University of California, Berkeley – College of Engineering

Department of Electrical Engineering and Computer Sciences

Summer 2010 Instructor: Josh Hug 2010-07-09

Last Name	
First Name	
Student ID Number	
Name of the person to your Left	
Name of the person to your Right	
All the work is my own. I had no prior knowledge of the exam contents nor will I share the contents with others in EE40 who have not taken it yet. I have not cleverly hidden notes and/or computational devices that give me an unfair advantage. ***(please sign)***	

Instructions (Read Me!)

- You have 80 minutes to complete this exam, which we'll start at ~**12:20 PM**. Once time is out at ~**1:40 PM**, we'll announce that time is up, and you should stop writing immediately. The exact times will depend on when we can get everyone settled in.
- There are 13 pages on the exam. All work should be on this exam. Don't hand in random sheets of paper.
- Please turn off anything that might make noise, unless it is necessary for you to stay alive. Remove all hats and headphones. Allow at least one empty seat between your neighbor and you. All backpacks, laptops, and jackets should be up front, and nothing should be in the seats or on the floor between you and your neighbors.
- There are no electronic devices allowed on this test, including calculators.
- You may use 1 page of notes (8.5" x 11" or A4), front and back, handwritten.
- Partial credit will be given for incomplete answers, so please show your work. **The best possible thing you can do if you start running out of time is to write out things like the correct node voltage equations for problems you haven't completed.** Overly complex solutions will be receive a minor penalty.
- If you get stuck on an algebra problem, move on! The numerical part of a problem will be worth less than the conceptual part!
- If you prefer to solve problems with resistive variables as conductances, feel free to do so on this exam. If you don't know what I just said, don't worry about it.
- The occasional problem has a hint! If you're stuck, look to see if you missed a hint. If there isn't one, sorry, but at least you're all in the same boat.
- This is a hard test, but hopefully not too hard! If the average is too low, remember that we're going to ooch grades up if we went too hard on you and wrote problems that were too difficult.

	P1	P2	P3	P4	P5	P6	Total
Earned							
Max	30	30	25	15	35	25	160

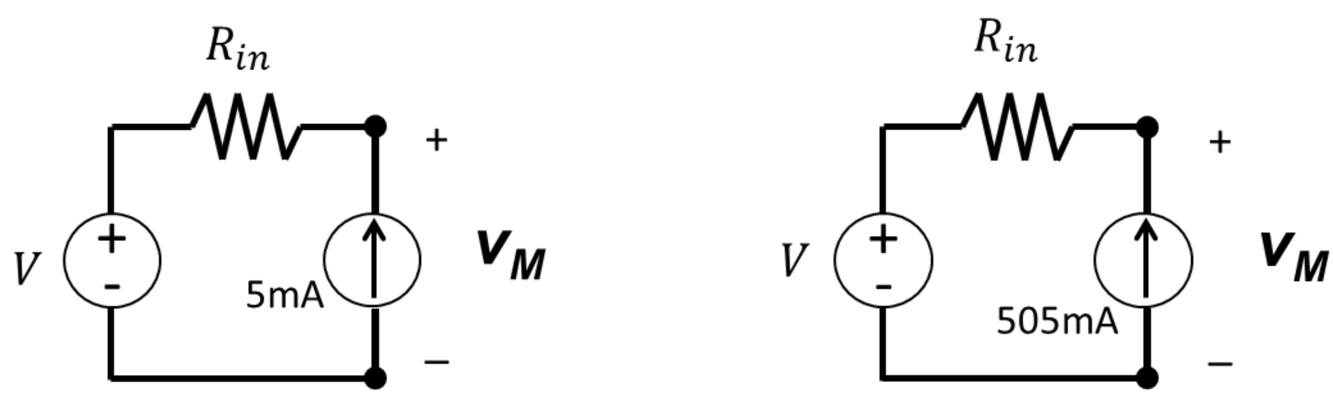
Name: ____________________

P1: Basics - Things you now know that you didn't know you knew (25 pts)

a) Birds routinely land and relax on power lines which carry tens of thousands of volts of electricity. Explain why these birds do not get electrocuted.

b) Suppose your car battery is dead, and you need to charge it using another car's battery. You have a pair of cables which you can use to connect the terminals of the batteries. In order to charge your car battery, should you connect the same terminals (positive of one battery to the positive of the other, and the same with the negative) or the opposite terminals (positive of one battery to the negative of the other battery)? Why did you choose this configuration?

c) A standard procedure for testing the internal resistance of a battery is the "dual pulse" test. We first attach an ideal 5 mA current source between the terminals of the battery, so that current flows in the usual direction (positive to negative), and measure the voltage across the battery terminals. We then remove the 5 mA source, and attach an ideal 505 mA current source instead, and again measure the battery terminals.



i. Suppose that we find a 1.485V voltage with the 5 mA source, and a 1.385 with the 505 mA source, what is the internal resistance?

ii. Assuming the battery is perfectly linear (i.e. accurately modeled by a Thevenin equivalent), is it possible to find the voltage provided by the battery with no load attached **using the data above**? If so, what is it? If not, why not?

d) An EE40 student has constructed a purely resistive circuit which drains the connected battery too quickly. He decides to add another battery in parallel to fix the problem (assume internal resistance of the battery is not important).

   a. Will adding another battery in parallel actually reduce the power provided by each battery?

   b. Will the load still receive the same total amount of current?

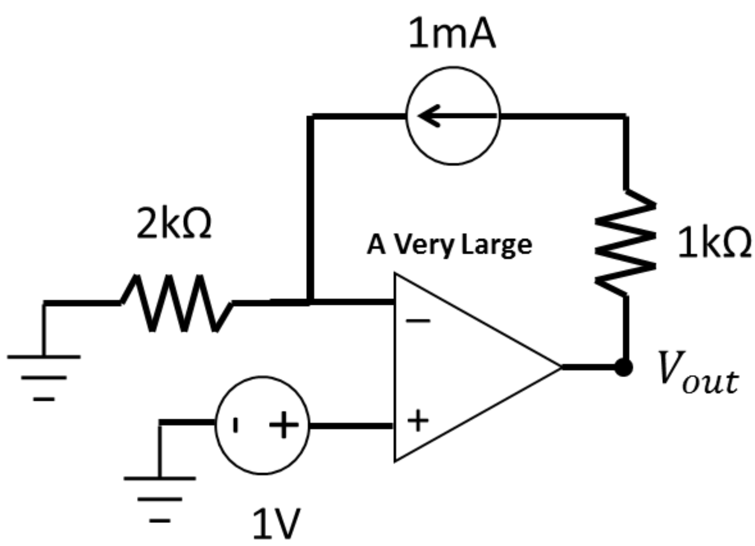
e) An EE40 student takes a random black box device (the contents of the box are unknown) and connects it to a 5V source. He finds that there is a 1A current and claims that the black box must contain only resistors, and that these resistors have a 5Ω equivalent resistance. Is the student right or wrong? If he is right, why? If he is wrong, give a specific counterexample of something else that might be in the box.

Name: ____________________

P2: Are these trick questions? Yes. All of them. **(30 pts)**

All of these problems might not quite be what they seem at first. There's a really easy way to do each of these that doesn't involve pages of algebra.

a) Find V^- in the circuit below [remember the summing point constraint doesn't always work. Maybe it does in this case, maybe it doesn't. You'll have to think about it carefully.]



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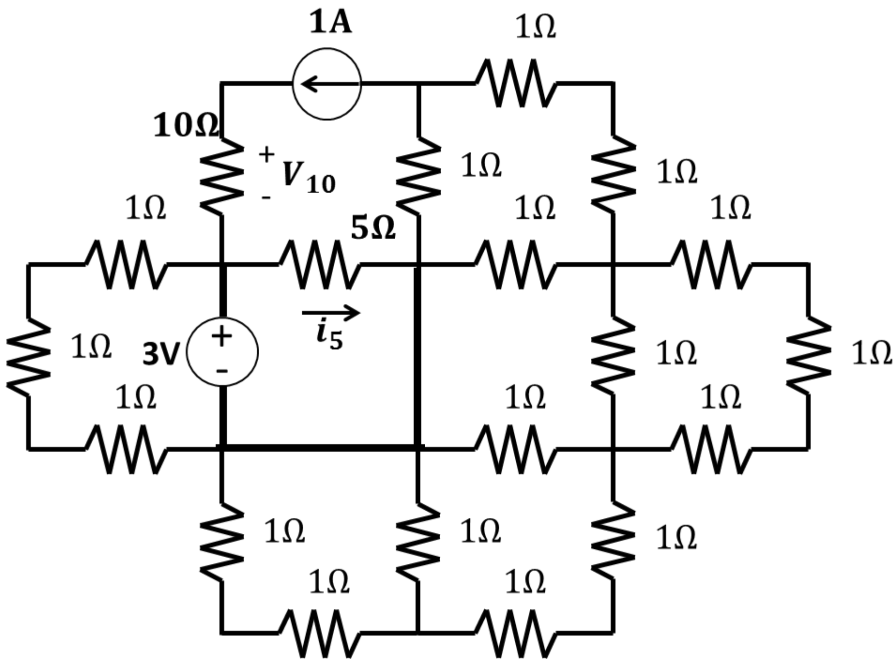
b) Find V_{10}, the voltage across the 10Ω resistor, and I_5, the current through the 5Ω resistor



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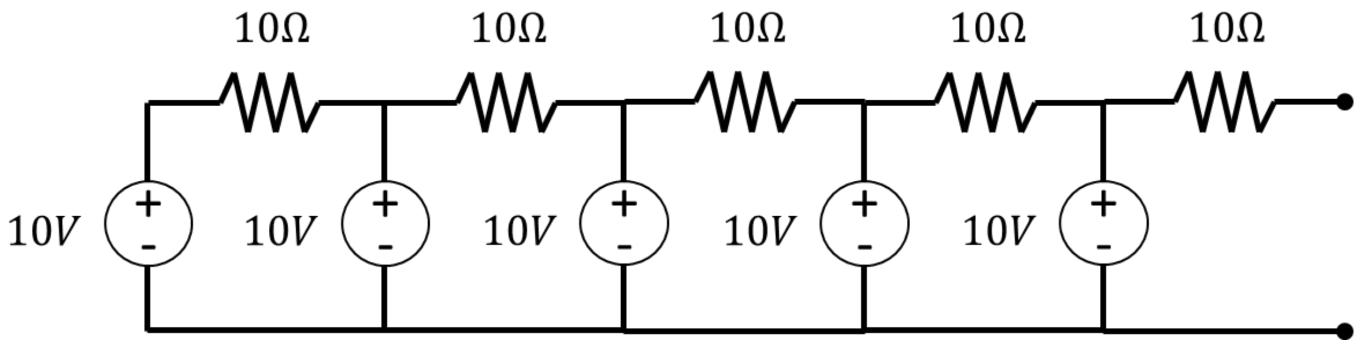
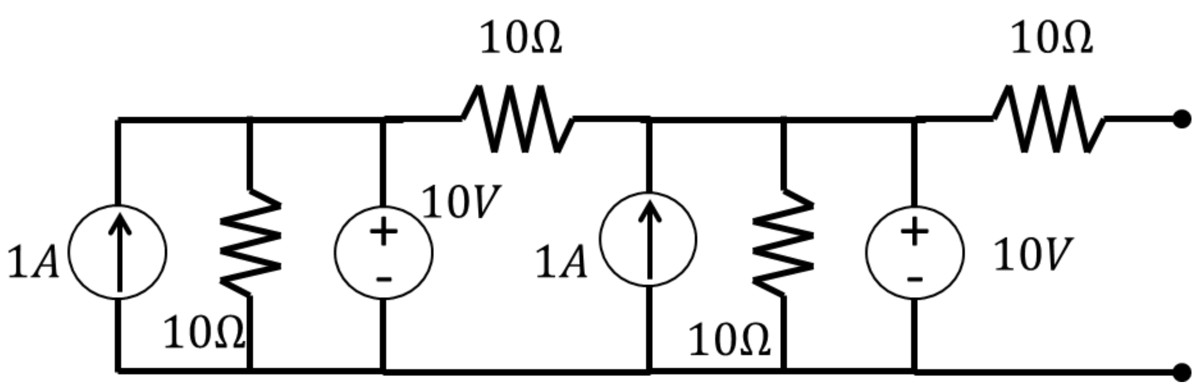
c) Find the Thevenin equivalent of the circuit below at the two terminals on the far right:

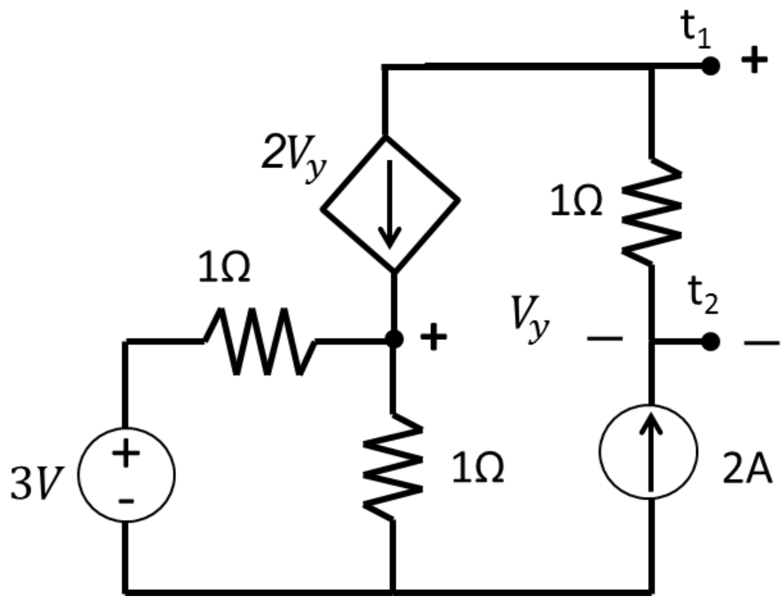


d) Find the Thevenin equivalent of the circuit below at the two terminals on the far right:



Name: ____________________

e) Find the Thevenin equivalent of the circuit below between terminals t_1 and t_2 [Think about the various algorithms we've used to find Thevenin equivalents. If you get stuck, complete the rest of these tricky problems and come back to this one and maybe some inspiration will reach you]:



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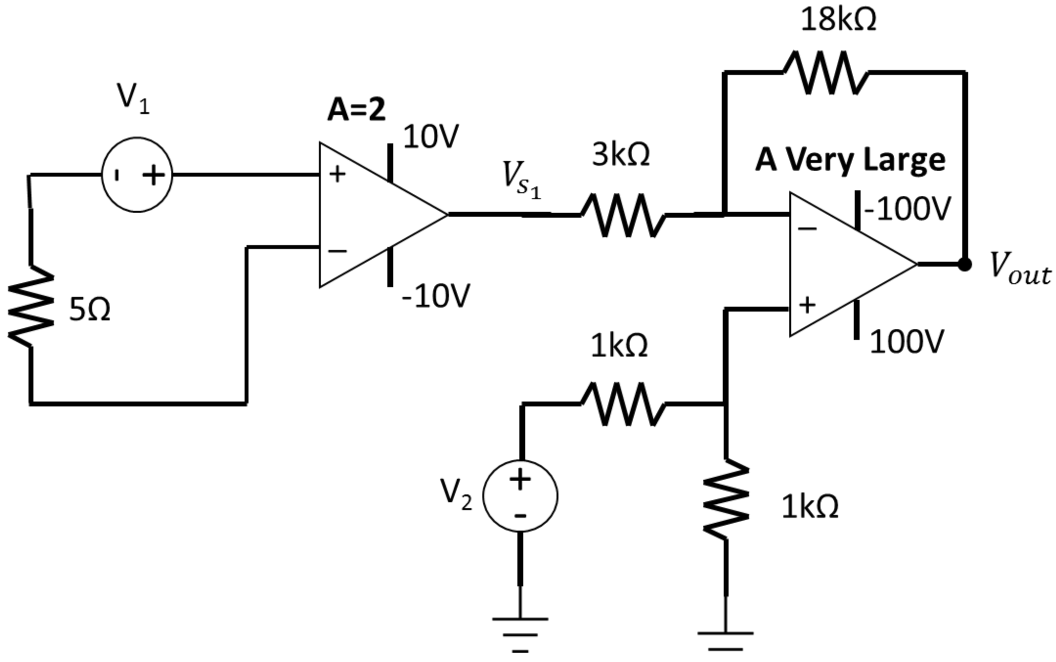
P3: Op-Amptimus Prime **(25 pts)**



a) Explain why it is safe to use the summing point constraint on the op-amp on the right.

b) Find V_{s_1} and V_{out} as a function of $V_1$and V_2. Assume that the input signals are small enough that the op-amps do not saturate. If you're not sure about V_{s_1}, you can also give V_{out}in terms of V_{s_1}.

c) If $V_2 = 1V$, and $V_1 > 0$, how large must V_1be before one of the op-amps saturates? Which op-amp will saturate first? (If you didn't get part b, you may assume for this sub-problem that $V_{out} = V_1 + V_2$ [this is not the right answer to part b])

Name: ____________________

P4: Amplifier Design **(15 pts)**

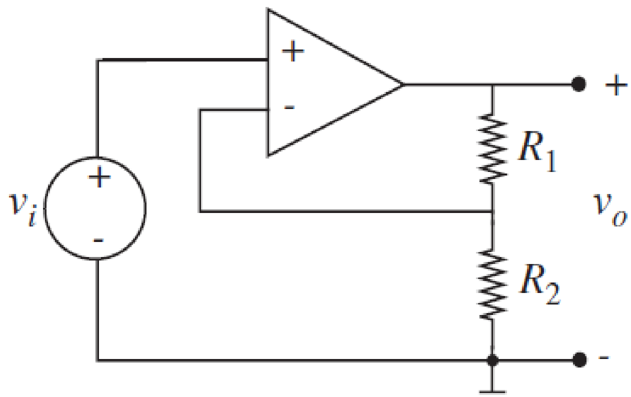
You are tasked with designing an amplifier circuit with the following specifications:

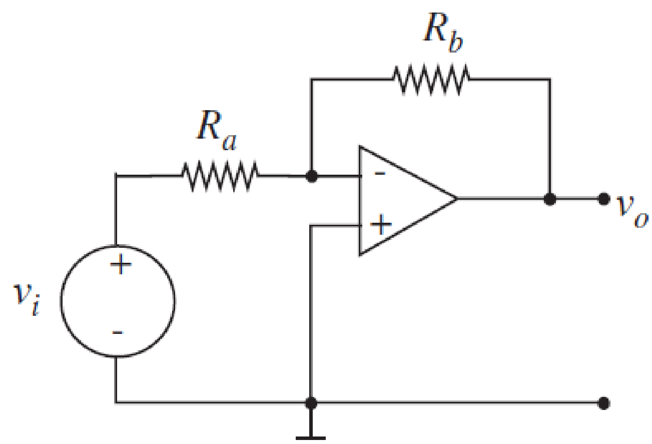
a) Generate an output gain Vo/V_i of approximately 1000 or approximately -1000 (either is fine)
b) Minimize the amount of power that the input source (V_i) must deliver to the amplifier

You may use any resistor values between 0.001Ω and 1,000,000Ω. You must use one of the two resistor configurations given below.

Choose one of the two circuits below, and choose resistor values so that you best meet the specification given above. If you don't know how to do one of these things, make an amplifier that meets the goal you understand how to meet.

Assume that we have op-amps which are **IDEAL**.





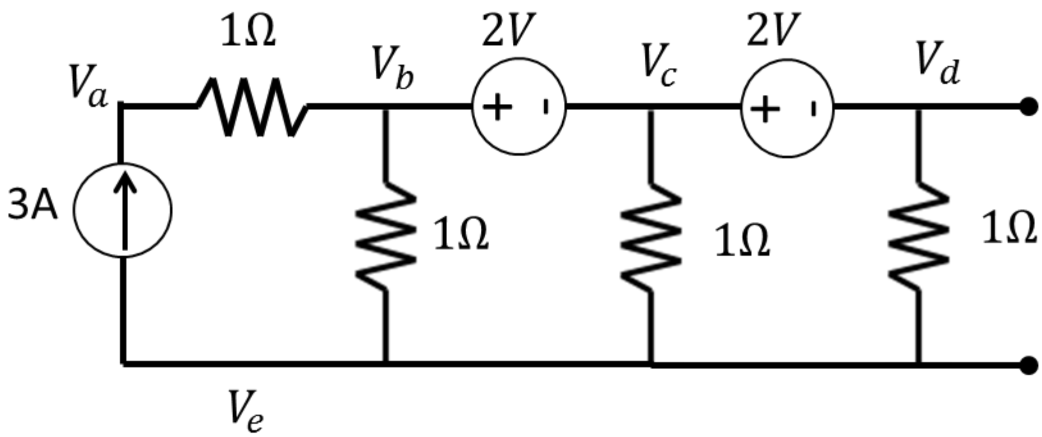
Use the space below to pick a circuit and resistor values. Make sure to clearly indicate which circuit you have chosen, and draw a box around the resistor values you've selected.

Give the equation which demonstrates that your circuit has the correct gain [approximately -1000 or 1000]. Also explain why your design minimizes power delivered by the input source.

Name: ____________________

P5: Thevenin Equivalents **(35 pts)**

a) Find the Thevenin equivalent of the circuit between the terminals on the far right. Recall that you can always check your work by finding all three Thevenin variables (V_{th}, I_{sc}, R_{th}) and seeing that they agree. When showing your work, please use our voltage labels to make grading quicker and more fun for everyone (of course, you can still pick a ground!)



b) Using your answer from part a, if you were to connect a $2/3\Omega$ resistor across the terminals to the far right, how much power would be delivered to this resistor? (If you didn't get part A, you can assume V_{th}=3V and R_{th}=7/3Ω just for the purposes of this problem [these are not the right answers to part a])

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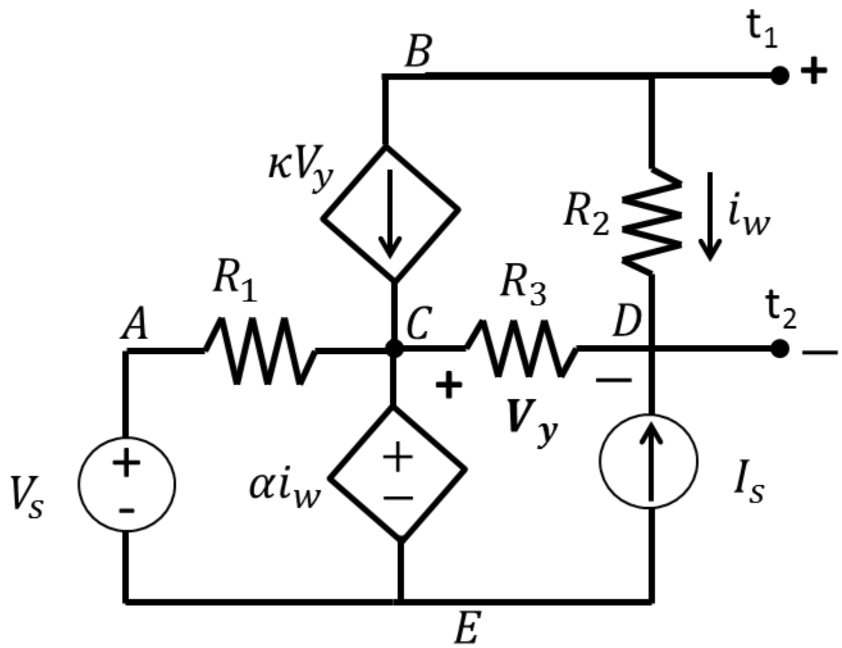
c) Write node equations (**DO NOT SOLVE!!**), which will allow you to find the open circuit voltage (voltage between terminals t_1 and t_2) of the circuit below:



Make sure you have as many equations as unknowns. $V_s, I_s, R_1, R_2, R_3, \kappa, \alpha$ are all known.

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P6: The hard problem that I promised **(25 pts)**

[Do this one last! It's much harder than the others]

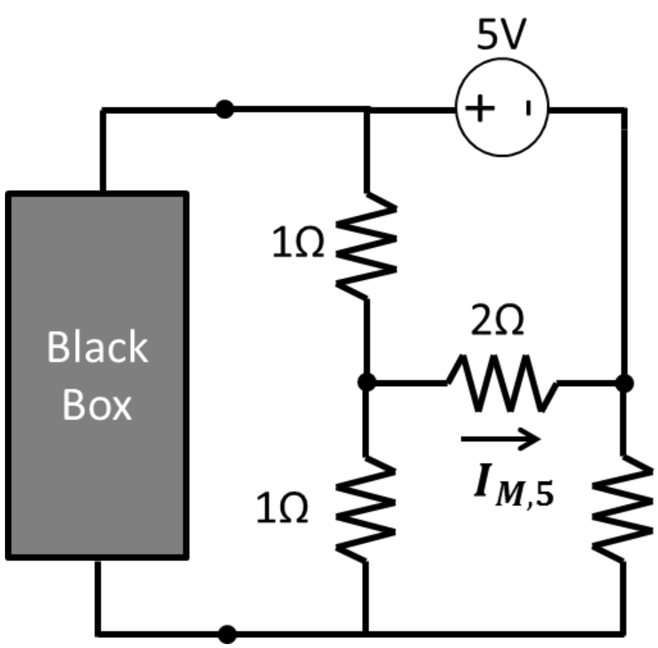
It is a grim post-apocalyptic future, but the survivors (you included), have adapted to this new way of life. Rugged and tiring though it may be, you are all happy.

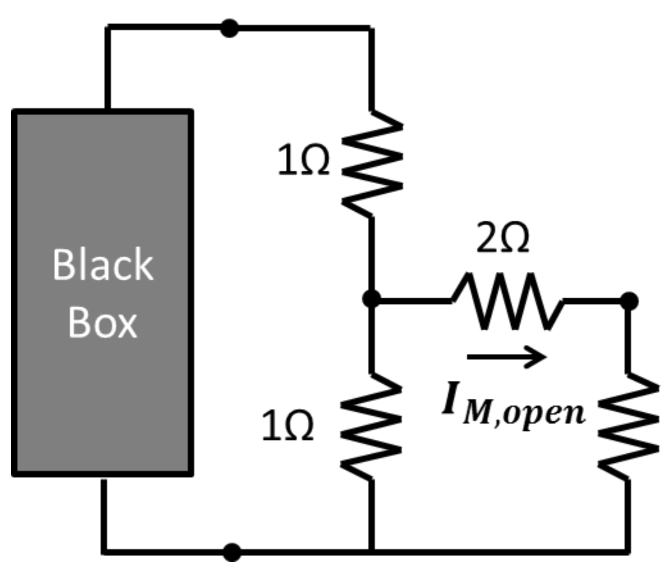
One day, you are brought a two terminal black box and it is extremely important to the future of the surviving members of the human race to know what is inside of this thing. Luckily, you know that (based on an old and faded but highly trustworthy label) that it contains only resistors and linear sources.

Thus, you know you can find the Thevenin equivalent of the circuit inside by applying tests using your lab equipment. "Piece of cake", you say", "I'll measure the open circuit voltage and the short circuit current, and then I will enjoy the gratitude and praise of my fellow man!"

Unfortunately, a dastardly dude has stolen all of your measurement equipment, and you are left with only the following asinine measuring device, abandoned in a corner, dusty and almost forgotten, designed for purposes unfathomable by persons unknown.

The device works as follows. It has two settings. In the first setting, it applies a voltage and gives you back the current through the 2Ω resistor, giving you $I_{M,5}$. In the other setting, it completely disconnects the voltage source, and still gives you the current through the 2Ω resistor, giving you $I_{M,open}$.





Name: ____________________

You try the first setting and find that $I_{M,5}$=1 ampere, and then when you try the other setting, you get that $I_{M,open}$ =1 ampere as well.

Using this information, determine what is in the box.