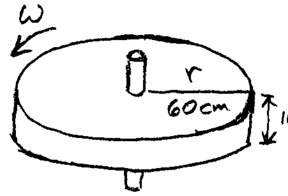
Automobile Flywheel

G:



Flywheel:
$m_f = 250\ kg$
$r = 0.60\ m$
$a_{max} = 5000g = 4.9 \times 10^5\ m/s^2$

Car: $M_{car} = 850\ kg$
$F_{ext.} = 150\ N$ at 60 mi/h $= 27\ m/s = v$
Electric Motor: 5 HP = 3730 W
(1 HP = 0.746 kW)

Find: ω_{max}, max. range, orientation of wheel, feasibility, + cost to operate

Assumptions: negligible loss of energy in power transfer mechanisms
(realistically we should assume 10% to 50% efficiency)
negligible weight of cargo for determining max. range.

Estimations: Cost of electricity ≈ 8¢/kW-h = 8¢/3.6 MJ
cost of gasoline ≈ $1.30/gal ; typical fuel economy = 30 MPG

O: This is a conservation of energy problem: Rot. KE to transl. KE + work to oppose friction

A: $KE_R = KE_T + W_{nc}$

or $W_{nc} = KE_R - KE_T$

$F \cdot d = \frac{1}{2}I\omega^2 - \frac{1}{2}Mv^2$

$\therefore d = \dfrac{1.84\,MJ - 0.40\,MJ}{150\,N}$

$\underline{d_{max} = 9.6\ km = 6.0\ mi}$

$KE_R = \frac{1}{2}I\omega^2$ where $I = \frac{1}{2}m_f r^2 = \frac{1}{2}(250\,kg)(0.6\,m)^2$

$\underline{I = 45\ kg \cdot m^2}$

$\omega_{max}^2 = \dfrac{a_{max}}{r} = \dfrac{4.9\times10^5\ m/s^2}{0.6\,m} = 8.17\times10^4\ rad^2/s^2$

$\therefore \omega_{max} = 286\ rad/s = 2{,}730\ rev/min$

$\therefore KE_R = \frac{1}{2}I\omega^2 = \frac{1}{2}(45\ kg \cdot m^2)(81{,}667\ rad^2/s^2) = \underline{1.84\ MJ}$

$KE_T = \frac{1}{2}Mv^2 = \frac{1}{2}(850\,kg + 250\,kg)(27\ m/s)^2 = \underline{0.40\ MJ}$

Time to "charge": $P = \dfrac{E}{t}$ $\therefore t = \dfrac{KE_R}{P} = \dfrac{1.84\,MJ}{3730\,W} = 493\,s = \underline{8.2\ min}$

cost for electricity = 1.84 MJ ($0.08/3.6 MJ) = $0.04 ← cheaper

cost for gasoline = $\dfrac{6\ mi}{30\ mi/gal}$ ($1.30/gal) = $0.26 ∴ gas is ~6 times more expensive

L: It appears that this flywheel could only propel the car a maximum of 6 miles before needing to be re-charged. (A range of ~3 miles is more realistic at 50% efficiency) Although this car does not meet the 50 mi. minimum range for marketability, the flywheel design with an electric motor looks like a cost-effective and environmentally-friendly transportation solution. This is probably why some city buses in Europe use flywheels similar to this.

One important design consideration is the orientation of the flywheel inside the vehicle. Since the flywheel has considerable angular momentum, it must be positioned horizontally (as shown above) so that the vehicle can turn left or right without exerting a torque on the flywheel. This then means that the car will tend to veer left or right whenever the car tilts up or down!