Exploring the World of Science

University of Michigan Science Olympiad
2021 Invitational Tournament

Circuit Lab C

Test length: 50 Minutes

Team name: _____ **Team number:** _____

Student names: _____

UMSO Circuit Lab Division C 2021

Multiple Choice Questions

1. Who suggested that the repulsion between two similarly charged particles is proportional to the square of their separation?

   a. Ampere
   b. Coulomb
   c. Kirchoff
   d. Volta
   e. Tesla
   f. Faraday

2. Who is credited with the invention of an enclosure to block electromagnetic fields?

   a. Ampere
   b. Coulomb
   c. Kirchoff
   d. Volta
   e. Tesla
   f. Faraday

3. Who was most influential in the invention of the Homopolar motor?

   a. Ampere
   b. Coulomb
   c. Kirchoff
   d. Volta
   e. Tesla
   f. Faraday

4. Who first discovered evidence that light and electromagnetism are related?

   a. Ampere

b. Coulomb
c. Kirchoff
d. Volta
e. Tesla
f. Faraday

5. Who is credited with the discovery of the battery?

a. Ampere
b. Coulomb
c. Kirchoff
d. Volta
e. Tesla
f. Faraday

6. Who discovered that two wires (both carrying current) placed next to each other can repel or attract each other?

a. Ampere
b. Coulomb
c. Kirchoff
d. Volta
e. Tesla
f. Faraday

7. Who suggested that the sum of currents entering and leaving a node must be zero?

a. Ampere
b. Coulomb
c. Kirchoff
d. Volta
e. Tesla
f. Faraday

8. What is the unit of conductance?

a. Ampere
b. Coulomb

c. Volt
d. Henry
e. Siemens
f. Watt

9. What is the SI unit for energy?

a. Joule
b. Watt
c. Ohm
d. Henry
e. Tesla
f. Volt

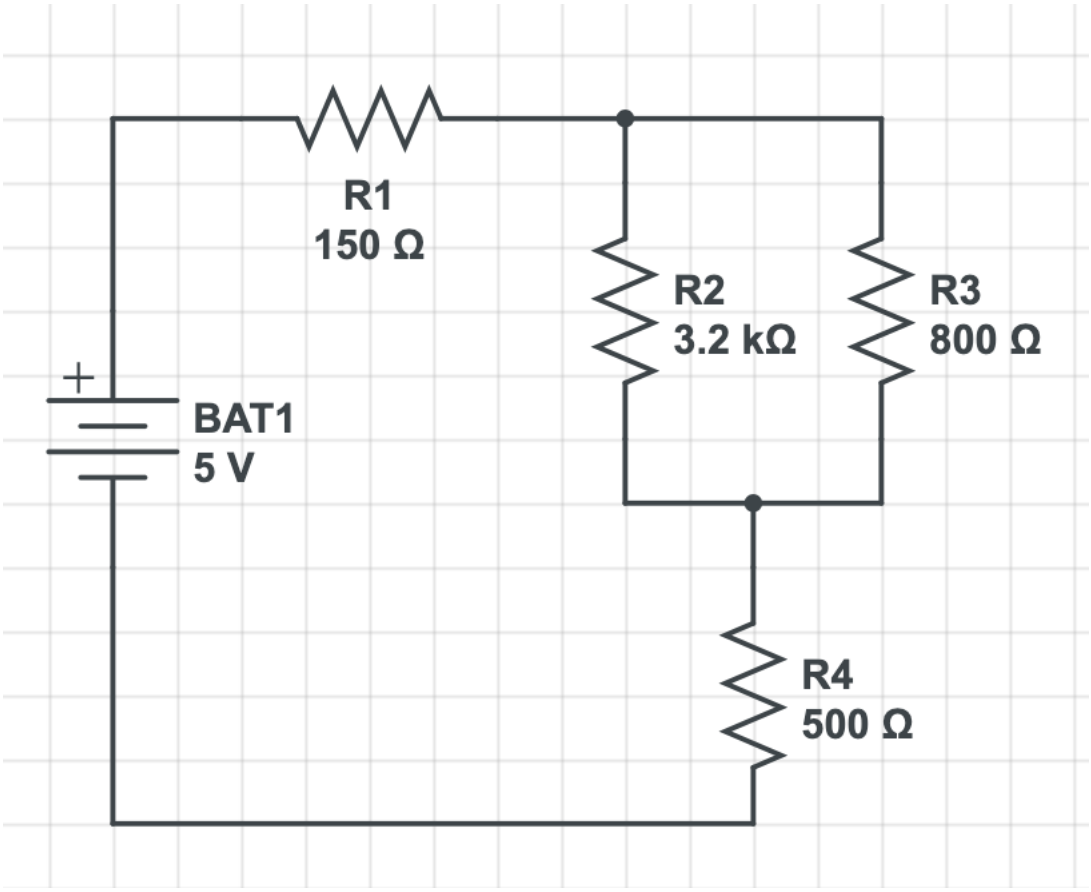
10. What is the SI unit for magnetic field strength?

a. Joule
b. Watt
c. Ohm
d. Henry
e. Volt
f. Tesla

11. Write the unit for current in base SI units (meter, kilogram, second, ampere)

a. $A \cdot s$
b. $(kg \cdot m^2)/(s^2 \cdot A^2)$
c. $(s^4 \cdot A^2)/(kg \cdot m^3)$
d. $kg \cdot m^2/s^2$
e. A
f. $kg \cdot m^2/s^3$

Questions 13-17 refer to the following picture:



12. What is the equivalent resistance of this circuit?

    a. 4650 Ω
    b. 1290 Ω
    c. 2650 Ω
    d. 3550 Ω
    e. 1190 Ω
    f. 2950 Ω

13. What is the voltage drop across R1?

    a. 2.48V
    b. 0.58V
    c. 0.11V
    d. 0.15V
    e. 1.6V
    f. 0.44V

14. What is the voltage drop across R3?

    a. 2.48V
    b. 0.58V
    c. 0.11V
    d. 0.15V
    e. 1.6V
    f. 0.44V

15. How much energy is consumed by the circuit every second?

    a. 0.019J
    b. 0.019W
    c. 0.019V
    d. 0.058J
    e. 0.058W
    f. 0.058V

16. What is the current through R2?

    a. 0.11mA
    b. 0.48mA
    c. 0.16A
    d. 0.77mA
    e. 1.7mA
    f. 7.7mA

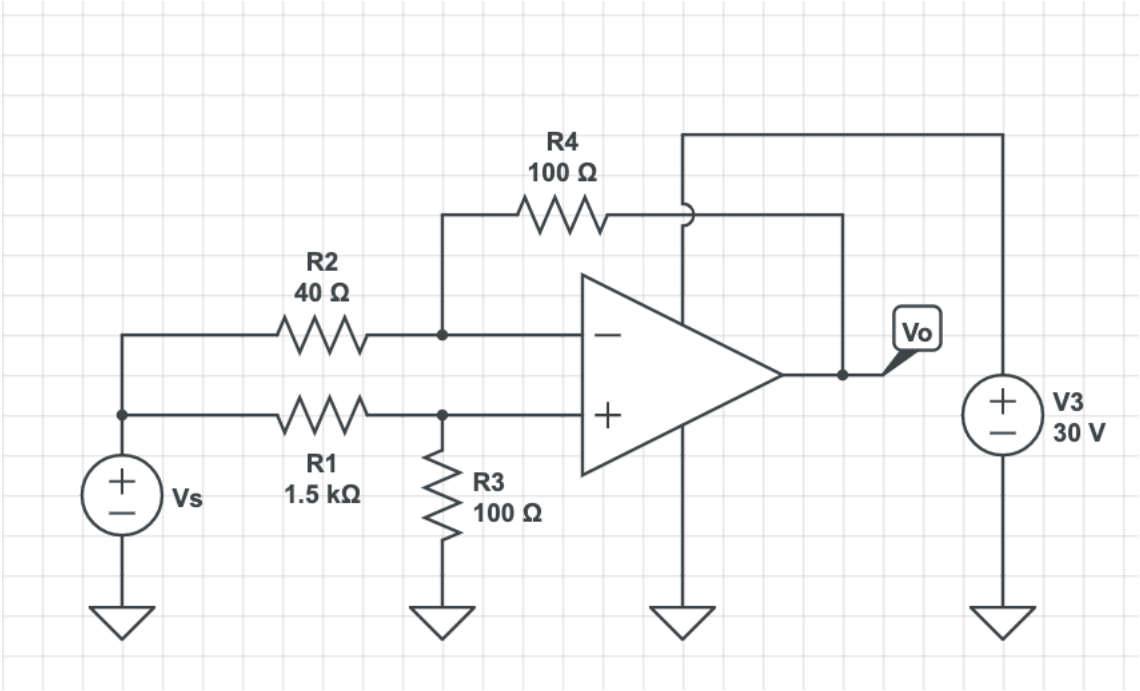
17. What is the direction of the magnetic force on an electron moving directly right through a magnetic field pointing out of the screen??

    a. Up
    b. Down
    c. Left
    d. Right
    e. Into Screen
    f. Out of Screen

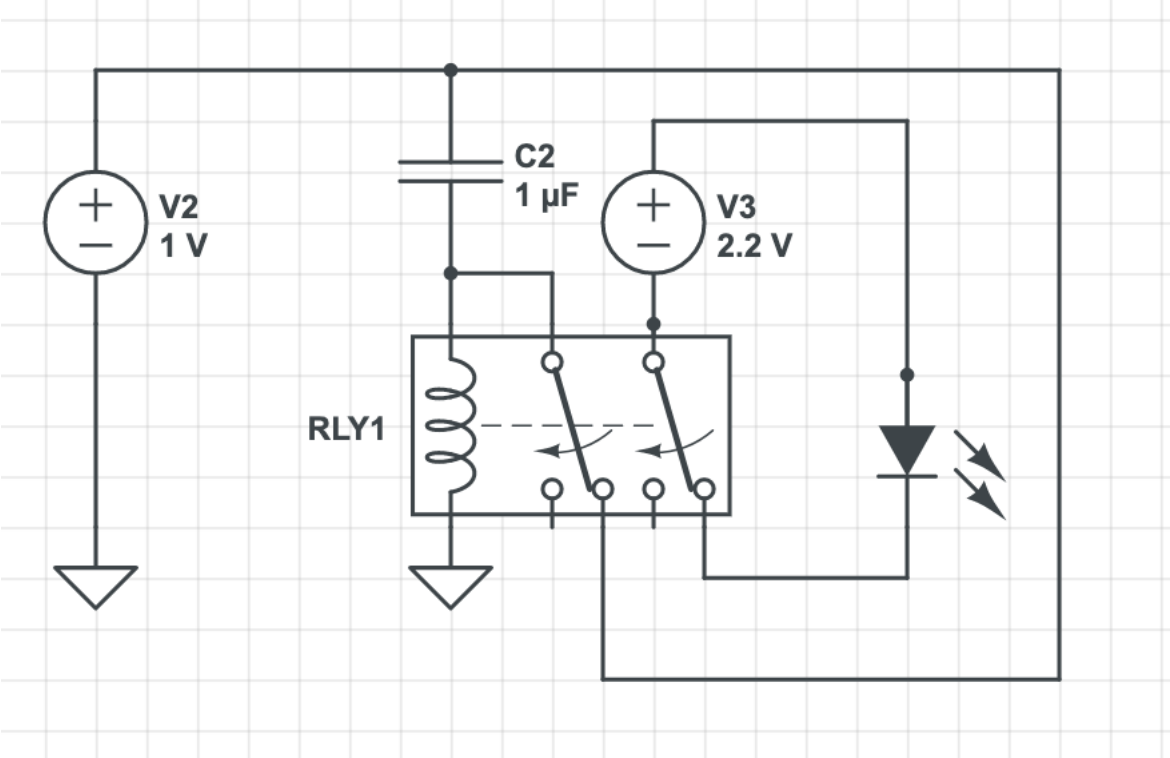
Short Answer Questions

For the short answer questions, please explain your thought process (show work) for full points.

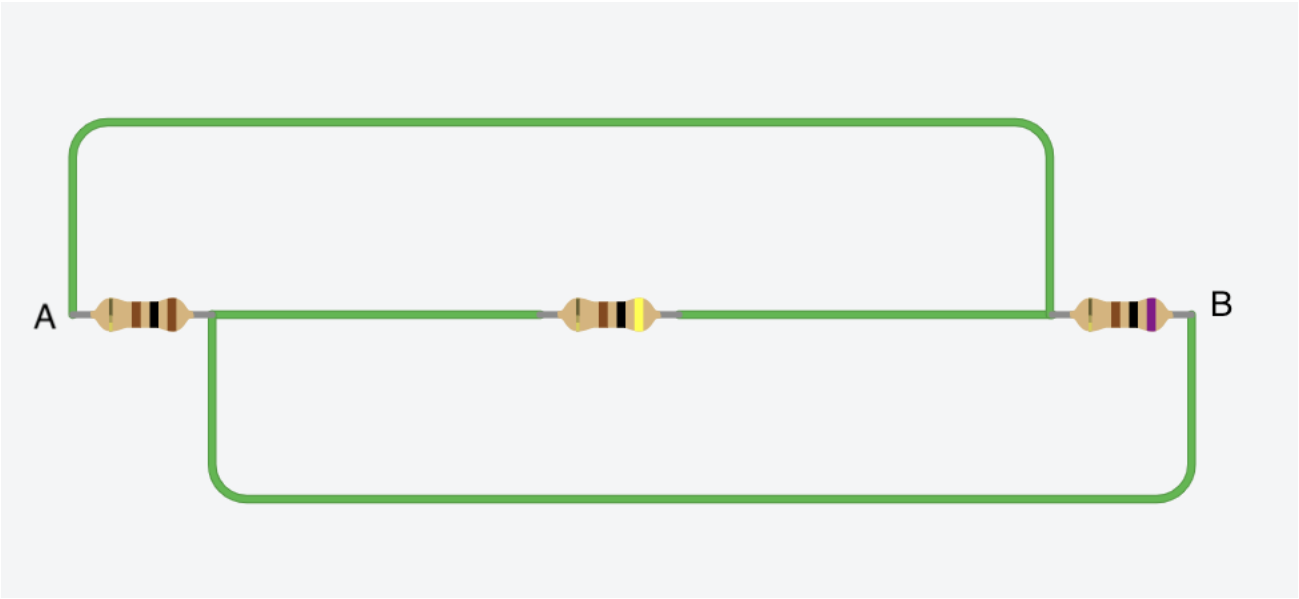
Questions 1 and 2 refer to the following diagram:



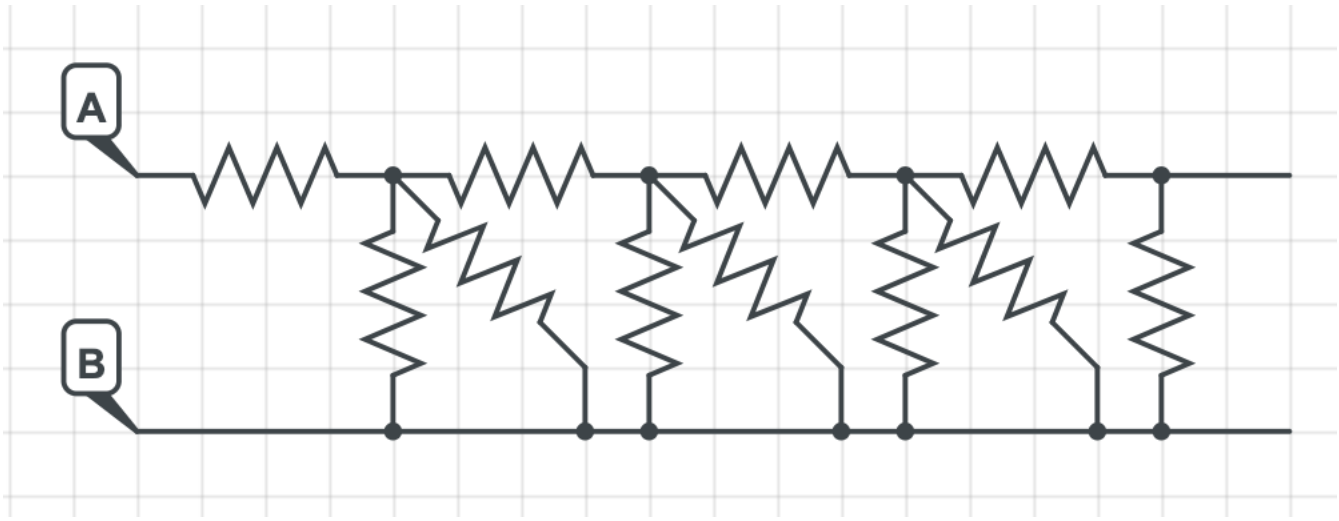
1. What is the gain of the circuit?
2. What are the minimum and maximum Vs that can be supplied so the output is not clipped?
3. What does the following circuit do, and what is it called?



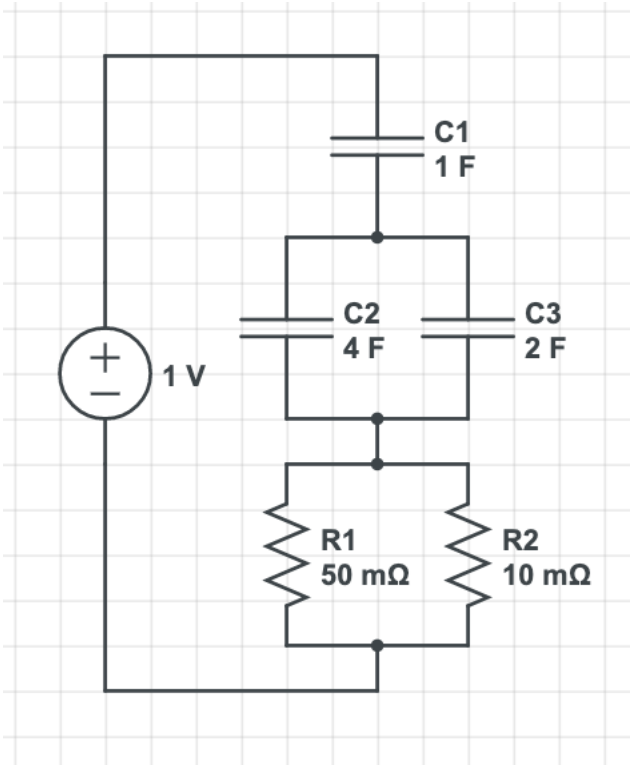
4. What is the resistance from point A to point B?



5. What is the resistance from point A to point B if the pattern continues forever and all resistors have resistance of $R\Omega$? (Your answer should be in terms of R.)



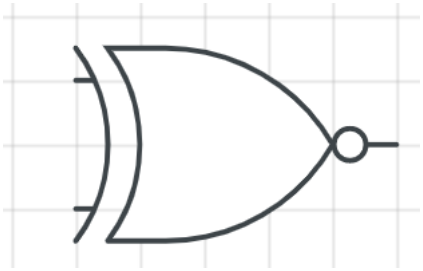
6. What is the time constant of the following circuit?



7. What are the two types of BJT transistors? List their similarities and differences.
8. What type of semiconductor would result from phosphorus doping of silicon?
9. What type of semiconductor would result from boron doping of silicon?
10. Describe a P-N junction, and how it contributes to the function of a diode.

11. Using boolean algebra, show $A\overline{B} + \overline{(A+B)} = \overline{B}$

12. What gate is this, what is its truth table, and what is its corresponding boolean algebra expression?



13. Which two logic gates are considered "Universal", and why?

14. Show you can make an XOR gate out of NAND gates.

15. What is a wheatstone bridge, and what is it used for?

16. What is a three-way switch? Give an application of a three-way switch.

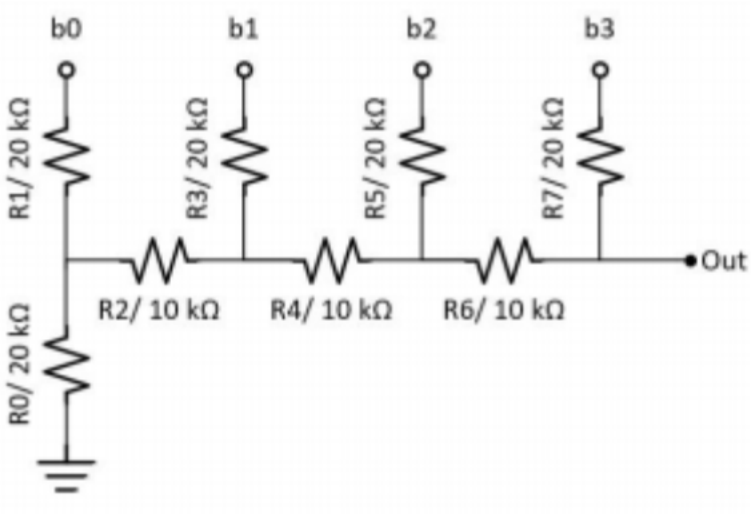
17. What are Kirchoff's laws?

Long(-er) Answer Questions

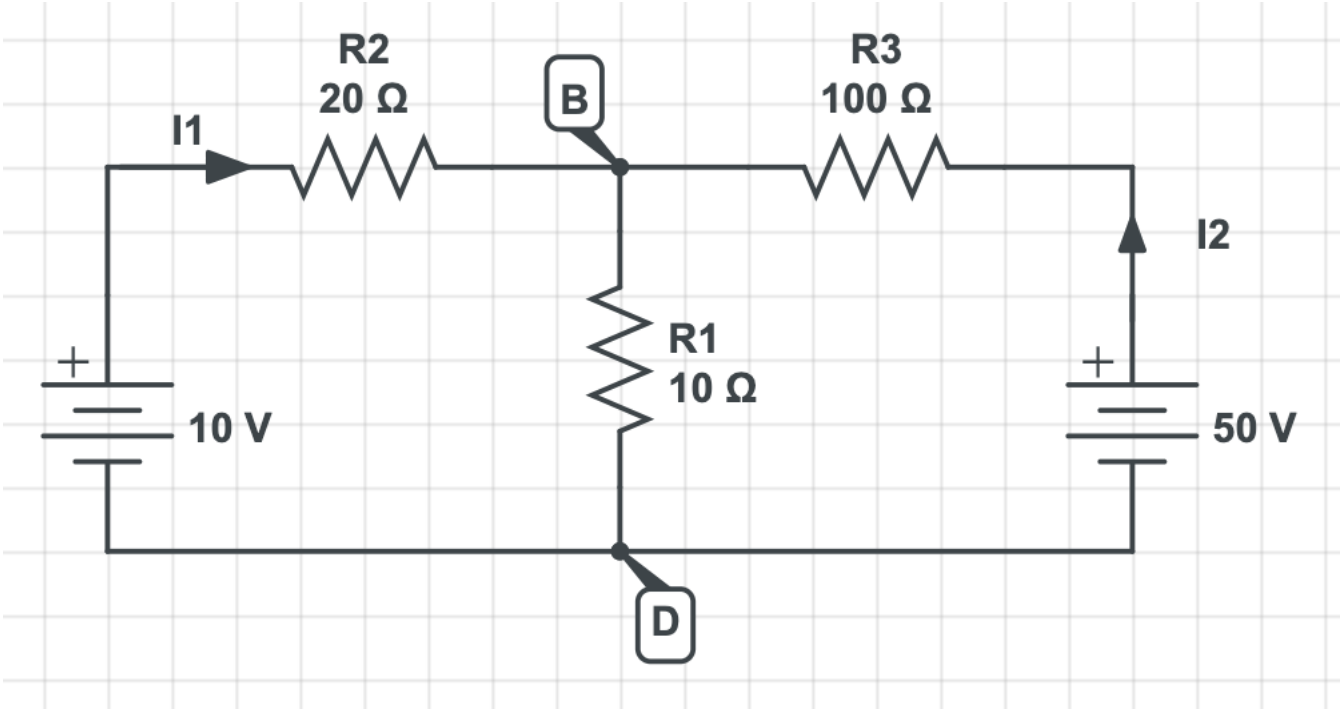
1. Magnetism in Space

   A proton is moving directly right at 44m/s when it encounters a magnetic field with strength 4T. This magnetic field is pointed directly out of the screen (perpendicular to both the ground and the electron's motion), and is 40nm wide. What is the magnitude and direction of the force on the electron from the magnetic field? Where does it exit the magnetic field relative to the entrance point (on what side and how far from the entrance point)?

2. What is the following circuit called? What is it used for?



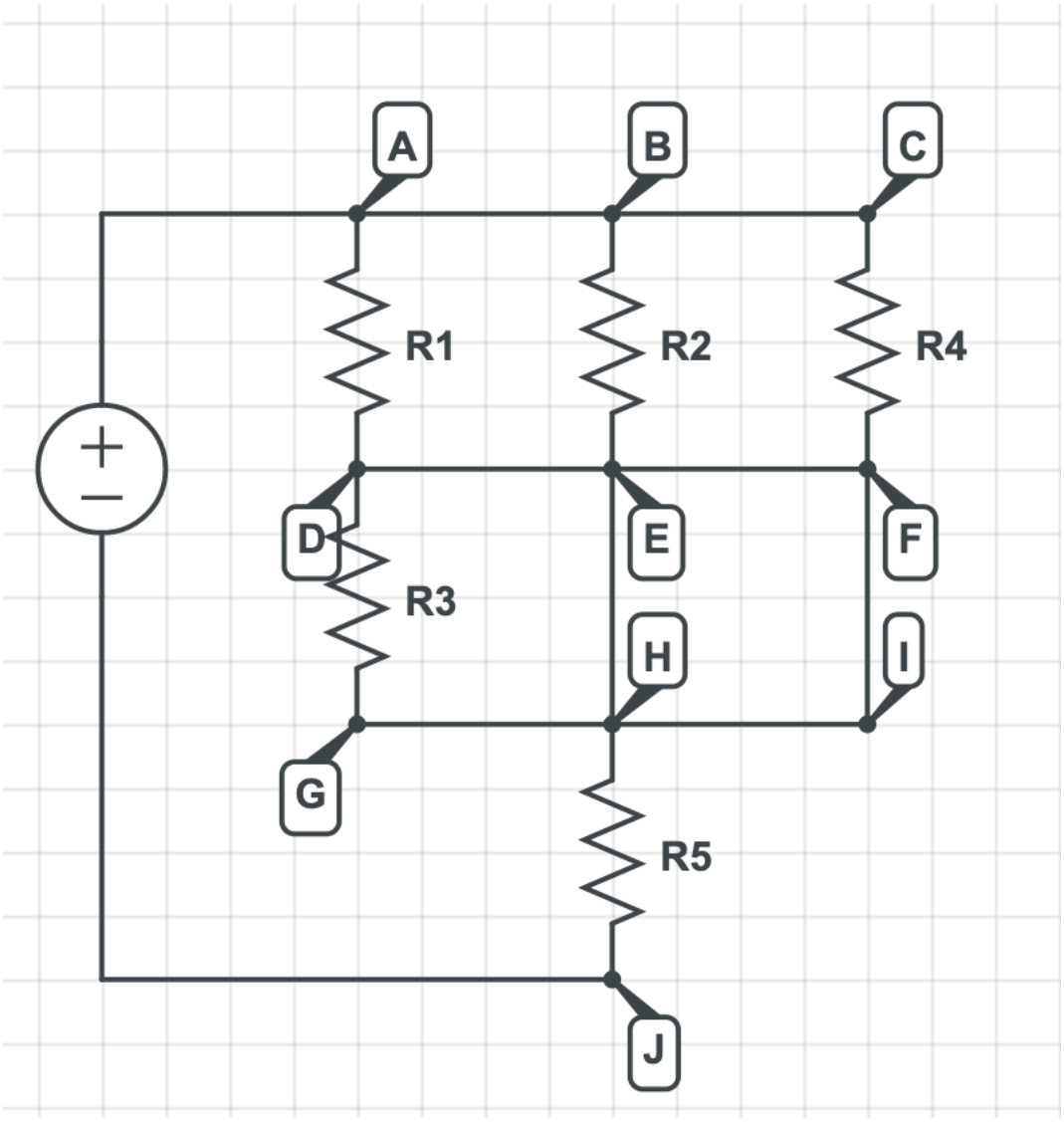
3. What are I1, I2, the voltage at point B, and the voltage at point D?



Lab

Will be making a tutorial video for autodesk tinkercad, hopefully there is a way to distribute it to participants. Obviously banning microcontrollers.

Questions 1 and 2 refer to the following image:



1. If you wanted to measure the current through R3, what tool would you use and where would you place its leads? (Feel free to use the provided node labeling, or qualitatively explain where to place the leads)

2. If you wanted to measure the voltage drop across R5, what tool would you use and where would you place its leads? (Feel free to use the provided node labeling, or qualitatively explain where to place the leads)

3. Build a circuit using only SPST switches, a DC motor, and a power supply so you can change the direction of the motor only using the switches. (This should be completed in Autodesk Tinkercad)

4. Build an adjustable comparator circuit (using an opamp) to trigger an LED. Make sure to keep the LED safe. That is, do not use too high current, which would damage

the LED. (This should be completed in Autodesk Tinkercad)