Battery 3

- LED flashlight → Basically a resistance and a power supply
  the batteries

  ▉ Four AA batteries → show series voltage → 1 cell, 2 cells, 4 cells

  \[ \text{How much power does the flash light need?} \]
  → Measure V → OCV
  → under load

  - Measure i → indirectly (load box)
  → directly (in-line)

  → Measure V in parallel
  → Measure i in series

  → Why does V decrease w/time?

  - Consumption → Composition Change
  - give AA Al/C Chemistry
  → mass transport

  → How much change is there?
    → called capacity
Calculating Battery Capacity

First, determine the limiting reactant in the cell. Commercially, it is:

$$\text{MnO}_2 + \text{H}_2\text{O} + e^- \rightarrow \text{MnOOH} + \text{OH}^-$$

Theoretical capacity is given by:

$$\text{Theoretical capacity} = \frac{\text{Change}}{\text{mass}} = \frac{\text{mole}^-}{\text{mol}} \cdot \frac{\text{C}}{\text{mol}e^-} \rightarrow \text{unit} = \frac{\text{C}}{\text{g}}$$

So,

$$\text{theoretical capacity (mAh/g)} = \frac{nF}{3.6 \cdot \text{MW}}$$

For MnO$_2$:

Capacity = \frac{(1)(96485.3)}{(3.6)(86.94)}

= 308.3 \text{ mAh/g}

In an AA, there is typically ~10g MnO$_2$:

Battery capacity $\approx 3000 \text{ mAh}$
How much energy?

Energy ($J$) = Charge $\cdot$ Voltage

\[
\Rightarrow (3000\text{mA\cdot h})(1.6\text{V}) = 4800\text{ mAh\cdot V} \\
= 4.8\text{ W\cdot h} \\
= 17\text{ kJ}
\]

**Specific energy (mWh/mass):**

\[
\frac{4.8\text{ W\cdot h}}{25\text{g}} \frac{1000\text{g}}{\text{kg}} = 190\text{ Wh/kg}
\]

What about a toy?

- Globe V w/ t
- Globe i w/ t  $\Rightarrow$ Complicated assortment of loads  $\Downarrow$ Base load  $\Downarrow$ Transient peak load

Your battery will need to consider this.
All of the devices we have looked at connect in series only, but there are advantages to series-parallel arrangements.

Series → increases V
Parallel → increases i

↓
Similar to just increasing Area
↓
so why not just make one big battery?
↓
redundancy

One bad cell in series → device dead

One bad cell in parallel → reduced performance, but still ok usually
↓
good for un-optimized cells like yours!

*Last, show pic of AA cross-section & discuss structure → minimizing V, increasing A*