PHY 240: Basic Electronics
Homework Problem H11

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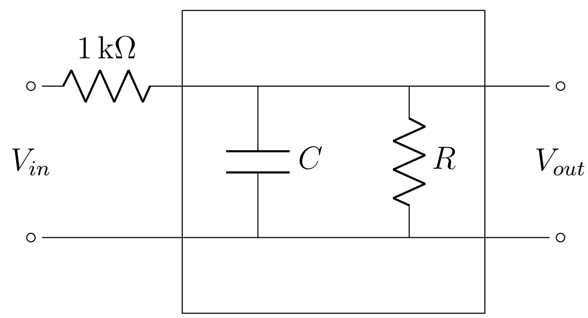
1. **RC Detective.**
Consider this circuit, in which we wish to determine the values of R and C. Unfortunately, R and C are locked up inside of a device (represented by the dashed line) that prevents their direct measurement.



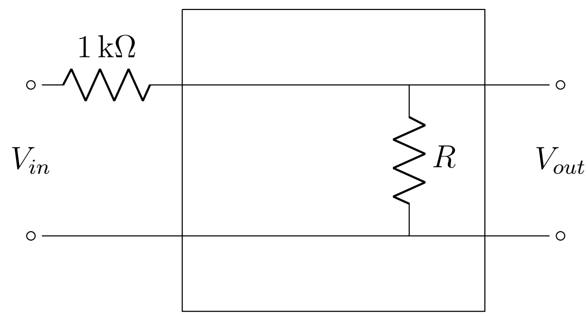
In order to determine the values of R and C within the device, we place a known resistor of resistance 1 kΩ in front of the device, hold the input voltage at 10 V for a long time, and then allow it to drop suddenly to 0 V at time t = 1 ms. While we do this, we monitor both V_{in} and V_{out}. The results are shown in the plot below (in which the dashed curve represents V_{in} and the solid curve represents V_{out}).

Use the plot to determine R and C. Here are a few hints:

- You can use the steady state behavior of the circuit to determine R!
- You can use the capacitor's discharge curve to determine the product $R_{eff}C$!
- You can relate R to R_{eff} by considering how the two resistors are configured from the point of view of a discharging C.

Graph here.

Solution: Finding R is easier, so let's do that first.
We know that $V_{in} = 10V$, $V_{out} = 8V$ and our chosen r is $1\,\text{k}\Omega$
At t = 0, the capacitor is fully charged, so it acts like an open circuit…



$$V_{in} = I(R_1 + R_2)$$

$$10V = I \cdot 1000\Omega + I \cdot R_2$$

The voltage drop across R_2 is V_{out} which is 8V, meaning

$$I \cdot 1000\Omega = 2V$$

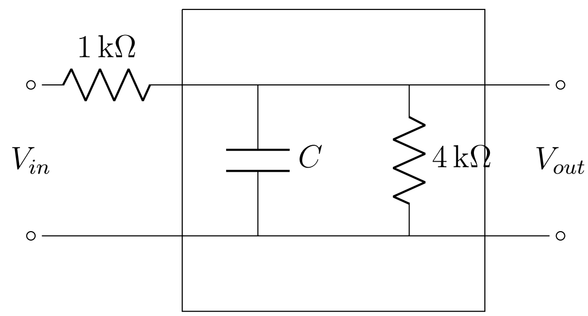
$$I \cdot R_2 = 8V$$

So $I = 0.002A$, naturally…

$$0.002A \cdot R_2 = 8V$$

$$R_2 = 4\,\text{k}\Omega$$

Now, we find C.



First, we must find R_{eff} which is just the resistances of these resistors in parallel.

$$R_{eff} = 800\,\Omega$$

The equation $V_{in} \cdot e^{\frac{-t}{RC}}$ tells us the voltage across the capacitor over time. Eyeballing the curve and plugging in known values, we get

$$2.3 = 8 \cdot e^{\frac{-0.0005}{800 \cdot C}}$$

Solving for C now. . .

$$C = \frac{-0.0005}{800 \cdot \ln \frac{2.3}{8}} \approx 0.5\mu\mathrm{F}$$