1 Mass calculations

Aluminium extrusions:

- 20x20 extrusions mass density: 0.44 kg/m
- T-slots: 0.02 kg; 40 brackets

$$(0.36 \cdot 4 + 0.26 \cdot 8) \cdot 0.44 + 0.02 \cdot 40 = 2.3488(kg)$$

Electronics

- 1 servo weight: 0.09 kg; 4 servos for the legs, 4 servos for the arm
- 1 motor approx: 0.205 kg; 6 motors for the wheels, 2 motors for the arm base rotation
- Raspberry pi 4 weight: 0.075 kg
- 1 battery weight: 0.405 kg; 2 batteries

$$0.09 \cdot (4 + 5) + 0.205 \cdot (6 + 2) + 0.075 + 0.405 \cdot 2 = 3.335(kg)$$

3d printed parts:

- 1 leg side without wheels is 0.214 kg; 2 leg sides, 1 arm and 1 base plate;
- 1 wheel is approx 0.113 kg (I used this wheel's weight)

$$0.214 \cdot 4 + 0.113 \cdot 6 = 1.534(kg)$$

Add everything

$$2.3488 + 3.335 + 1.534 = 7.2178(kg)$$

Round up to **8 kg** for all the buck converters, wires, and stuff.

2 Motor torque and rpm calculations

Rolling friction force 4 wheels in contact:

$$F = \frac{Wb}{\sqrt{r^2 - b^2}} = \frac{2 \cdot 9.81 \cdot 0.002}{\sqrt{0.055^2 - 0.002^2}} \approx 0.7139(N)$$

in which W is weight per wheel $(8/4 \cdot 9.81)$, b is coefficient of rolling friction (which I generously guesstimate to be 0.002), r is radius.

Static friction force:

- Climbing stairs, 4 wheels in contact:

$$F = \mu N = 0.7 \cdot 2 \cdot 9.81 = 13.734(N)$$

- 30 degree incline static friction force, 6 wheels in contact:

$$F = \mu mgcos(\theta) + mgsin(\theta) = 0.7 \cdot 8/6 \cdot 9.81 \cdot cos(30) + 0.7 \cdot 8/6 \cdot 9.81 \cdot sin(30) = 12.5(N)$$

Torque

$$T = r \times F = 0.055 \cdot 13.734 \approx 0.755(Nm) = 7.70(kg \cdot cm)$$

RPM

$$rpm = \frac{vt}{2\pi r} = \frac{1 \cdot 60}{2\pi \cdot 0.055} \approx 174$$