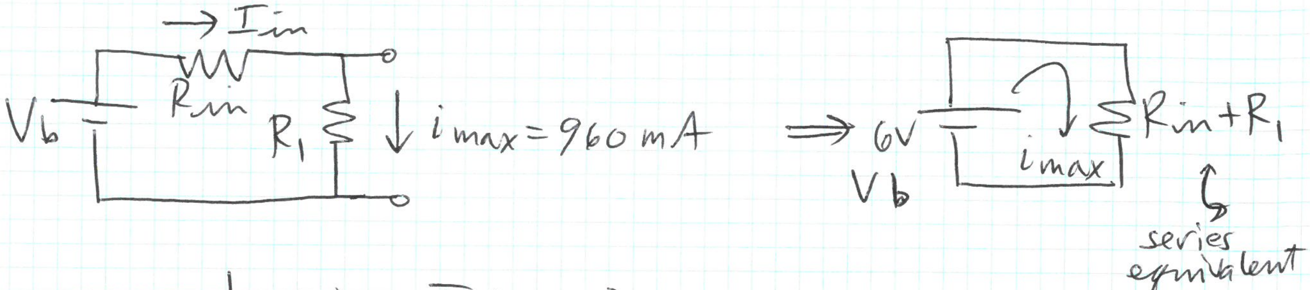
COUNT FLAPULA

a)



We know $I_{in} = i_{max} = I$

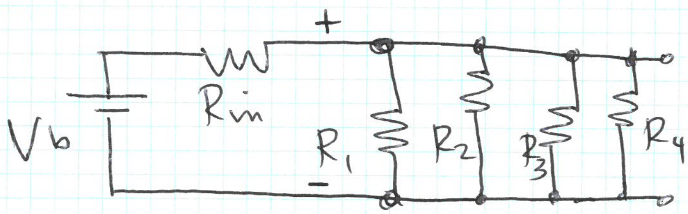
Ohm's Law : $i_{max} = \dfrac{V_b}{R_{in}+R_1}$

$$\Rightarrow R_{in} + R_1 = \frac{V_b}{i_{max}} = \frac{6V}{960\,mA} = 6.25\,\Omega$$

$$R_1 = 6.25\,\Omega - 0.32\,\Omega = \boxed{5.93\,\Omega}$$

This is the resistance of a motor.

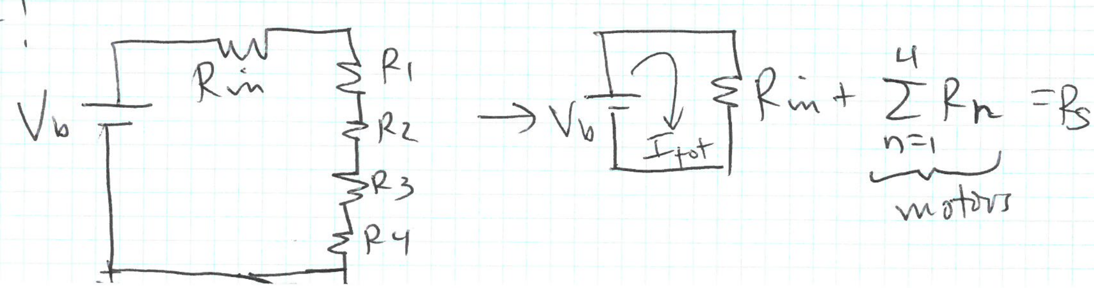
b)



~~Idea~~ This configuration, all 4 motors plug directly into the power supply (NiMH battery). Think about the + and − terminals of the battery and where they live on the diagram.

One common idea/question is "How about series config?"

Try it!



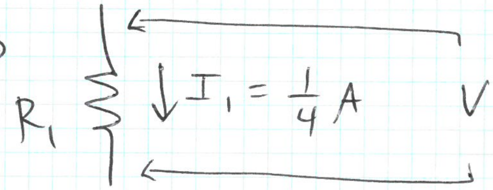
$$I_{tot} = \frac{V_b}{R_s}$$

V_b ← 6V

R_s ← $0.32 + 4(5.93\,\Omega) \simeq 24\,\Omega$

Thus $I_{tot} \simeq \frac{6V}{24\,\Omega} = \frac{1}{4}\,A$

For one motor, example R_1 ⇒

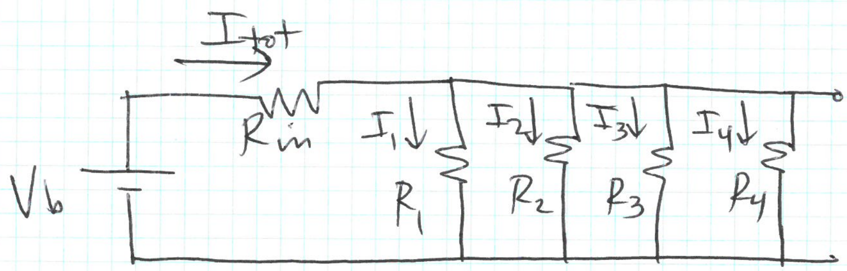


$V_{R_1} = I_1 R_1 \simeq \left(\frac{1}{4}\,A\right)(5.93\,\Omega)$

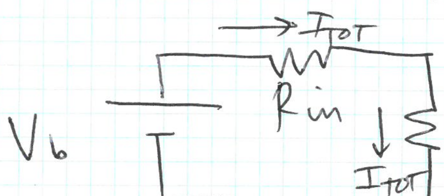
$\simeq \underline{1.5\,V}$

Uh-oh, this won't work, voltage supplied is too low! (see part f).

c)



↓



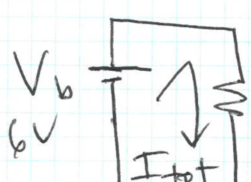
$R_p = R_1 \,||\, R_2 \,||\, R_3 \,||\, R_4 = \frac{5.93\,\Omega}{4} = 1.48\,\Omega$

(NOTE: THIS IS A VOLTAGE DIVIDER)

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$$

↑ $R_p =$

↓



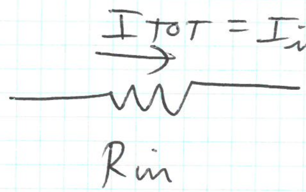
$R_{eq} = R_{in} + R_p = 0.32\,\Omega + 1.48\,\Omega = \underline{1.80\,\Omega}$

$$\boxed{I_{tot} = \frac{6V}{1.8\,\Omega} = 3.3\,A}$$ (3)

current splits equally 4 ways in motors - they are identical:

$$\boxed{I_1 = I_2 = I_3 = I_4 = \frac{1}{4} I_{TOT} = 833\,mA}$$ (4)

voltage dropped internally in battery



$$V_{in} = I_{in} R_{in} = I_{TOT} R_{in}$$

$$= (3.33A)(0.32\Omega)$$

$$\boxed{V_{in} = 1.06\ V}$$ (2)

voltage dropped across motors: KVL:

~~KVL : V_bat~~

$$V_b = V_{in} + V_{motors}$$

$$V_{motors} = V_b - V_{in}$$

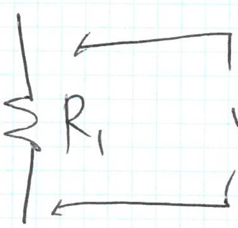
$$= 6V - 1.06V$$

$$\boxed{V_{motors} = 4.94\ V}$$

↑ same voltage across all; they are in parallel!

Alternatively / equivalently, apply Ohm's Law

$\frac{1}{4} I_{TOT} = I_1 \downarrow$

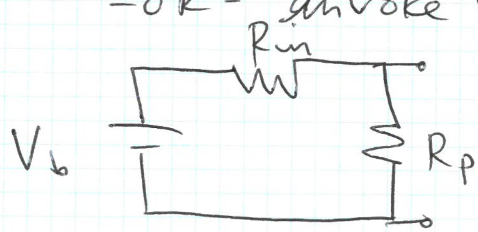


$$V_{R1} = I_1 R_1 = \left(\frac{I_{TOT}}{4}\right) R_1$$

$$= (833\ mA)(5.93\Omega)$$

$$= 4.94\ V$$

-OR- invoke voltage divider:



$$V_{R_p} = V_b \left(\frac{R_p}{R_{in} + R_p}\right)$$

($V_b / (R_{in}+R_p) = I_{TOT}$; $R_p = \frac{R_1}{4}$)

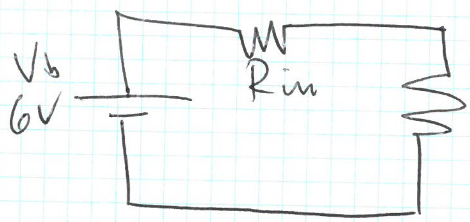
you will get the same answer

d) We computed in part c) that $I_{TOT} = 3.33A$.

The battery has 1600 mA hr = 1.6 A·hr

Thus $\Delta t = \dfrac{1.6\ A\ hr}{3.33\ A} \approx$ **29 min** or $\approx \frac{1}{2}$ hr

e) Note we're already on the hairy edge with 4 motors powered at 4.94V, so intuitively we don't expect many more one possible to add before dropping below the 4.8V cutoff.



$$R_N = \left(\frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_N}\right)^{-1}$$

for N motors

$$R_N = \frac{R_1}{N}$$

Voltage across motors is V_{RN}.

$$V_{RN} = V_b \left(\frac{R_N}{R_{in} + R_N}\right) \quad \text{solve } R_N.$$

(V_{RN}: set to 4.8V; V_b: 6V; R_{in}: 0.32Ω)

$V_{RN}(R_{in} + R_N) = V_b R_N \Rightarrow$ ~~$V_b R_{in} / R_N$~~

$$V_{RN} R_{in} + V_{RN} R_N = V_b R_N \Rightarrow R_N = \frac{V_{RN} R_{in}}{(V_b - V_{RN})} = \frac{(4.8V)(0.32\Omega)}{(6-4.8)V}$$

$R_N = 4\,(0.32\,\Omega) = 1.28\,\Omega.$

Recall $R_N = \dfrac{R_1}{N} \Rightarrow N = \dfrac{R_1}{R_N} = \dfrac{5.93\,\Omega}{1.28\,\Omega}$

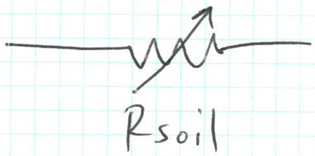
$= \underline{\underline{4.63 \text{ motors}}}$

Of course we have to have integer number of motors, so 4 is the max

[This is a tricky part of the problem – but achieveable]

f) They were wired in series ! See page (2)

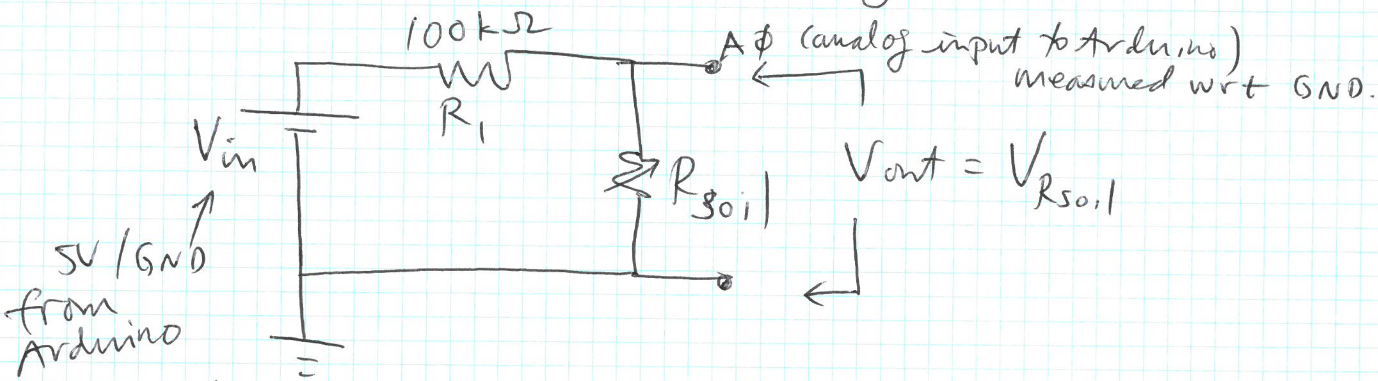
SOIL MOISTURE MONITOR



This is a variable resistor depending on hydration of soil.

Need to add more elements to sense a change in resistance

This is just like our CdS photocell lab so we can do something like this:



Measure output across Rsoil

Need to choose R_1 sensibly.

$$V_{out} = V_{R_{soil}} = V_{in}\left(\frac{R_{soil}}{R_1 + R_{soil}}\right)$$

VOLTAGE DIVIDER! NOTE: THIS IS JUST OHM'S LAW IN HIDING: $I_1 = I_{R_{soil}} = \frac{V_{in}}{R_1 + R_{soil}}$

We know Rsoil ranges from ≈ 30 – 300 kΩ.

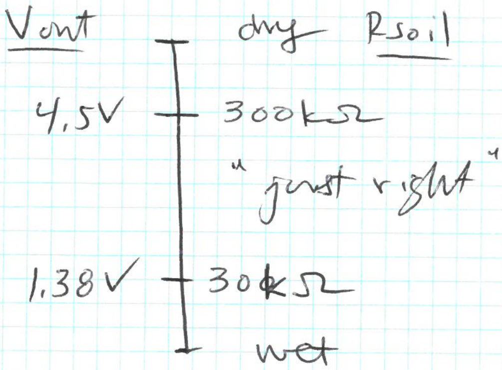
Choose $R_1 \approx 100$ kΩ in middle of this range for Rsoil

What, then, is expected dynamic range wet vs. dry?

Wet: $R_{soil} \approx 30k\Omega \Rightarrow V_{out} \approx 6V\left(\frac{30k\Omega}{130k\Omega}\right) = 1.38V$

dry: $R_{soil} \approx 300k\Omega \Rightarrow V_{out} \approx 6V\left(\frac{300k\Omega}{400k\Omega}\right) = 4.5V$

That's a nice big change from 1.38 to 4.5V (at bare minimum!) wet vs. dry.



Rsoil ↑ so does Vout

Arduino code: int sensorVal = analogRead(A0);
float Vout = sensorVal (5.0/1023);

```
if (Vout < 1.38) {
    digitalWrite (greenpin, HIGH);
    digitalwrite (yellowpin, LOW);
    digitalwrite (redpin, LOW);
}

else if (Vout > 4.5) {
```

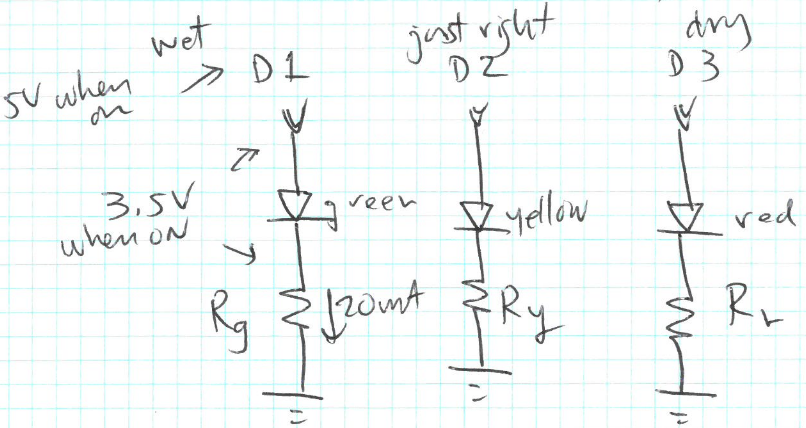
pseudocode // (I got lazy :))

```
    greenpin → write LOW
    yellowpin → write LOW
    redpin → write HIGH
}

else {        // just ~~w~~ right ("write"?)

    green → LOW
    red → LOW
    yellow → HIGH
}
```

LED CIRCUITRY



For example calc of choosing current limiting resistor.

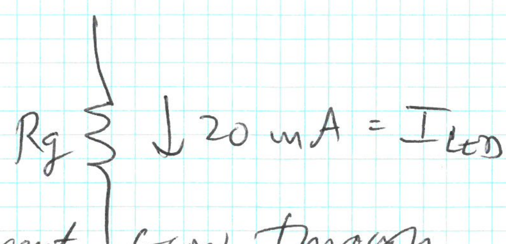
GREEN: green turn on voltage is ≈ 3.5V (from Table provided)

If LED illuminated: D_1 = 5V wrt ground.

LED eats up 3.5V so 1.5V must drop across R_g (KVL). Formally.

$$5V = \underbrace{V_{LED}}_{3.5} + \underbrace{V_{R_g}}_{1.5V}$$

$$V_{R_g} = 1.5V = I_{R_g} R_g$$



I_{R_g} = 20 mA. all current flow through LED must flow R_g. It is a series combo LED - R_g!

$$\therefore R_g = \frac{1.5V}{20mA} = \underline{\underline{75\Omega}}$$

Compute similarly for yellow and red.