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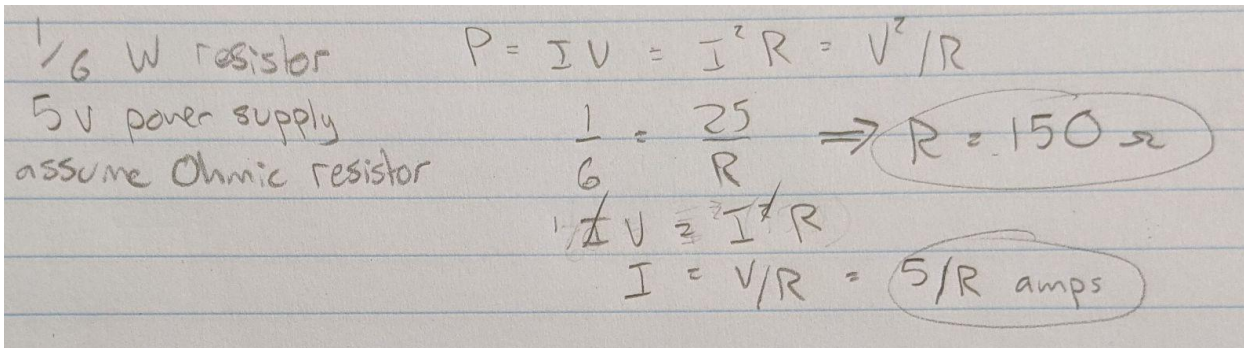
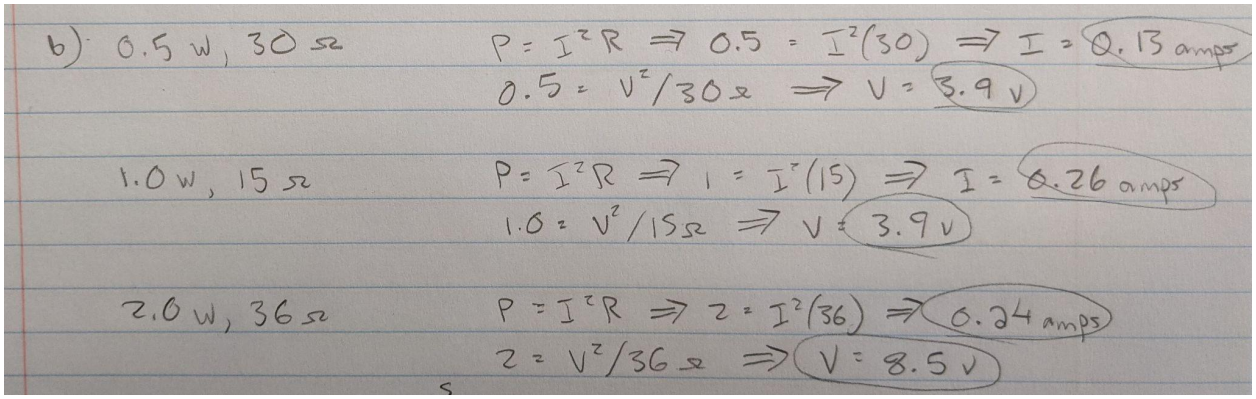
LAB 2 - POWER AND EQUIVALENT RESISTANCE

Exercises:

1) Preliminary calculations:
    a) Assuming you are using a ⅛W resistor from the resistor bins in McC305, what is the smallest resistance you could attach across a 5V power supply without exceeding its power rating? How much current would that resistor draw? (Answers in terms of R)

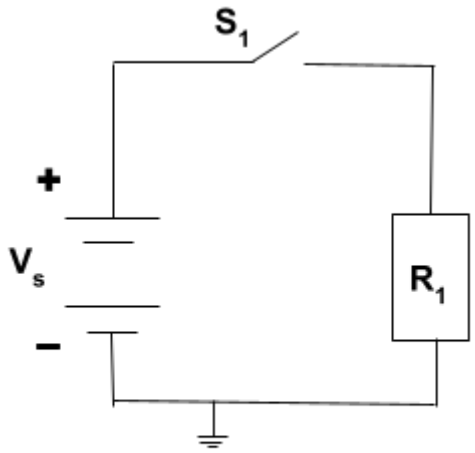


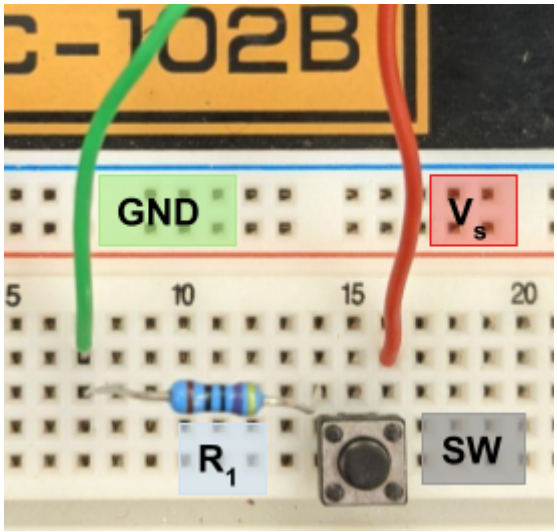
    b) Find the maximum current and voltage for the following higher power resistor available in the larger resistor bins:
        i) 0.5W 30Ω
        ii) 1.0W 15Ω
        iii) 2.0W 36Ω



2) Design and build a simple circuit with a power source and a resistor, in which
    a) you do not exceed the current rating of a ⅛W resistor. You should use the 5V wall plug power supply, and any ⅛W resistor that you deem appropriate for this experiment. Observe/feel the temperature of the resistor by pressing your finger against the resistor.

Figure 1 (Left). Diagram of circuit not intended to exceed ⅛W current rating.
Figure 2 (Right). Circuit built not to exceed ⅛W current rating.



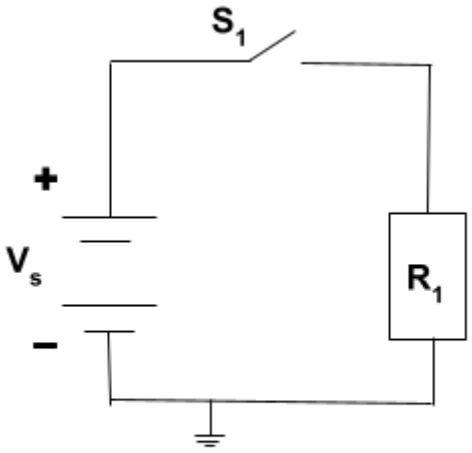


To avoid exceeding the current rating of a ⅛W resistor, a resistor of 150Ω or greater should be used. In the circuit pictured above, a 470Ω resistor was used. Prior to circuit construction, the actual resistance was measured as 468Ω using a DMM. This is within tolerance.

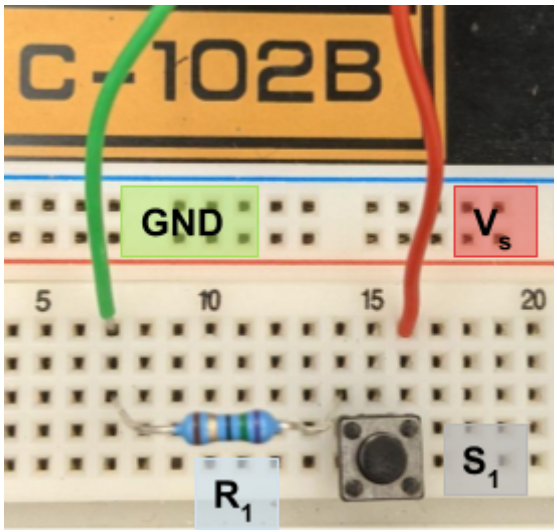
The temperature of the resistor did not change when it was added to the circuit. It remained a similar temperature to the ambivalent temperature of the room.

b) you expect to exceed the current rating of a ⅛W resistor. Observe/feel the temperature of the resistor by pressing your finger against the resistor.

Figure 3 (Left). Diagram of circuit intended to exceed ⅛W current rating.
Figure 4 (Right). Circuit built to exceed ⅛W current rating.



V_s = +5V DC; R_1 = 75Ω



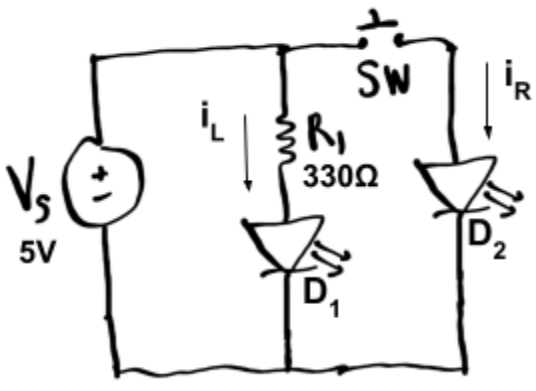
To exceed the current rating of a ⅛W resistor, a resistor of less than 150Ω should be used. In the circuit pictured above, a 75Ω resistor was used. Prior to circuit construction, the actual resistance was measured as 74.7Ω using a DMM. This is within tolerance.

The temperature of the resistor noticeably increased when it was added to the circuit. It was warm to the touch, and continued getting warmer the longer the circuit remained powered.

c) Summarize what you observed including photos if anything interesting happened. Then explain why you think whatever you observed happened.

I observed that exceeding the current rating of the resistor caused it to dramatically increase in temperature. I think this is because more current means more electric power that is dissipated as heat by the resistor.

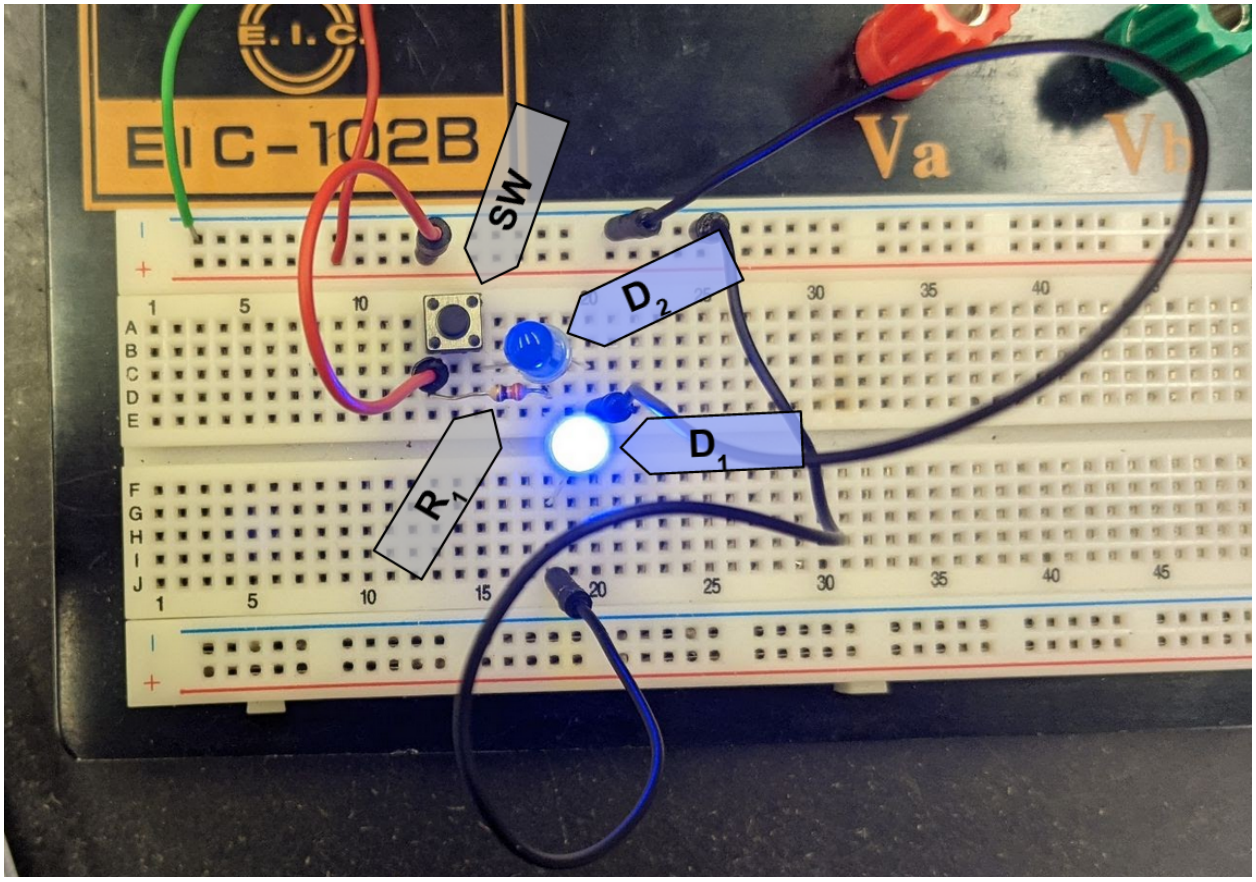
3) Build the circuit shown using a 5V power supply, and R_1 = 330Ω. You can pick any color LED, but use the same color in each branch of the circuit. Measure the current in each branch, and observe the temperature of the two LEDs with the IR



thermometer. Note: the item labeled SW in the circuit is a button switch. Be sure the button is pressed when you are measuring the current in the rightmost branch of the circuit.

a) Summarize what you observed including photos or video if anything interesting happened. Be sure you include any noticeable differences in current, brightness and temperature. Then explain why you think whatever you observed happened. Specifically address the role of the 330Ω resistor, since that item's presence/absence is the main difference between the two branches of the circuit.

Figure 5. Circuit built with two LEDs, a switch, and a 330Ω resistor.



When the button switch was not pressed, LED D_1 was on steadily, while LED D_2 remained off, as it did not have any current flowing through it. When the button was pressed, D_2 was connected to the circuit and both LEDs were on steadily. A video of the circuit in both states is available here: https://youtu.be/yGM0efh-o2Y

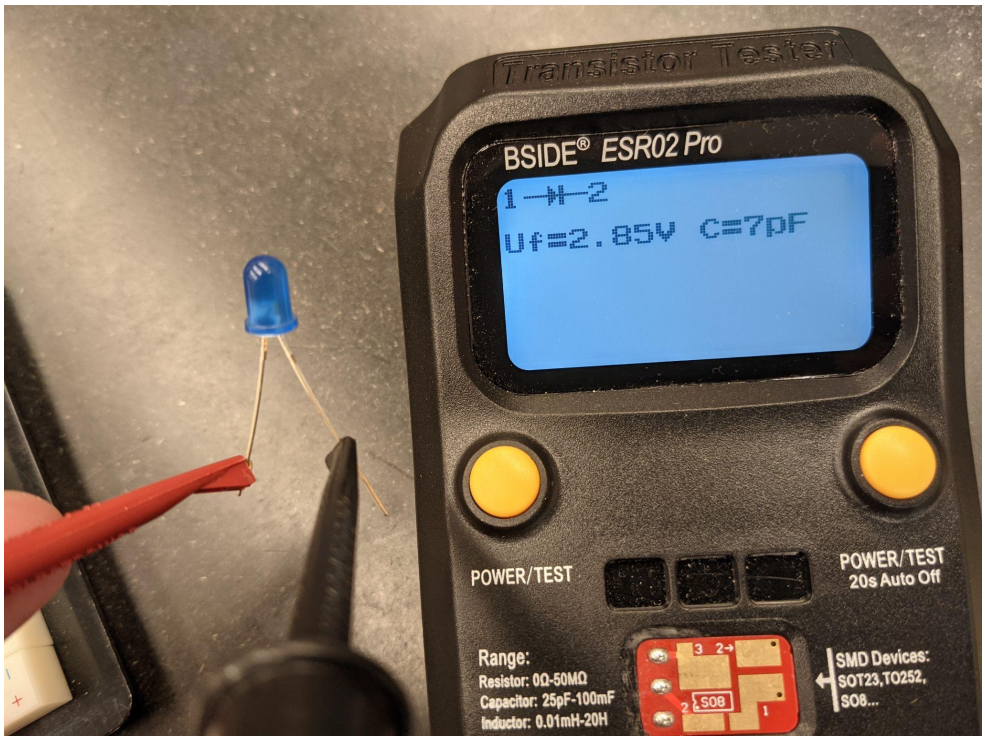
LED D_1 was noticeably dimmer than LED D_2. The presence of the 330Ω resistor in series with D_1 meant that less current flowed through D_1 than D_2. Current i_L through the left branch of the circuit (containing the resistor and D_1) was measured with the DMM to be about 6.0-6.5 amps. A video of this measurement is available here: https://youtu.be/NjVZlxHvjJk

In contrast, current i_R through the right branch of the circuit (connected via button switch and containing only D_2) was measured with the DMM to be about 60-70 amps. A video of this measurement is available here: https://youtu.be/2V4nRmUJsN8

b) Replace the 5V power source in your circuit with a 3V battery pack, and report the results as in part (a)

Upon replacing the 5V power source with a 3V battery pack, the circuit no longer appeared to function. Neither LED lit up, despite voltage measurements with the DMM confirming that there were no issues supplying 3V to the circuit. It turns out that the threshold voltage (measured with the LCR) for the blue LEDs used in the circuit is just below 3V. So the LEDs were only just barely receiving enough power for current to flow through the LEDs, meaning any changes in LED brightness were not dramatic enough to be easily seen.

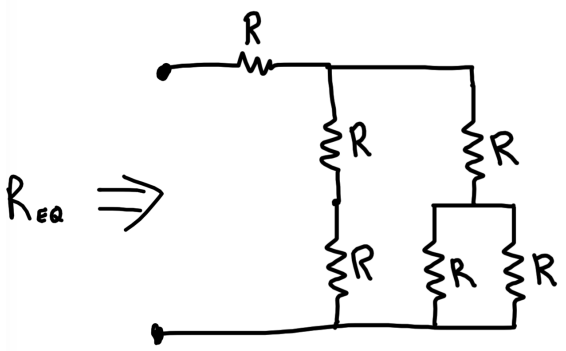
Figure 6. Measuring the threshold voltage of an LED used in the previous circuit.



The blue LEDs were swapped out with yellow LEDs (measured to have a threshold voltage of approximately 2V), and the qualitative behavior of the circuit was the same as it was when powered by the 5V source.

4) Find the equivalent circuit resistance for each case drawn below. Your answer will be in terms of R. Show your work. Check your final answer against the posted solutions or by building the circuit and measuring the equivalent resistance with your DMM.

Circuit 1:



All resistors have a resistance equal to R.

combining R_6 and R_5 which are in parallel:

$$\frac{R_5 R_6}{R_5 + R_6} = \frac{R^2}{2R} = \frac{1}{2}R$$

combining R_4 and the $\frac{1}{2}R$ resistance, which are in series:

$$R_4 + \frac{1}{2}R = R + \frac{1}{2}R = \frac{3}{2}R$$

combining R_2 and R_3, which are in series:

$$R_2 + R_3 = R + R = 2R$$

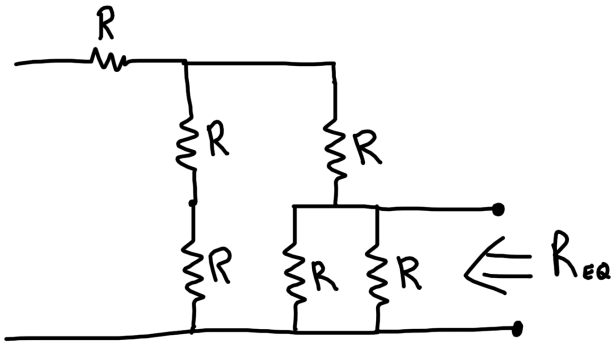
combining the $2R$ and $\frac{3}{2}R$ resistances which are in parallel:

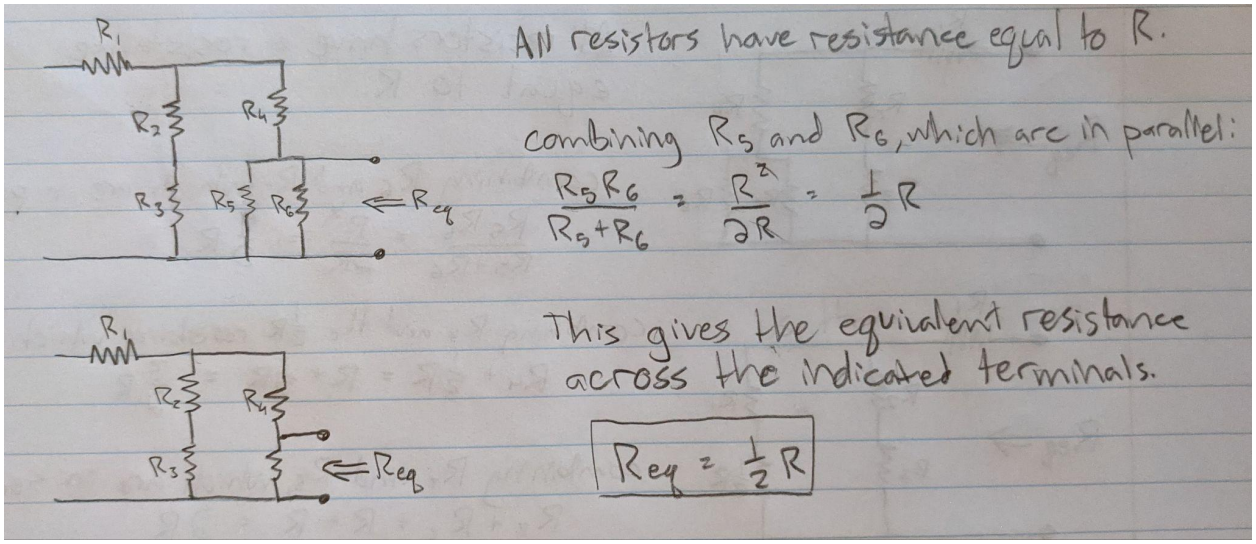
$$\frac{(2R)(\frac{3}{2}R)}{2R + \frac{3}{2}R} = \frac{3R^2}{\frac{7}{2}R} = \frac{6}{7}R$$

combining R_1 and the $\frac{6}{7}R$ resistance, which are in series:

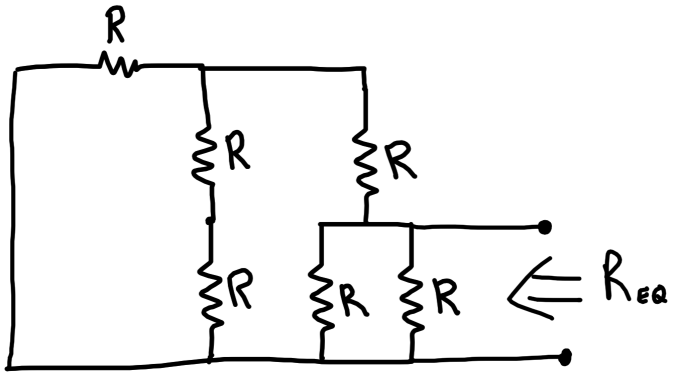
$$R_{eq} = R_1 + \frac{6}{7}R = R + \frac{6}{7}R = \boxed{\frac{13}{7}R}$$

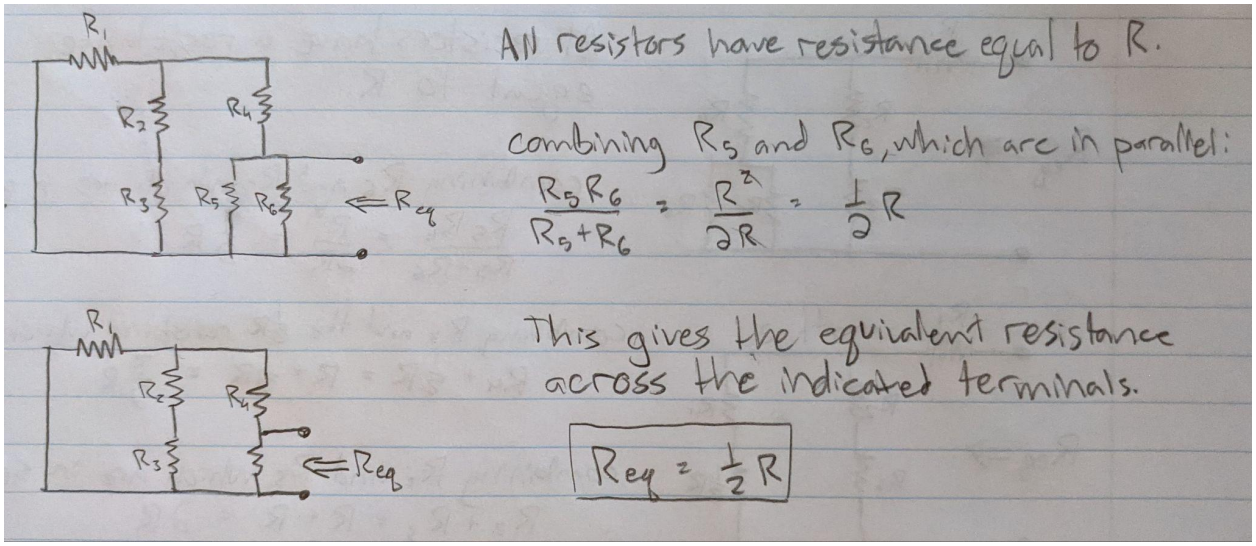
Circuit 2


R
R
R
R
R
R
R_{EQ}


R_1
R_2
R_4
R_3
R_5
R_6
R_{eq}
R_1
R_2
R_4
R_3
R_{eq}
All resistors have resistance equal to R.
combining R_5 and R_6, which are in parallel:
$\frac{R_5 R_6}{R_5 + R_6} = \frac{R^2}{2R} = \frac{1}{2}R$
This gives the equivalent resistance across the indicated terminals.
$R_{eq} = \frac{1}{2}R$

Circuit 3


R
R
R
R
R
R
R_{eq}


R_1
R_2
R_4
R_3
R_5
R_6
R_{eq}
All resistors have resistance equal to R.
combining R_5 and R_6, which are in parallel:
$\frac{R_5 R_6}{R_5 + R_6} = \frac{R^2}{2R} = \frac{1}{2}R$
R_1
R_2
R_4
R_3
R_{eq}
This gives the equivalent resistance across the indicated terminals.
$R_{eq} = \frac{1}{2}R$