GOLDEN GATE
INVITATIONAL

2020 Golden Gate Invitational Tournament

Circuit Lab C

Exam Booklet

- DO NOT BEGIN UNTIL GIVEN PERMISSION
- You will have **50 minutes** to complete the exam || You **may** separate the exam
- For calculation questions, it is **not** required that you show your work, however partial credit will be assigned if correct steps are shown with an incorrect answer.
- Answers must be given with appropriate **significant figures** and **units** to receive full credit.
- All final answers must be placed inside the designated box, including multiple choice.
- **Lab:** You will have up to **20 minutes** to complete **each** lab section **(2 total)**. A proctor will instruct you when it is your turn. You will not be given any replacement components, so be careful not to damage them.
- **Allowed materials:** 3-ring binder, writing utensils, two calculators, basic multimeter
- **Tie-breaker order:** 5, 12, 20, 23, 27, 30, 31, 34, Lab 2

Competitors: _____

_____

School Name: _____

Team Number: _____

Rank: _____

Score: _____

Kevin Hao[1], Asher Noel[2], Megan Pramojaney[3]
[1]University of Florida - BS Biology '21, MD '24 kevin@floridascienceolympiad.org
[2]Harvard College – BA Computer Science and Statistics '23 ashernoel@college.harvard.edu
[3]University of North Carolina Chapel Hill – BS Physics '23 pramoj23@live.unc.edu

This page is for administrative use only. DO NOT WRITE ON THIS PAGE.

Page Number	Possible Score	Your Score
3	20	
4	22	
5	24	
6	26	
7	20	
8	22	
9	29	
LAB 1	41	
LAB 2	34	
Total	238	

1. **[A]** Choose the scientist whose law is depicted. [1] **(2 pts)**

	A. Ampere	B. Coulomb	
	C. Kirchhoff	D. Volta	
	E. Tesla	F. Faraday	

2. **[B]** Choose the scientist that invented the device depicted. [1] **(2 pts)**

	A. Ampere	B. Coulomb	
	C. Kirchhoff	D. Volta	
	E. Tesla	F. Faraday	

3. **[C]** Choose the scientist that discovered the phenomenon depicted. [1] **(2 pts)**

	A. Ampere	B. Coulomb	
	C. Kirchhoff	D. Volta	
	E. Tesla	F. Faraday	

4. **[D]** Choose the scientist that made the discovery depicted. [1] **(2 pts)**

	A. Ampere	B. Coulomb	
	C. Kirchhoff	D. Volta	
	E. Tesla	F. Faraday	

5. **[E]** Choose the scientist whose law is depicted. [1] **(2 pts) (TB#1)**

	A. Ampere	B. Coulomb	
	C. Kirchhoff	D. Volta	
	E. Tesla	F. Faraday	

6. Which scientist's patents helped to perfect AC distribution. [1] **(2 pts)**

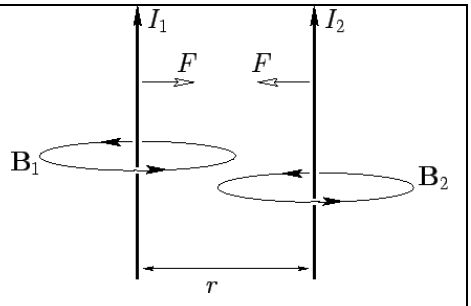
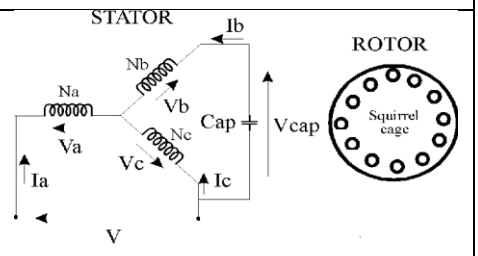
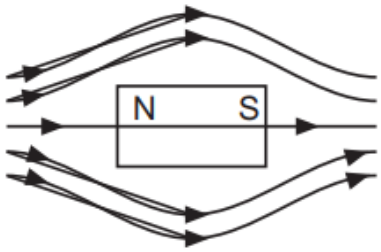
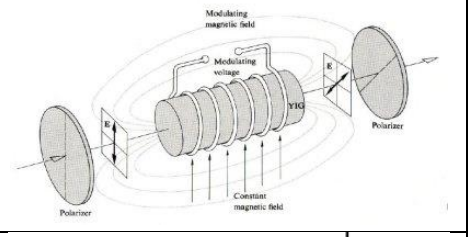
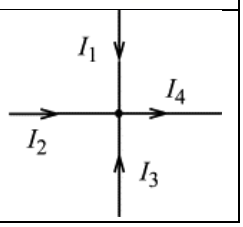
	A. Ampere	B. Coulomb	
	C. Kirchhoff	D. Volta	
	E. Tesla	F. Faraday	

7. An electric motor converts electrical energy to _____. [1] **(2 pts)**

	A. Mechanical	B. Electrical	
	C. Nuclear	D. Wind	

8. Choose the device that converts AC to DC. [1] **(2 pts)**

	A. Generator	B. Commutator	
	C. Alternator	D. Rectifier	

A	
B	
C	
D	
E	$I_4=I_1+I_2+I_3$ 

9. Two parallel wires with the same current exert forces on each other with equal magnitudes. What happens to the magnitude of this force if the current is halved? [1] **(2 pts)**

	A. Magnitude is quartered	B. Magnitude is halved	
	C. Magnitude is doubled	D. Magnitude is quadrupled	

10. If a force *F* is exerted on a charged particle when the particle enters a magnetic field *B* at a velocity *v*, which of the following is always true? [1] **(2 pts)**

	A. Vectors F and B are parallel	B. Vectors F and B are perpendicular	
	C. Vectors F and v are parallel	D. Vectors B and v are perpendicular	

____ / 20

11. What is the fastest Analog-to-Digital converter (ADC)? [1] **(2 pts)**

☐ A. Digital Ramp ADC
B. Successive Approximation ADC
C. Flash ADC
D. Sigma-delta ADC

12. Which of the following correctly describes an electrostatic interaction? [1] **(2 pts) (TB#2)**

☐ A. Two positive charges have an attractive force
B. Two negative charges have an attractive force
C. One positive and one negative charge will attract
D. One positive and one negative charge will repel

13. A Wheatstone bridge can NOT be used to indirectly measure which of the following?[1] **(2 pts)**

☐ A. Force
B. Temperature
C. Pressure
D. Time

14. Which of the following cause hysteresis in ferromagnetic materials? [1] (Select all that apply) **(4 pts)**

☐ A. Rotation of magnetization
B. Change in size of magnetic domains
C. Change in temperature
D. Change in pressure

15. Which of the following describes the velocity (v) and acceleration (a) of a small sphere of charge +q when placed near a large, fixed sphere of charge +Q? It will move away from the large sphere with: [1] **(2 pts)**

☐ A. Decreasing v, constant a
B. Decreasing v, increasing a
C. Increasing v, constant a
D. Increasing v, decreasing a

16. How much energy is dissipated as heat in 10 seconds by a 100 Ω resistor with a 0.5 A current? [1] **(2 pts)**

☐ A. 25 J
B. 100 J
C. 250 J
D. 500 J

17. For an ohmic conductor, doubling the voltage without changing the resistance will cause the current to? [1] **(2 pts)**

☐ A. Decrease by a factor of 4
B. Decrease by a factor of 2
C. Increase by a factor of 2
D. Increase by a factor of 4

18. A hollow metal sphere is placed inside an electric field. An electron is then placed at the center of the sphere. In what direction will the electron move? [3] **(2 pts)**

☐ A. In the direction of the electric field
B. Opposite of the electric field
C. Perpendicular to the field
D. None of the above

19. Assuming all other conditions are equal, which of the following scenarios would you expect a human to have the lowest amount of body capacitance? [3] **(2 pts)**

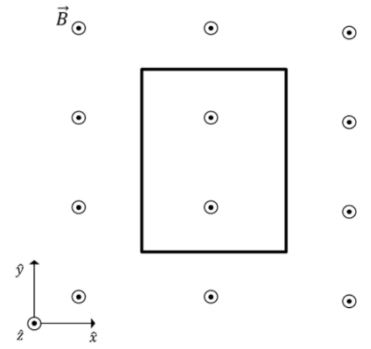
☐ A. Standing on top of the Golden Gate bridge on an arid afternoon
B. Leaning against the bottom of a grounded 20 ft metal pole in humid conditions
C. Body capacitance is the same in all scenarios
D. Leaning against a metal shed wall on an arid night

20. Consider a simple closed circit with a battery and a resistor. If the battery is 12 V and the current flowing through the circuit is 1.0 mA, what are the first three band colors of the resistor? [3] **(2 pts) (TB#3)**

☐ A. Brown, Red, Red
B. Brown, Red, Orange
C. Red, Black, Red
D. Red, Black, Orange

_____ / 22

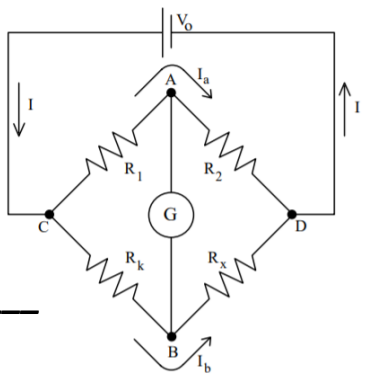
21. A rectangular loop is placed in a constant magnetic field region as shown below. The magnetic field region is initially perpendicular to the loop's plane. The loop is then rotated about an axis running through its center in the y-direction such that the angle of the loop's surface to the direction of the magnetic field region varies. Perform the following: [3] **(6 pts; 3, 3)**
    - Determine the angle of the loop's surface to the direction of the magnetic field region that gives the largest amount of magnetic flux through the loop. **(3 pts)**
    - Determine the angle, if any, between the loop's surface and the direction of the magnetic field region that gives the largest amount of current running through the loop. **(3 pts)**



Θ φ_{MAX} = _____ ***Θ I_{MAX} =*** _____

22. Draw a California 3-way connection system to complete the circuit between the hot line and the light bulb. **(6 pts)**

23. In the circuit shown, R_k and the ratio of R_2/R_1 are known. R_x is not known. Perform the following: [1] **(12 pts) (TB#4)**
    - State the name of the circuit. **(2 pts)**
    - State the purpose of the circuit. **(2 pts)**
    - State an equation for the V_{AB} in terms of V_o, R_k, R_x, R_1, and R_2. **(8 pts)**



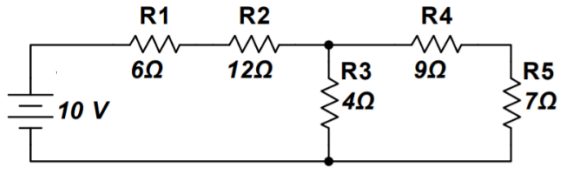
Name: _____

Purpose: _____

V_{AB} = _____

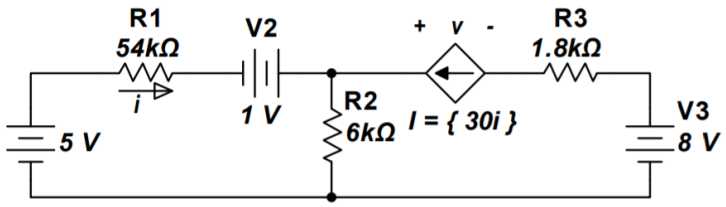
____ / 24

24. Determine the power dissipated by R1, R3, and R4. Provide your answers to 3 significant figures. [1] **(6 pts; 2, 2, 2)**



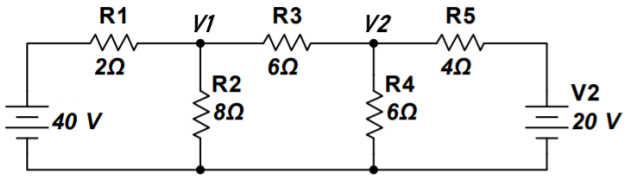
P_{R1} = _____ P_{R3} = _____ P_{R4} = _____

25. Determine the current *i* thru resistor R1 and the voltage *v* across the dependent source. Provide your answers to 3 significant figures. [1] **(12 pts; 6, 6)**



i = _____ *v* = _____

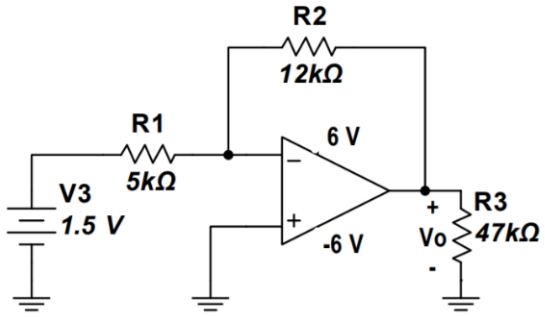
26. Determine the voltages V_1 and V_2 in the circuit below. Provide your answers to 3 significant figures. [1] **(8 pts; 4, 4)**



V_1 = _____ V_2 = _____

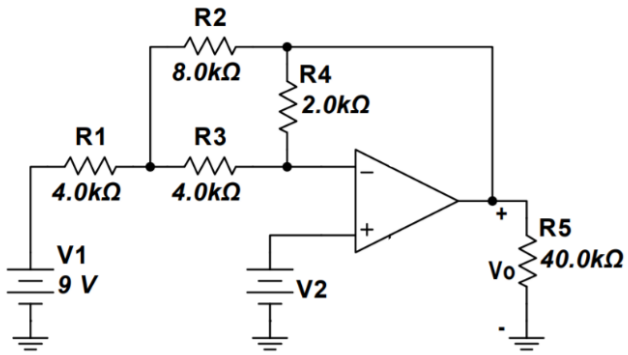
____ / 26

27. Determine V_o. Provide your answer to 3 significant figures. [1] **(6 pts) (TB#5)**



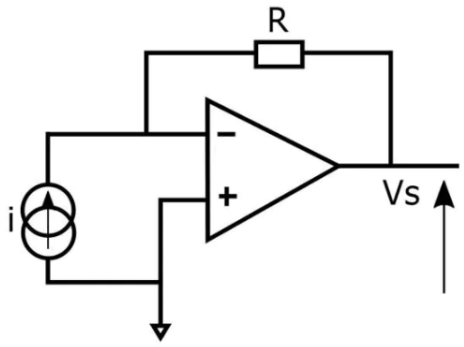
V_o = _____

28. Write V_o in terms of V_2. Then determine V_o when V_2 = 0 V. Provide your answers to 3 significant figures. [1] **(8 pts; 6, 2)**

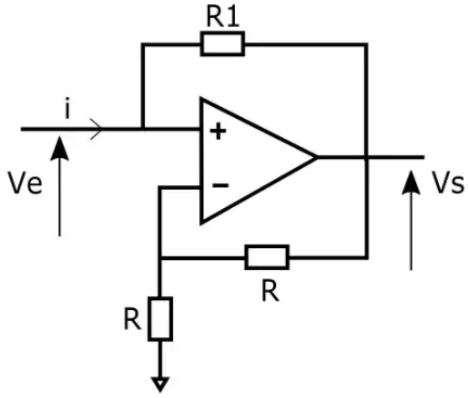


$V_o(V_2)$ = _____ ***$V_o(0)$ =*** _____

29. Determine expressions for V_s in terms of the variables present in each circuit diagram shown. [1] **(6 pts; 3, 3)**



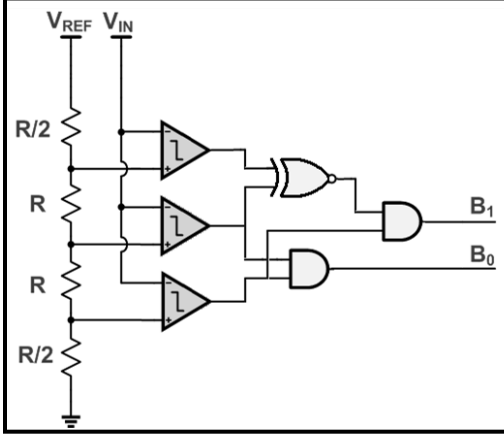
V_s = _____



V_s = _____

_____ / 20

30. Shown in the circuit diagram below is a 2-bit flash Analog-to-Digital Converter (ADC). Given that V_{REF} = 3.0 V, determine the following: [1] **(10 pts; 2, 4, 2, 2) (TB#6)**
    - Determine the Least Significant Bit (LSB) and Most Significant Bit (MSB). **(2 pts)**
    - Provide the binary outputs (B_1 and B_2) for each of the given input (V_{IN}) in the table below. **(4 pts)**
    - What is the resolution of the flash ADC shown below? **(2 pts)**
    - Most practical ADCs require 8-bits. How many comparators would be needed for an 8-bit flash ADC? **(2 pts)**



Circle one for each:

LSB = (B_1 || B_0)

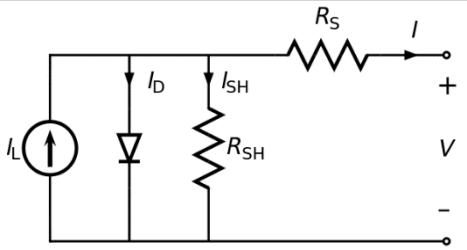
MSB = (B_1 || B_0)

Resolution = _____

Comparators needed = _____

V_{IN}	B_1	B_0
0 V		
1 V		
2 V		
3 V		

31. Solar cells can be modelled by the circuit shown in the diagram below. R_{SH} = 0.1 mΩ, R_S = 5.0 Ω, and I_D = 251 μA. Note that all of the elements in the circuit are operating under ideal conditions at room temperature (300 K). Perform the following: [3] **(8 pts; 2, 2, 4) (TB#7)**
    - Describe the purpose of the shunt resistor R_{SH} in the circuit. **(2 pts)**
    - Describe the purpose of the flyback diode in the circuit. **(2 pts)**
    - Suppose you attach an LED to the open terminals shown that requires 1.8 V to turn on. Will the LED turn on? Assume that the saturation current of the diode is 10^{-12} A. **(4 pts)**



R_{SH} : _____

_____

_____

Flyback Diode : _____

_____

_____

LED turns on? (Circle one): **(YES || NO)**

32. Briefly explain how light is created by an LED when a forward-biased voltage is applied. [1] **(4 pts)**

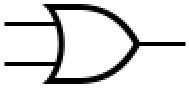
_____

_____

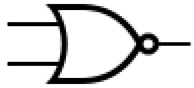
_____

_____ / 22

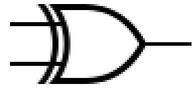
33. Complete the truth table for each logic gate shown. [1] **(8 pts; ½ pt each)**



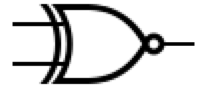
A	B	**Q**
0	0	
1	0	
0	1	
1	1	



A	B	**Q**
0	0	
1	0	
0	1	
1	1	



A	B	**Q**
0	0	
1	0	
0	1	
1	1	



A	B	**Q**
0	0	
1	0	
0	1	
1	1	

34. Draw logic circuits for the following expressions. Label all inputs and outputs. [1] **(12 pts; 4, 8) (TB#8)**

$\boldsymbol{Q = (A + B)C}$

$\boldsymbol{Q = \overline{(A + B)}(C + D)\overline{C}}$

35. Bipolar Junction Transistors (BJTs) can be operated in cutoff mode, saturation mode, and active mode. Describe the flow of current, biasing of p-n junctions, and the function for each of the three modes. **(9 pts)**

LAB 1 (Circuit Diagnostics): At this station, you will analyze two circuits, determine the problem with each, and propose a solution to fix them. [1] **(41 pts total)**

36. **Circuit 1** is a voltage divider designed to reduce the 5V input to a 3.3V output at the terminal indicated "OUTPUT", however the current output votage is out of the acceptable range. Perform the following: [1] **(18 pts)**
    - **(A) Draw** the provided voltage divider circuit and calculate the theoretical output. **(6 pts; 4, 2)**
    - **(B, C) Draw up to 2 unique** voltage dividers **using values representative of the provided resistors** that produce an output within 10% of 3.3V. Calculate each theoretical output voltage. Provide your answers to 3 significant figures. **(12 pts; 6, 6)**

A	B	C
V_{OUT} = _____	V_{OUT} = _____	V_{OUT} = _____

37. **Circuits 2** is designed to power an LED according to its datasheet, however the LED is currently not operating optimally. Perform the following: [1] **(23 pts; 4, 6, 8, 5)**
    - **Calculate** the optimal current-limiting resistance for the circuit. The LED has a 20. mA forward current and 2.0 V forward voltage. **(4 pts)**
    - **Draw** the corrected circuit. Label all components. **(6 pts)**
    - **Construct** the corrected circuit and **call over a procter** to verify. **(8 pts)**
    - Would your circuit be different if the LED color was different? **Explain**. **(5 pts)**

Circuit 2: Corrected

R = _____

Proctor Initials = _____

_____

_____

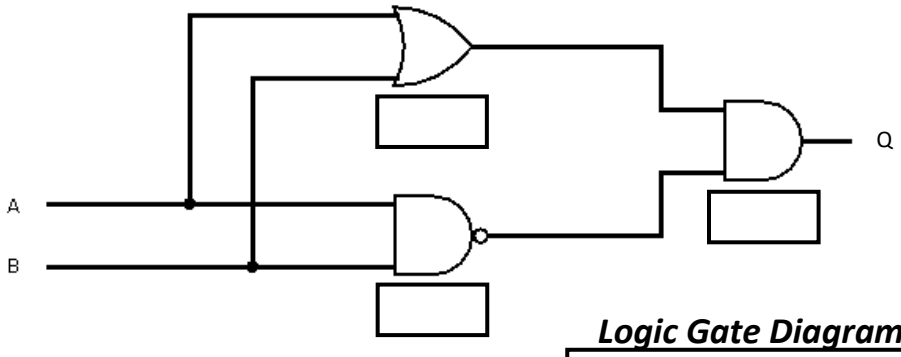
_____

_____

_____ / 41

LAB 2 (Electrical Control): At this station, you will **analyze** and **construct** a circuit. Below these instructions is an image of a digital logic gate. Provided at this station is a breadboard and the necessary components for you to build the logic gate circuit. [1] **(34 pts total) (TB#9)**

38. **[Analysis]** Perform the following for the digital logic diagram pictured: [1] **(12 pts)**
    - **Label** the three logic gates. **(3 pts)**
    - **Complete a truth table** for the circuit using the template provided. **(4 pts)**
    - The three logic gates that compose this circuit can be replace with a single logic gate. **Name** that gate. **(2 pts)**
    - **Draw** the single logic gate that can replace this circuit. Label A, B, and Q. **(3 pts)**



Logic Gate Diagram

Logic Gate Name: _____

A	B	**Q**
0	0	
1	0	
0	1	
1	1	

39. **[Construction]** Using the components provided, build a digital logic circuit that obeys the truth table pictured above. There are many solutions to this problem; you will receive full credit as long as your circuit meets the criteria specified below. Individual gates do not need to be represented. **Call over a proctor to verify your circuit functions correctly before time is up. (22 pts)**
    - The circuit has the correct output for all combinations of input A and B. **(12 pts)**
    - NPN transistors and resistors are used correctly. **(4 pts)**
    - Push buttons comprise inputs A and B. **(4 pts)**
    - An LED is used to represent the output. **(2 pts)**

Proctor Initials = _____

____ / 34