
possible with Li-ion (120 Wh/kg)
→ range > 500 km