



Circuit Lab

NEW YORK STATE SCIENCE OLYMPIAD
LAKE ERIE/NIAGARA 2018-2019 INVITATIONAL COMPETITION
DECEMBER 8, 2018 - BUFFALO STATE COLLEGE

Instructions: You have 50 minutes to complete this event. This event is composed on two parts. Part I is a written test. Part II consists of hands-on tasks.

There are two hands-on tasks. There are different stations to each task. You will spend 25 minutes at the first station, then switch to the second station for 25 minutes. You may work on the written test at any point. You may not return to the prior station once the time is up.

You may use any reference within a single three-ring binder, provided they are attached using the rings. You may use two stand-alone calculators of any type, but cell phones may **not** be used as calculators and must remain **OFF** (not on vibrate or silent) for the duration of the event. For hands-on tasks where a multimeter is required, one will be supplied. Participants may elect to use their own multimeter if they desire to do so. **Please write your team name and number on this page and your answer sheet.** If you choose to detach any pages from this test booklet, please write your team name and number on those pages as well.

There are 29 questions in the test plus the two hands-on tasks. Point values for each question are indicated. You may not finish the test in the allotted time, thus, you are encouraged to complete the test in any order that you choose.

Tiebreakers: Questions 19, 27, 24, 3, 8

Team name: _____ Team number: _____

Members: 1. _____ 2. _____

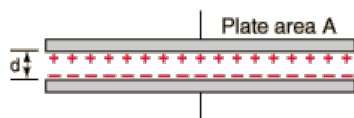
PART I - WRITTEN TEST

MULTIPLE CHOICE: Choose the one alternative that best completes the statement or answers the question.

- (2%) Alessandro Volta's discovery of the electrochemical series led to the creation of the
 - capacitor.
 - battery.
 - silicon PN junction.
 - light-emitting diode.

- (3%) Two point charges, $Q_A = +8 \mu\text{C}$, and $Q_B = -5 \mu\text{C}$, are separated by a distance of 10 cm. What is the electric force between the two particles?
 - 36 N
 - +36 N
 - -4.0×10^{-9} N
 - $+4.0 \times 10^{-9}$ N

- (3%) Two flat metallic plates each have an area $A = 25 \text{ mm}^2$ and are separated by a distance $d = 0.5 \text{ mm}$ as shown in the figure below. The space between the two plates is occupied by Teflon which has a relative permittivity of 2.1. What is the capacitance?



- 930 pF
- 0.93 pF
- 0.44 pF
- 440 pF
- 1.8 nF

- (2%) In conventional current flow, which direction does the electrical current flow in?
 - In the direction that the electrons flow.
 - Opposite the direction that the electrons flow.
 - In the direction of highest to lowest resistance.
 - The current does not flow.

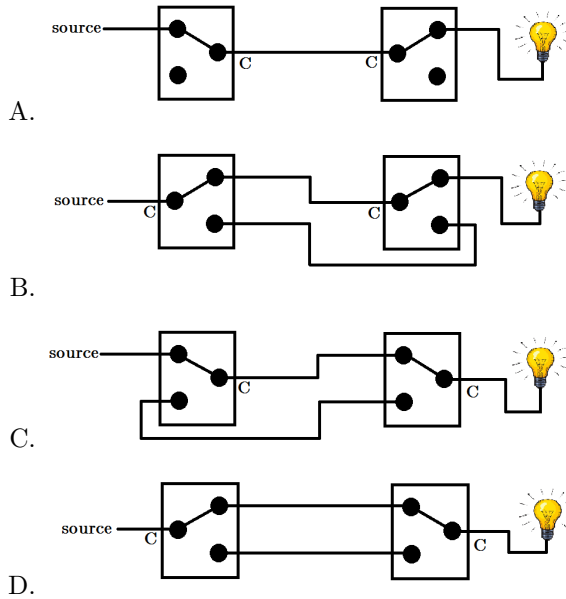
- (2%) Which of the following explains why Alternating Current (AC) is favored over Direct Current (DC) in power grid distribution?
 - AC has less power loss than DC over the same distance.
 - Digital consumer electronics require internal AC power.
 - Light bulbs will not work with DC power.
 - AC voltages can be easily increased or decreased through the use of transformers.
 - AC power is safer for birds that sit on power lines.

- (2%) What term best refers to the opposition of the flow of electric current?
 - Capacitance
 - Voltage
 - Current
 - Conductance
 - Resistance

- (2%) Which electromagnetic device uses brushes and a commutator?
 - DC Motor
 - Speaker
 - Relay
 - Solenoid
 - Battery

- (3%) Calculate the magnetic flux through a circular loop of radius 0.5 m that is in a magnetic field of strength 1.5 T if the area of the loop is perpendicular to the direction of the field?
 - 0.30 Wb
 - 4.7 Wb
 - 1.2 Wb
 - 2.4 Wb
 - 0 Wb

9. (2%) Which of the following diagram shows the correct wiring of a 3-way switch for lighting control?



10. (2%) How should a voltmeter be connected to measure the voltage drop of a component in a circuit?

- A. In parallel with the component.
- B. In series with the component, on the positive side of the component.
- C. In series with the component, on the negative side of the component.
- D. In series with the component, on either side.

11. (2%) Through which electrode of a diode do electrons enter?

- A. Anode
- B. Cathode

12. (2%) What are the color bands for a $6.8\text{ k}\Omega (\pm 5\%)$ resistor?

- A. black-green-red-gold
- B. blue-gray-green-gold
- C. red-green-black-silver
- D. blue-gray-red-gold
- E. red-green-black-gold

13. (2%) What happens to the quantum efficiency of an LED as temperature increases?

- A. Linear increase
- B. Linear decrease
- C. Exponential increase
- D. Exponential decrease
- E. Logarithmic increase

14. (2%) The sum of all voltages in any closed loop is equal to

- A. zero.
- B. the sum of all voltage sources.
- C. the current times the resistance of all loads.
- D. infinity.

15. (2%) Nodal analysis involves systematically applying which of the following laws to the nodes of a circuit?

- A. Ohm's Law
- B. Faraday's Law
- C. Kirchhoff's Voltage Law
- D. Kirchhoff's Current Law
- E. Helmholtz's Law

16. (2%) What type of gate is represented by the following truth table?

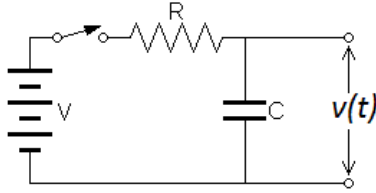
Inputs		Outputs
X	Y	Z
0	0	1
0	1	0
1	0	0
1	1	0

- A. AND
- B. OR
- C. NOT
- D. NAND
- E. NOR

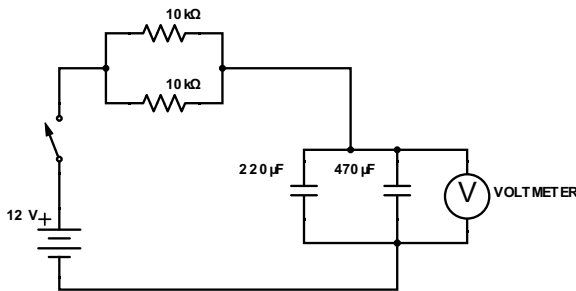
17. (2%) True or False: In an RC circuit, capacitor voltage can change instantaneously.

- A. True
- B. False

18. (2%) The capacitor in the circuit below is initially uncharged and the switch is open. When the switch is closed, what happens to the voltage $v(t)$ in the capacitor?



- A. Increases linearly with time
 B. Increases logarithmically with time
 C. Increases exponentially with time
 D. Decreases linearly with time
 E. Does not change
19. (4%) The switch in the circuit below is closed at time $t = 0$. What is the voltage measured by the voltmeter at $t = 6.9$ s?

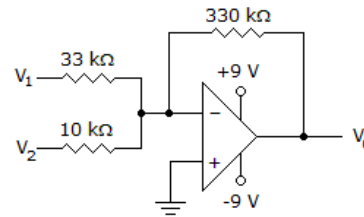


- A. 7.6 V B. 10.4 V C. 12.0 V D. 4.7 V
 E. 0 V
20. (2%) A P-N junction diode allows electric current only in
- A. zero bias.
 B. reverse bias.
 C. forward bias.
 D. silicon diodes.
 E. vacuum.

21. (2%) What is the term for the voltage that must be applied across a diode before the diode begins conducting current?

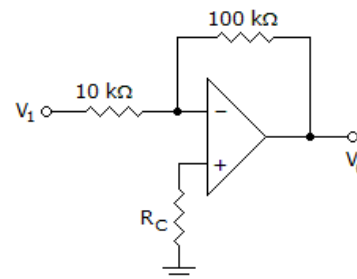
- A. Barrier Voltage
 B. Breakdown Voltage
 C. Schottky Voltage
 D. Conduction Voltage
 E. Bypass Voltage

22. (3%) Calculate the output voltage if $V_1 = -0.2$ V and $V_2 = 0$ V.



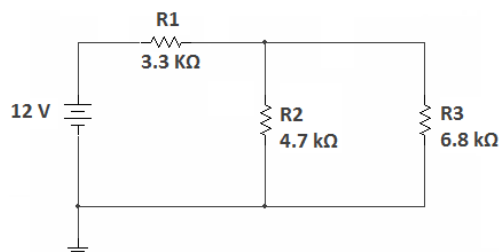
- A. 0 V
 B. -6.6 V
 C. -4 V
 D. 2 V

23. (3%) Calculate the input voltage for this circuit if $V_0 = -11$ V.



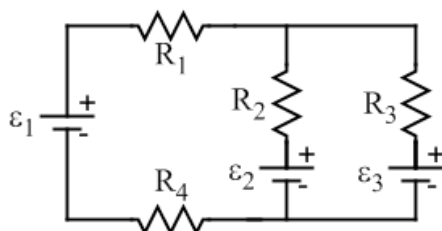
- A. 1.1 V
 B. -1.1 V
 C. 1 V
 D. -1 V
 E. 0 V

Questions 24 and 25 are based on the following circuit.



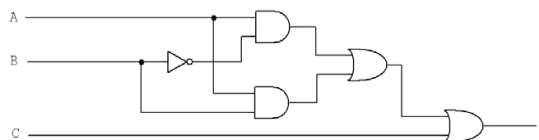
24. (3%) What is the voltage across resistor R2?
 A. 12 V B. 6.51 V C. 5.49 V D. 0 V
 E. 1.97 V
25. (3%) What is the current through resistor R2?
 A. 1.97 mA B. 1.17 mA C. 1.97 A
 D. 0.8067 mA E. 2.55 mA

Questions 26 and 27 are based on the following circuit, where $R_1 = 1.0 \Omega$, $R_2 = 5.0 \Omega$, $R_3 = 2.0 \Omega$, $R_4 = 3.0 \Omega$, $\varepsilon_1 = 2.0 \text{ V}$, $\varepsilon_2 = 15 \text{ V}$, and $\varepsilon_3 = 12 \text{ V}$.



26. (3%) What is the voltage drop across resistor R_1 ?
 A. -13 V B. 2.0 V C. 2.4 V
 D. 3.1 V E. 17 V
27. (3%) What is the total current flowing through resistor R_2 ?
 A. 1.0 A B. 2.0 A C. 3.0 A
 D. 5.0 A E. 5.8 A
28. (2%) Which of the following is a rule of Boolean algebra?
 A. $A + 1 = A$
 B. $A + 0 = 1$
 C. $A + 1 = 1$
 D. $A + \bar{A} = 0$

29. (3%) Which of the following un-simplified Boolean expressions represent the logic circuit shown below?



- A. $F = AB + A\bar{B} + \bar{C}$
 B. $F = \bar{A}B + A\bar{B} + C$
 C. $F = A\bar{B} + AB + C$
 D. $F = A\bar{B} + \bar{A}B + \bar{C}$

PART II: HANDS-ON TASKS

Station I:

30. (2% each) At this station you will find a box with five sets of terminal connections. The five components below have been connected across one set of terminals each. Using a multimeter, identify on your answer sheet which of the following components span each set of terminals.
- A. Battery
 B. Resistor
 C. Capacitor
 D. Diode
 E. Insulator

Station II:

31. At this station you will find a box with three terminals. Inside the box are three resistors connected between the terminals. Using the a multimeter, measure the resistance between each set of terminals. Then, in your answer booklet, draw a plausible schematic of the resistors and indicate their resistance values. (5% for diagram, 5% for each value)