The special case for our Lego motors in 2014

As it happens, this year's Lego motors have their own little gearbox incorporated inside the motor unit. The situation is as shown in Fig. 1. We can measure V, i and ω_L directly. Given the known N:1 speed ratio, we have $\omega_m = N\omega_L$.

1. We solve for R as usual, using $V - i_s R = 0$ at stall, and plotting points at a few voltages, as in Assignment 4.

2. When the motor is spinning, $V - iR - kN\omega_L = 0$. Thus, by measuring V, i and ω_L, and knowing R from the measurements above, we can solve for k. We can do this at no-load, trying several voltages for a good estimate.

    (a) Note that if we remove the motor from its gearbox (as Marcus did) then we get k directly, just for the motor: $V - iR - k\omega_m = 0$

3. The torque balance is: $N(ki - T_{fm}) - T_{fg} = T_L$

4. At no load, $T_L = 0$ so $Nki_{nl} = T_{fg} + NT_{fm}$. We can lump the right hand side together as $T_{fL} \equiv T_{fg} + NT_{fm}$ where $T_{fL}\omega_L$ represents the total mechanical power loss in the motor with its gearbox. We can't really tell how much of this comes from T_{fg} versus T_{fm} and it doesn't matter because they are always together.

5. At this point, we can compute things like peak power and peak efficiency, using V, R, k and T_{fL} and k or Nk, depending on what we are looking at. As before, $i_s = V/R$ and now $i_{nl} = T_{fL}/(Nk)$.
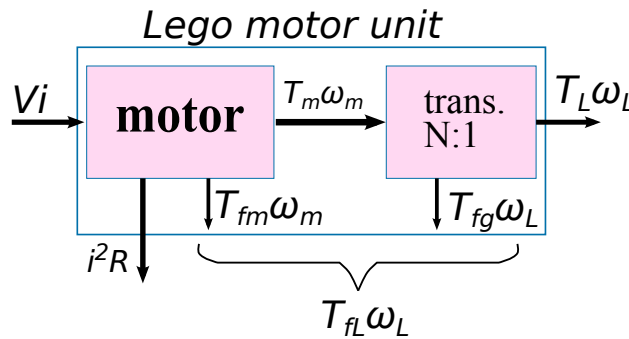

Figure 1: Schematic of Lego motor unit, showing the quantities for the motor and the small gearbox inside.

Note that you can always stick a pulley on the end of the Lego motor unit and wrap a string around it and use the string to lift a weight. Apply some voltage and time how fast the motor lifts the weight. There is no slippage or rolling resistance in this case. So the output power, mgv_y (where v_y is the lifting speed) is the same as the motor output power, $T_L\omega_L$. And, as always, the input power is Vi. This gives you a check on the actual motor efficiency under working conditions.