Circuit Lab Test

Middlesex County Academy Science Olympiad

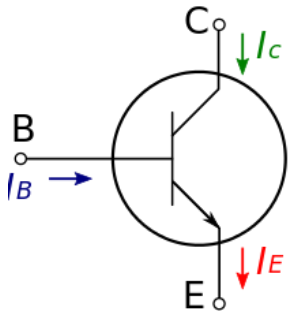
Captain's Exchange 2019

Score: _____ / 75

50 minutes

I. Multiple Choice (1 point each)

1. The ____ is used to simplify calculations with op-amps.
    a. Virtual Short Model
    b. R-2R model
    c. Open Loop
    d. Closed Loop
2. The following is a:



    a. PNP Transistor
    b. Resistor
    c. NPN Transistor
    d. Diode
3. An object cannot become charged through which of the following:
    a. Friction
    b. Conduction
    c. Polarization
    d. Electric Fields
4. The brightness of a bulb directly depends on:
    a. Internal resistance
    b. Current through the bulb
    c. Power dissipated by the bulb
    d. Capacitance
5. Who showed that the magnetic field around a wire was circular?
    a. Nikola Tesla
    b. Alessandro Volta
    c. Michael Faraday
    d. André-Marie Ampere
6. Who invented the first electric motor and dynamo?
    a. Nikola Tesla
    b. Alessandro Volta

c. Michael Faraday

d. André-Marie Ampere

7. Who disproved the concept of animal electricity?

a. Nikola Tesla

b. Alessandro Volta

c. Michael Faraday

d. Georg Ohm

8. Who invented the radio?

a. Nikola Tesla

b. Georg Ohm

c. Michael Faraday

d. Gustav Kirchhoff

9. What was Volta's first battery called and how was it created?

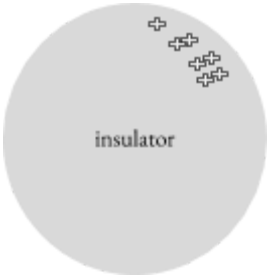
a. Voltaic stack, alternating disks of zinc and silver separated by paper or cloth soaked in either saltwater or sodium hydroxide.

b. Voltaic pile, alternating disks of zinc and silver separated by paper or cloth soaked in either saltwater or sodium hydroxide.

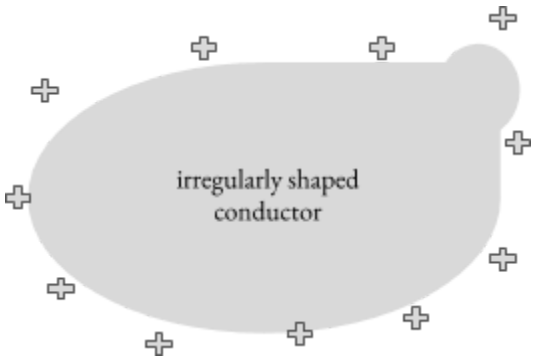
c. Voltaic stack, alternating cubes of copper and iron separated by paper or cloth soaked in either saltwater or sodium hydroxide.

d. Voltaic pile, alternating cubes of copper and iron separated by paper or cloth soaked in either saltwater or sodium hydroxide.

10. Which of the following is an incorrect charge distribution?

a. 

b.



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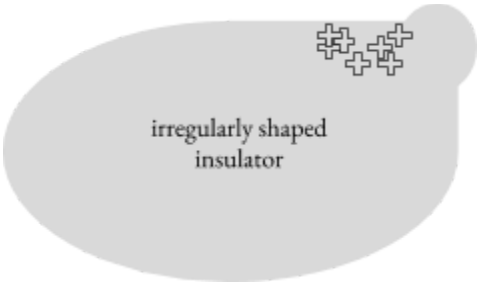
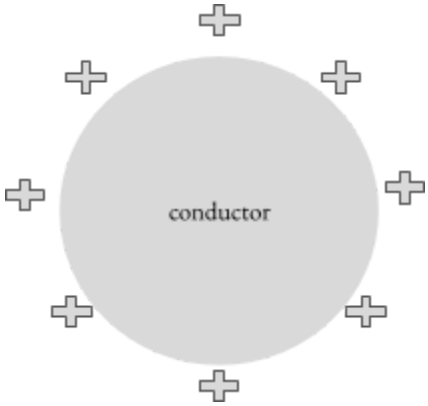


d.



11. Consider the diagram at the right. This diagram depicts 2 parallel plates a fixed distance apart and a potential difference between the plates of V. Point A is twice as far from the negative plate as point B. Which of the following statements is true?

a. The electric potential is the same at points A and B.

b. The electric potential is two times larger at A than at B.

c. The electric potential is two times larger at B than at A.

d. The electric potential is four times larger at B than at A.

12. Simple circuits consisting of resistors and capacitors are called:
    a. AC circuits
    b. DC circuits
    c. RC circuits
    d. Electromagnetic circuits
13. Which of the following can materials exhibit when placed in a magnetic field?
    a. Ferromagnetism
    b. Paramagnetism
    c. Diamagnetism
    d. A and C
    e. B and C
    f. All of the above
    g. None of the above
14. A proton enters a magnetic field directed out of the page, traveling from left to right. The resulting path of the proton is a circle. What is the radius of the circle in terms of the mass of the particle m, the velocity v, the charge q, and the magnetic field B?
    a. $mvBq$
    b. $\frac{qv}{mB}$
    c. $\frac{qB}{mv}$
    d. $\frac{mB}{qv}$
    e. $\frac{mv}{qB}$
15. Which of the following processes involves a capacitor?
    a. Taking a picture with a flash camera
    b. A relay switching between two outputs
    c. Transferring electrical energy between two circuits with a transformer
    d. Creating an electromagnet by winding wire around a nail

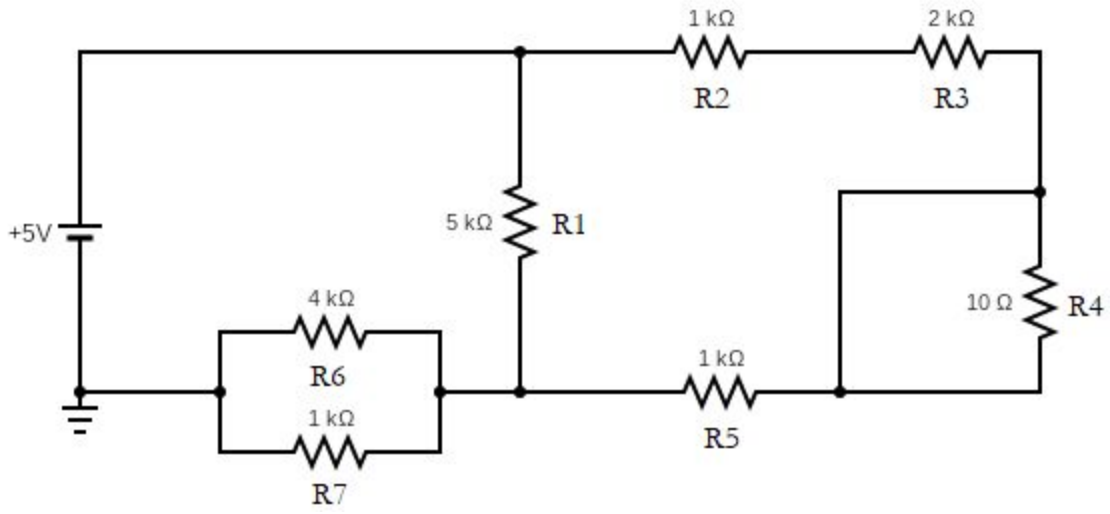
II. Fill in the blank (1 point per blank)

1. Coulomb's Law states that like charges attract and opposite charges repel with a force proportional to the product of their charges and inversely proportional to the square of their distance.
2. Ohm derived the equation which relates voltage as a product of current and resistance.
3. When a capacitor has just been connected to a resistor circuit it can be represented by a short/wire.
4. The magnetic force is always perpendicular to the velocity of the moving charge.
5. LED stands for light-emitting diode,

III. Section 3

Consider the following circuit:

1. What is the total (equivalent) resistance of this circuit across the battery? (3 points)



R_T=3.02kΩ

2. Calculate the voltage across each resistor. (0.5 point each)

V_1 = 3.68 V	V_4 = 0 V	V_7 = 1.32 V
V_2 = 0.92 V	V_5 = 0.92 V	
V_3 = 1.84 V	V_6 = 1.32 V	

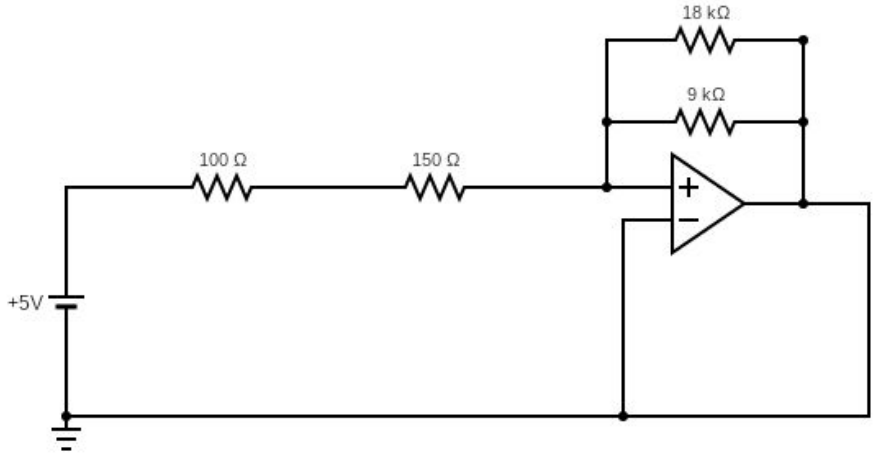
3. Calculate the current through each resistor. (0.5 point each)

I_1 = 0.74 mA	I_4 = 0 A	I_7 = 1.33 mA
I_2 = 0.92 mA	I_5 = 0.92 mA	
I_3 = 0.92 mA	I_6 = 0.33 mA	

4. Calculate the power dissipated by the circuit. (2 points)

P_T=8.3 mW

Consider the following op-amp circuit:



5. Assuming an ideal op-amp, find the voltage gain (output/input) of the network. (4 points)

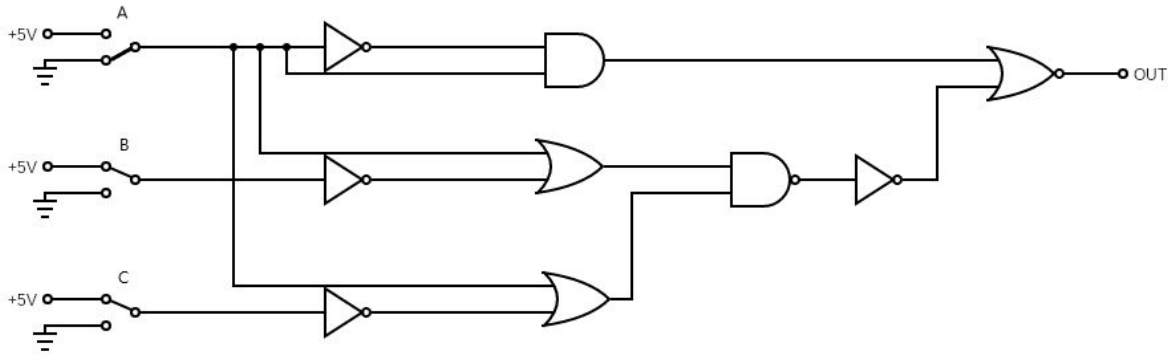
G=24

6. Simplify the following Boolean equation (4 points):

$$\overline{(\overline{A}(B+\overline{C})+\overline{B}\overline{C})}\ \overline{(A\overline{B}+C+\overline{A}BC)}$$

1 or True

Consider the following circuit:



7. Will the output be a high or low? (3 points)

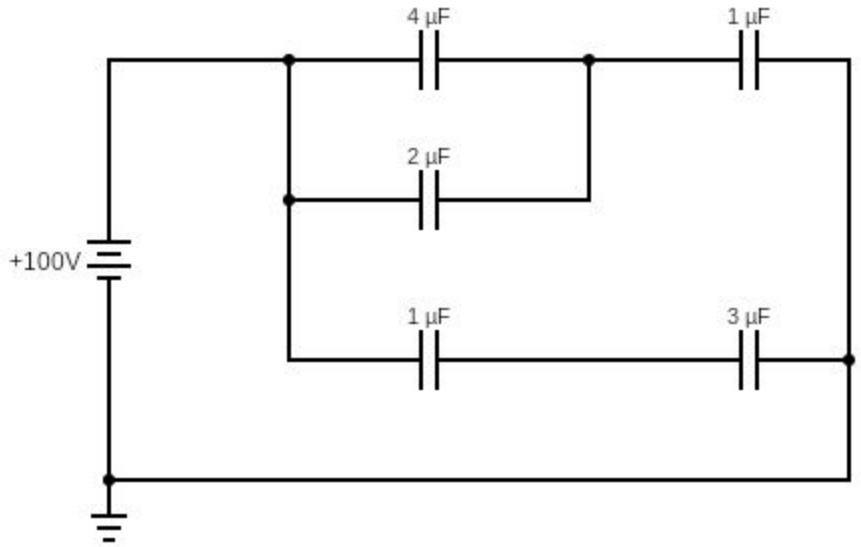
High/5v

8. Write and simplify a boolean equation representing the circuit in terms of inputs A, B, and C. (4 points).

$$A\overline{A} + \overline{(A + \overline{B})(A + \overline{C})}$$

$$\overline{A}B + \overline{A}\,C$$

Consider the following circuit for question 10:

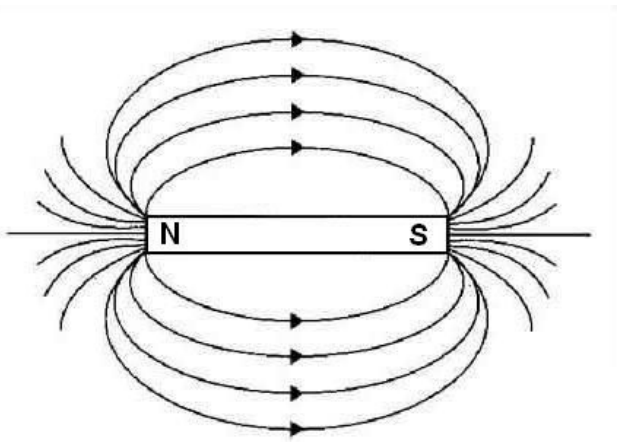


9. What is the total (equivalent) capacitance of the circuit across the battery (3 points)?

C_T=0.4μF

10. Draw the electric field created by 2 opposite charged parallel plates (2 points).

11. Draw the magnetic field lines of this bar magnet: (2 points)



12. Two point charges A and B are located on the x-axis. A is located at (-2m, 0) and has a charge of -3μC, and B is located at (2m, 0) and has a charge of 3μC. Position P is (0, 5m) and is initially empty.

a. What is the electric field at point P due to charges A and B? (2 points)
b. If a proton is placed at point P, what would be the magnitude and direction of the force exerted on it? (2 points)
c. What is the electric potential at P due to charges A and B? (2 points)

a. 280 N/C to the left
b. 4.5 * 10^-17 N to the right
c. 0

13. Name a similarity and a difference between gravitational force and electrostatic force. (2 points)

Similarities:

Inversely proportional to square of distance, similar calculation (constant times two quantities over distance squared), caused by fields, etc.

Differences:

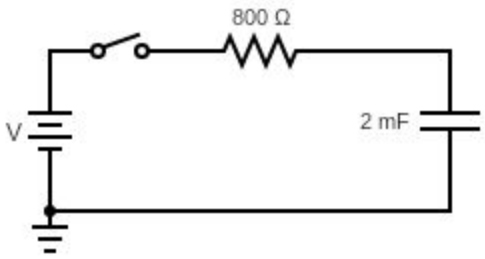
Relative strength of forces (gravitational much stronger), gravitational force only attracts while electrostatic force can attract or repel, caused by different type of fields, gravitational force calculation uses mass while electrostatic uses charge, etc.

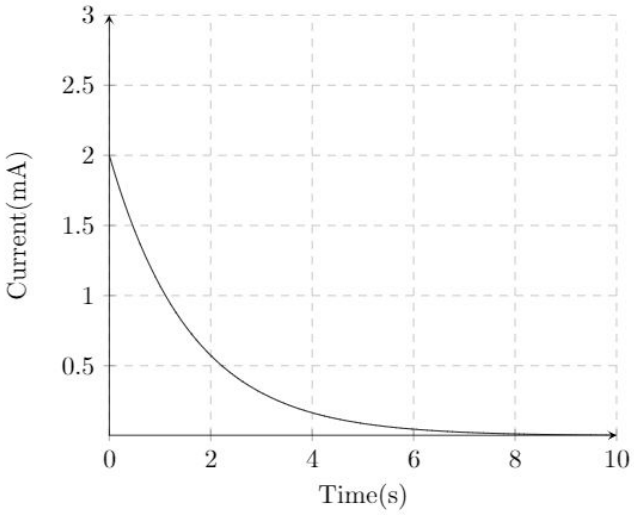
14. Are appliances in your house hooked up in series or in parallel? Why? A brief explanation will do. (2 points)

Parallel +1

Appliances can be unplugged without others being disconnected, all appliances get the same voltage, outlets can be added or removed, difference appliances draw different amounts of current, etc. +1

15. In the circuit shown, the values for the resistance and capacitance are known, but the constant voltage V delivered by the battery is unknown. At time t=0, the capacitor is uncharged and the student closes the switch. The current as a function of time is measured, and the following graph is obtained.





a. Using the data, calculate the battery voltage V. Show all work. (3 points)

$V=IR$ at time t=0 +1

V=(2mA)(800Ω) = 1.6V +2

b. Calculate the voltage across the capacitor at time t=2s. (3 points)

$V=IR+V_c$ +1

V_c=1.6V - (0.6 mA)(800Ω) = 1.12V (or similar approximation for current) +2

or

$V_c=V(1-e^{-t/\tau})$ +1

$V_c=(1.6V)(1-e^{-(2s)/((800\Omega)(2mF))})=1.14V$ +2

c. On the axes below, sketch a rough graph of the charge on the capacitor as a function of time. (2 points) Similar shape +2