Name: _____   Lab section/TA: _____

ENGR 40M Problem Set 2
### Due 1:30pm, July 14, 2017

Homework should be submitted on Gradescope, at `http://www.gradescope.com/`. The entry code to enroll in the course is available at `https://web.stanford.edu/class/engr40m/restricted/gradescope.html`.

Problem 1: Series and parallel

(8 points)

(a) On the circuit diagrams below, circle the pairs of resistors which are in series. For the purposes of this problem, don't include larger combinations that will be in series after some simplification. *Hint: There are a total of 3 pairs. Some circuits might not have any.*
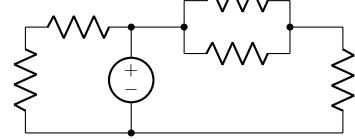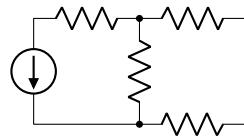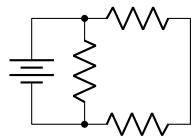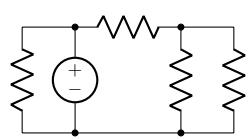

(b) On the diagrams below, circle the pairs of resistors which are in parallel. Again, don't circle larger combinations. *Hint: There are a total of 3 pairs. Some circuits might not have any.*
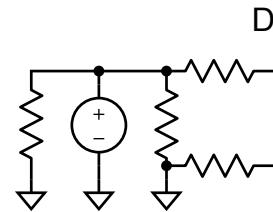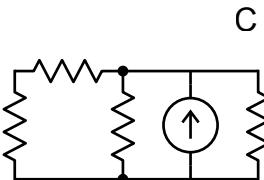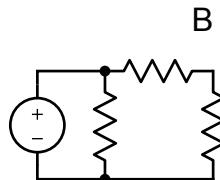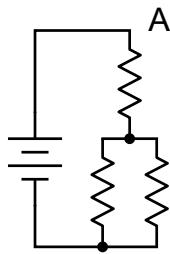
Problem 2: Your non-ideal multimeter

(15 points)   We've seen in class that the *ideal voltmeter* looks like an open circuit, and that the *ideal ammeter* looks like a short circuit, so as not to affect the circuit it's measuring. However, in real life—the world in which engineers operate—voltmeters and ammeters aren't ideal. Voltmeters take a small current, and ammeters a small voltage, in order to operate. In this problem, we'll study the *non-ideal ammeter*.

One way to model an ammeter that takes a small voltage is to model it as an ideal ammeter in series with a resistor of resistance R_m (the ammeter symbol represents the ideal ammeter):
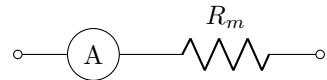
We'll study how this ammeter affects our measurement of the current in the following circuit:
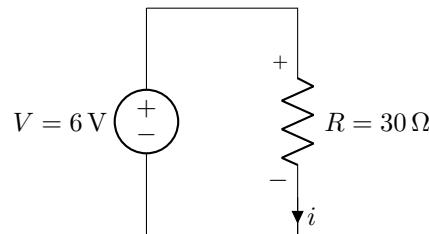
(a) Draw the same circuit, but with an *ideal* ammeter inserted to measure the current i.

(b) Find the current i, that is, the current an *ideal* ammeter would read.

Now we'll use a non-ideal ammeter. Assume that the ammeter has non-ideal resistance $R_m = 1.2\,\Omega$.

(c) Draw the model for the non-ideal ammeter inside the blue box below, to complete the circuit diagram.
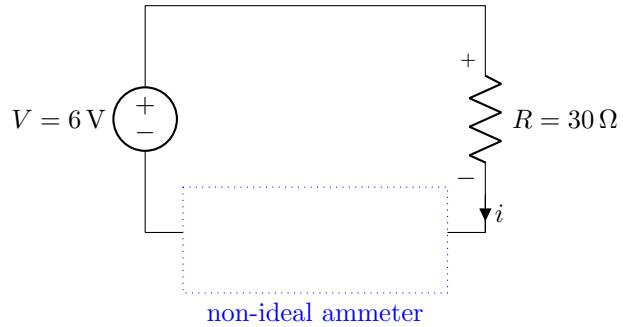
non-ideal ammeter

(d) What current will this non-ideal meter measure?

Your classmate missed the memo about not connecting ammeters in parallel, and instead connected the non-ideal ammeter to the circuit in the way that voltmeters are supposed to be connected. (You should never do this, by the way.)

(e) Draw the model for the non-ideal ammeter inside the blue box above, to complete the circuit diagram.

non-ideal ammeter
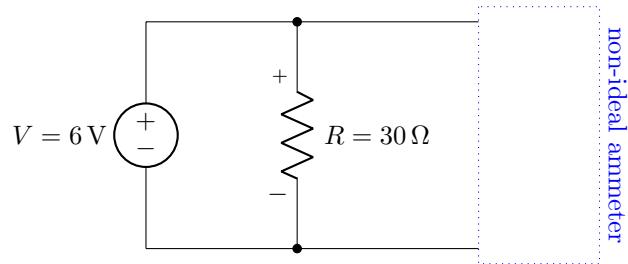
(f) Assume the ammeter somehow, magically, doesn't get fried as a result. What current will your class-mate measure?

Problem 3: A circuit with two sources

(10 points) Solve for the current through each resistor using any method you like. Make sure to label your reference directions.

There are multiple ways to do this, so you might check your answer by using a second method to solve it.
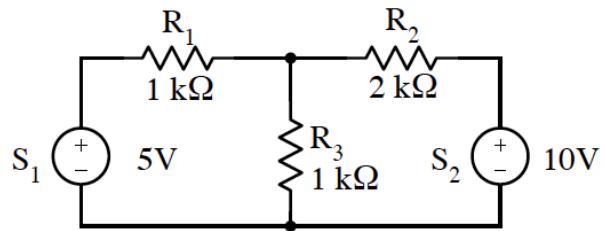
Problem 4: Catching worms with electricity

(14 points) One way to harvest earthworms for use as fishing bait is to pass electrical current through the soil, which stimulates the worms to come to the surface; the "worm-getter" setup is shown below. The positive terminal of a 120 V battery is connected by a 7 m-long wire to a metal probe inserted in the ground. The negative terminal is connected to a copper grounding rod. The resistance of the wire is $1.5\,\Omega/\text{m}$ and the resistance of the soil is $150\,\Omega/\text{m}$. The probes have no resistance and you can also neglect the resistance of the short vertical wire segments connecting the battery and the probe to the long horizontal wire.
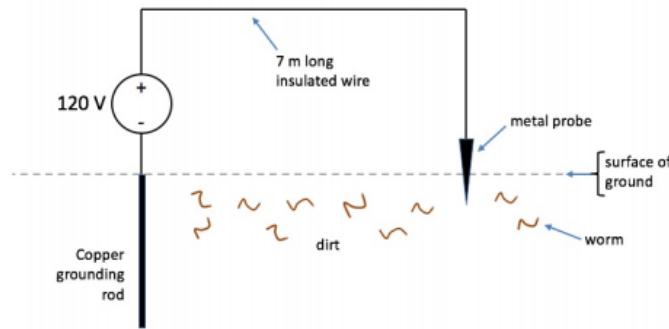
(a) Draw the circuit model for the worm-getter. It should consist of a battery and two resistors.

(b) Find the current in mA leaving the positive terminal of the battery.

The barefoot worm-catcher accidentally touches the metal probe with his bare hand, with the result that the circuit is changed. Each foot is located 1 m from the metal probe. The resistances of his body are as follows: hand and arm: $150\,\Omega$, torso: $200\,\Omega$, each leg and foot: $100\,\Omega$.

7 m long
insulated wire

120 V

metal probe

surface of
ground

Copper
grounding
rod

dirt
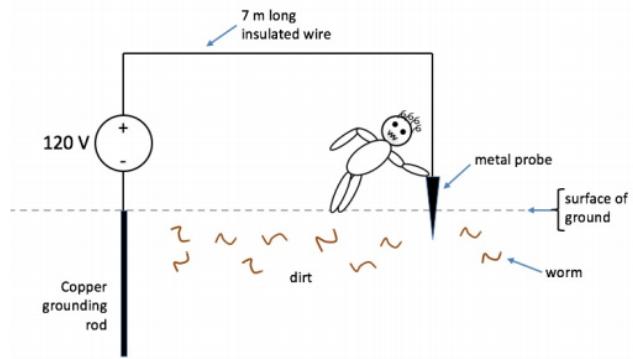
worm

(c) Draw a circuit model for this unfortunate situation. You should evaluate the values of all the resistors in the circuit.

(d) Find the current through the worm-catcher's torso in mA.

Note: Commercial products for catching worms used 120 AC voltage rather than a battery, which made them even more dangerous. The U.S. Consumer Product Safety Commission banned these products in 1991, after at least 28 people had been electrocuted while using them: `https://www.cpsc.gov/ko/node/11740`

Problem 5: NMOS and PMOS Transistors

(6 points) For each of the circuits below, find V_G and V_{out} (relative to ground). $V_{dd} = 5\,\text{V}$, $R_G = 10\,\text{k}\Omega$, $R_D = 10\,\text{k}\Omega$. The transistors have a resistance of $50\,\Omega$ between the source and drain when they are on (connected), and a resistance of $500\,\text{M}\Omega$ when off (disconnected).

a
b
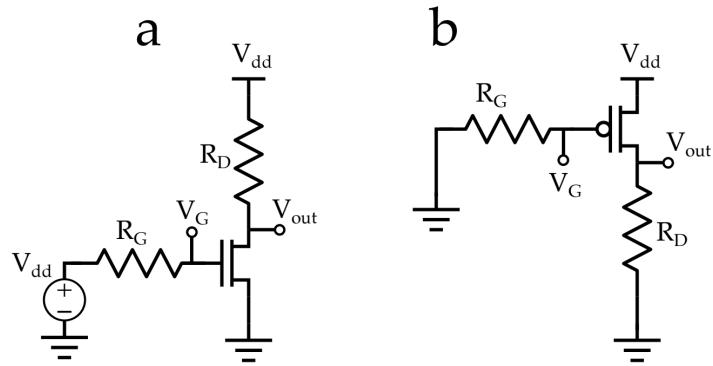
Problem 6: Reflection

(2 points)

(a) How long did it take you to complete this assignment?

(b) Which problem was the most difficult, and why?