November, 2019

NEW TRIER & BOCA RATON TRYOUT

Circuit Lab C

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Directions:

1. This test is separable. Only marks within the designated boxes will be scored.
2. Work is not required; however, incorrect solutions are eligible for partial credit.
3. Full credit necessitates correct significant figures and units.
4. Each team will have 10 minutes to complete the practical section. Proctors will invite competitors at designated times. Replacement parts will not be given.

Team Number: N/A

Team Name: Exam Key

Team Members: Kevin Hao, Asher Noel

Score:	
Rank:	

Good Luck!

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Note:
This page is for administrative use. No competitor action is required.

Page Number	Possible Score	Test Score
2	24	
3	32	
4	28	
5	36	
6	32	
7	22	
8	24	
9	26	
Lab	60	
Total	274	

Note: there are various issues with this exam regarding question distributions and relevance to the rules.

Author Statement:
This exam was written for the benefit of the Science Olympiad community. To ensure that neither of the test writers' alma maters gain an unfair advantage, they will release the exam immediately after its administration on the scioly.org test exchange.

Fill in the blank: Identify the last name of the individual associated with the following epithets:[2] **(1 point each)**

1. Killed an elephant. Edison
2. Flew a kite in a thunderstorm Richmann
3. FSolved equations; exclaimed: "and then there was light!" Maxwell
4. Thought his work had "no practical applications!" Hertz
5. Showed that $Q \propto V$ for capacitors. Volta
6. Experimentally supported Maxwell years before Hertz. Rowland
7. Born in 1816 and died in 1892. Siemens
8. Invented the Bunsen Burner. Faraday
9. Published "On the Attractive force of Electric Fire." Volta
10. Only major 18th century female contributor to the field. Nobody

Multiple Choice: Select the best answer for the following questions:[2] **(2 points each)**

11. What is the best technique to reduce radiation above 200 Ghz?

    [D] A. Twisted Pairs B. Coaxial Cables C. Waveguides D. Fiber Optics

12. What is the standard RMS voltage and frequency in Vanuatu?

    [D] A. 120V, 60Hz B. 180V, 50Hz C. 200V, 50Hz D. 220V, 50Hz

13. How many deaths were due to Electrocution in 1993 in the US?

    [B] A. 150 B. 550 C. 850 D. 1050

14. Which multiway switching system was prohibited in the US in 1923?

    [C] A. Traveler B. Alternative C. Carter D. Hao

15. How are Foucault currents minimized?

    [C] A. Autoclaving B. Resistance C. Lamination D. Powerwashing

16. Which side of a PN Junction has a negative charge?

    [A] A. Anode B. Cathode C. Neither D. Big Foot

17. What increases with temperature to increase the conductivity of semiconductors?

    [C] A. e^- mobility B. e^- energy C. # of mobile e^- D. e^- degeneracy

18. The skin effect (Increases/Decreases) power loss in (AC/DC) circuits.

[A] A. Increases, AC B. Decreases, AC C. Increases, DC D. Decreases, DC

19. What is the term for the dependence of the state of a system on its history

[C] A. Remembrance B. Markovity C. Hysteresis D. Coercivity

20. What is the approximate value of the relative permeability for iron cores?

[D] A. 1 B. 14 C. 153 D. 209

21. What is the degree of the time term in the SI units of the henry?

[C] A. 0 B. -1 C. -2 D. -3

22. What are the SI units for the proton magnetic moment?

[B] A. T B. J/T C. C T D. C/T

23. In a different universe, the vacuum permeability and permittivity are both eight times their value in our universe. If Maxwell's theories hold, what is the speed of light?

[D] A. c/8 B. c/64 C. c/512 D. c/4096

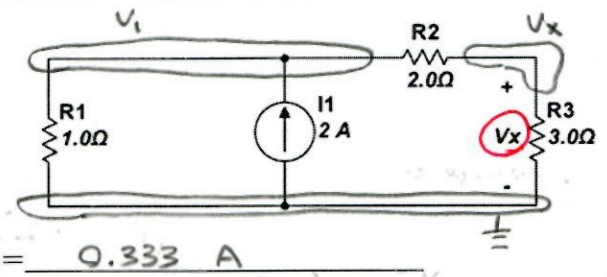
24. Determine the voltage V_{R3} and current I_{R3} across R_3. Provide your answer to 3 significant figures. [1] **(8 pts; 4, 4)**

Fix Variables

$\frac{V_1}{1} - 2 + \frac{V_1 - V_x}{2} = 0$ $\quad V_1 = 1.\overline{6}$ V

$\frac{V_x - V_1}{2} + \frac{V_x}{3} = 0$ $\quad V_x = 1.0$ V

$I_{R3} = \frac{V_x}{R_3} = \frac{1.0}{3.0} = 0.\overline{3}$ A



V_{R3} = 1.00 V I_{R3} = 0.333 A

25. Determine V_{R3} and I_{V1}. Then, draw the equivalent circuit with V_1, R_{eq}, labels, and values.[1] **(12 pts; 4, 4, 4)**

$R_1 \| R_2 = \left(\frac{1}{R_1} + \frac{1}{R_2}\right)^{-1} = \left(\frac{1}{6} + \frac{1}{12}\right)^{-1} = 4\Omega$

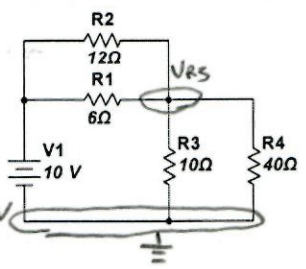
$R_3 \| R_4 = \left(\frac{1}{R_3} + \frac{1}{R_4}\right)^{-1} = \left(\frac{1}{10} + \frac{1}{40}\right)^{-1} = 8\Omega$

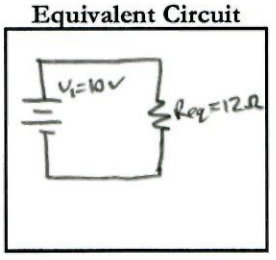
$R_{eq} = 4 + 8 = 12\Omega$

$V_{R3} = V_{R4}$

$\frac{V_{R3} - 10}{6} + \frac{V_{R3} - 10}{12} + \frac{V_{R3}}{10} + \frac{V_{R3}}{40} = 0$ $\quad V_{R3} = 6.\overline{6}$ V

$I_{V1} = \frac{10\text{V}}{12\Omega} = 0.8\overline{3}$ A



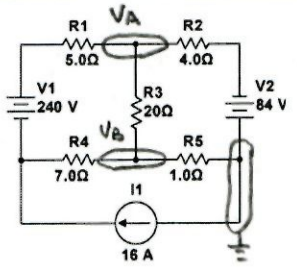


V_{R3} = 6.67 V I_{V1} = 0.833 A

26. Determine V_{R3} and the power P_{R1+R2}. Provide your answer to 3 significant figures.[2] **(12 pts; 6, 6)**

Using Superposition

(+2) $V_{01} = 60\ V$
(+2) $V_{02} = -50.4\ V$ } Sum
(+2) $V_{03} = 18.4\ V$

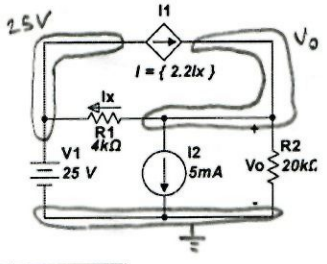


$V_{R3} =$ 28.0 V (+6) $P_{R1+R2} =$ Not scored

27. Determine the current (I_X) through the resistor R1 and the voltage (V_O) across the resistor R2. Provide your answers to 3 significant figures. [1] **(8 pts; 4, 4)**

$\frac{V_o}{20{,}000} + 0.005 + \frac{V_o - 25}{4{,}000} - 2.2I_x = 0$ } $V_o = 50\ V$

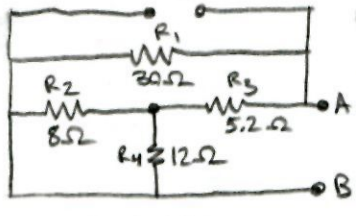
$I_x = \frac{V_o - 25}{4{,}000}$ } $I_x = 6.25\ mA$



$I_X =$ 6.25 mA $V_O =$ 50.0 V

28. Draw the Thévenin equivalent circuit with respect to the terminals A and B in the circuit below. Provide your answers to 3 significant figures. [1] **(8 pts)**

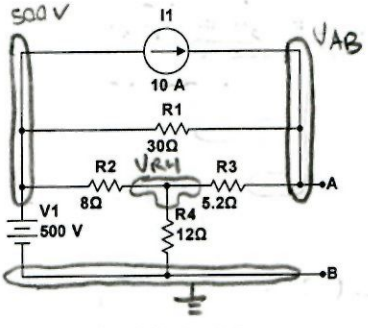
R_{TH}: Voltage sources shorted, current sources open



$R_2 \| R_4 = \left(\frac{1}{8} + \frac{1}{12}\right)^{-1} = 4.8\Omega$

$R_3 - (R_2 \| R_4) = 5.2 + 4.8 = 10\ \Omega$

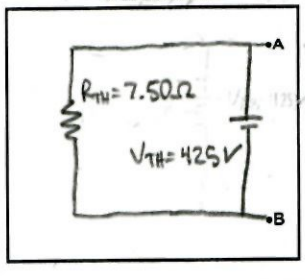
$R_{TH} = \left(\frac{1}{30} + \frac{1}{10}\right)^{-1} = 7.5\Omega$



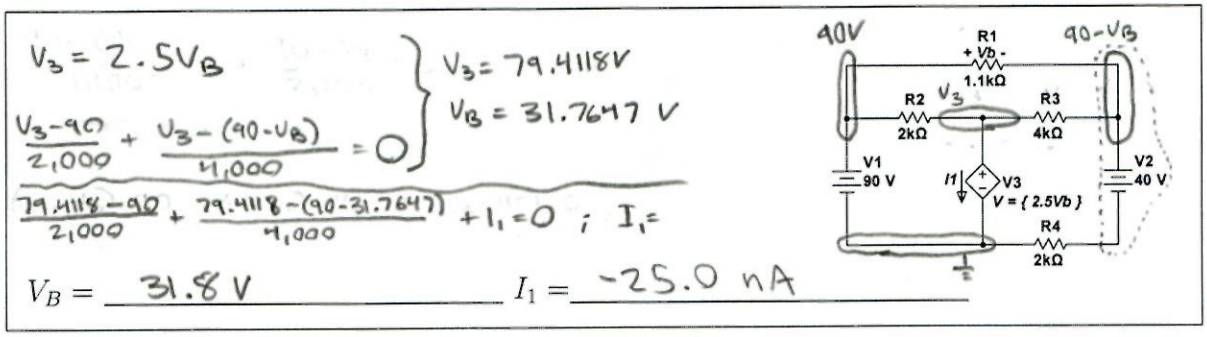
$\frac{V_{AB} - 500}{30} + \frac{V_{AB} - V_{R4}}{5.2} - 10 = 0$ } $V_{AB} = 425V$

$\frac{V_{R4} - 500}{8} + \frac{V_{R4}}{12} + \frac{V_{R4} - V_{AB}}{5.2} = 0$ } $V_{R4} = 360V$

Thévenin



29. Determine the voltage V_b across resistor R1 and the current I_1 through the dependent source in the circuit below. Provide your answer to 3 significant figures.[1] **(12 pts; 6, 6)**



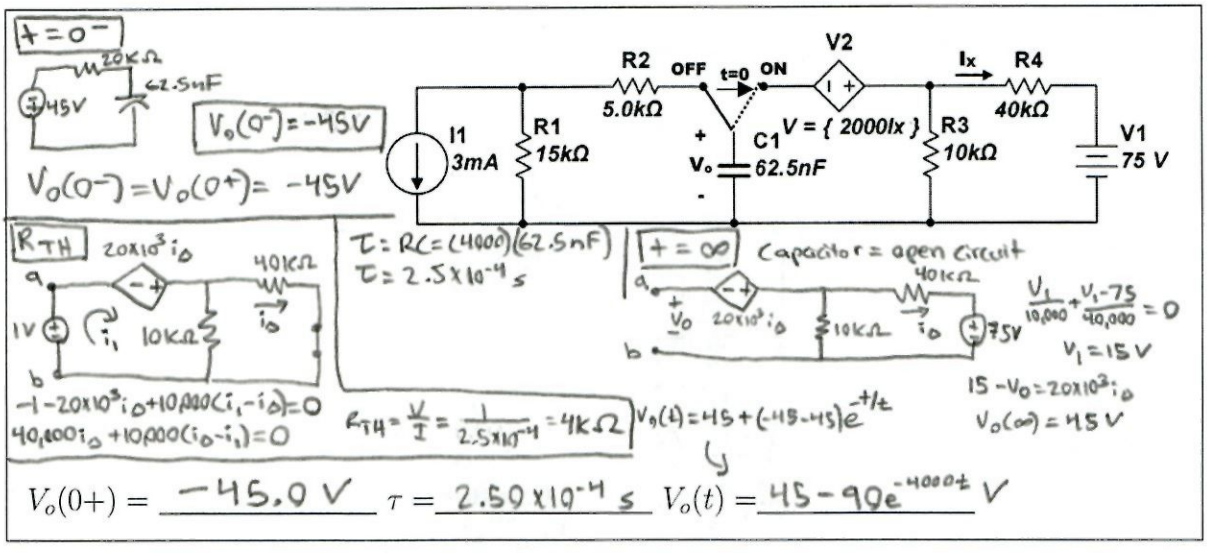
$V_3 = 2.5V_B$

$\frac{V_3-90}{2{,}000} + \frac{V_3-(90-V_B)}{4{,}000} = 0$ → $V_3 = 79.4118$ V, $V_B = 31.7647$ V

$\frac{79.4118-90}{2{,}000} + \frac{79.4118-(90-31.7647)}{4{,}000} + I_1 = 0$; $I_1 =$

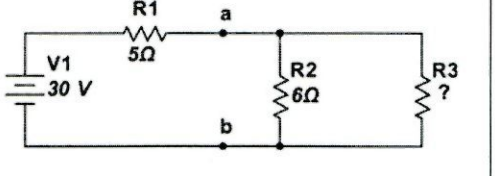
$V_B =$ 31.8 V $I_1 =$ −25.0 nA

30. The switch in the circuit shown has been in the OFF position for a long time. At $t = 0$, the switch moves instantaneously to the ON position. Determine the voltage across the capacitor after the switch has moved to the ON position $V_o(0+)$), the time constant of the capacitor τ for $t \geq 0$, and the voltage across the capacitor $V_o(t)$ for $t \geq 0$. [1] **(18 pts; 4, 4, 10)**



$V_o(0+) =$ −45.0 V $\tau =$ 2.50x10⁻⁴ s $V_o(t) =$ $45 - 90e^{-4000t}$ V

31. Find the value of the unknown resistance that will result in the maximum power dissipation for the elements connected between nodes a and b.[1] **(6 pts)**



Max power dissipation occurs when

$R_{AB} = R_1$

$5 = \left(\frac{1}{6} + \frac{1}{R_3}\right)^{-1}$

$R_3 = 30\,\Omega$

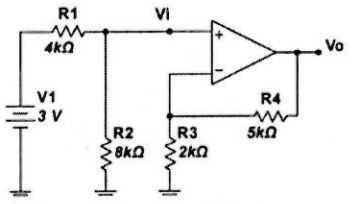
$R_3 =$ 30.0 Ω

32. Determine V_i and V_o. Provide your answer to 3 significant figures[2] **(8 pts; 4, 4)**

$V_i = 3\left(\frac{8}{4+8}\right) = 2V$

$2 = V_o\left(\frac{2}{2+5}\right)$

$V_o = 7V$



$V_i =$ 2.00 V $V_o =$ 7.00 V

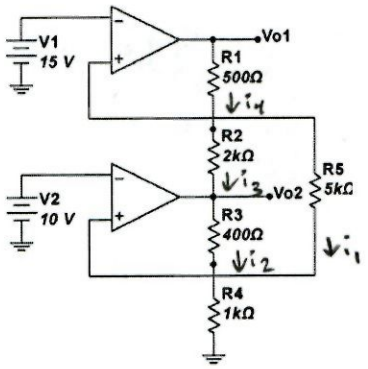
33. Determine V_{o1} and V_{o2}. Provide your answer to 3 significant figures.[2] **(12 pts; 6, 6)**

$i_1 = 15mA$

$i_2 = 9mA$

$i_3 = 0.7mA$

$i_4 = 1.7mA$



$V_{o1} =$ 15.9 V $V_{o2} =$ 13.6 V

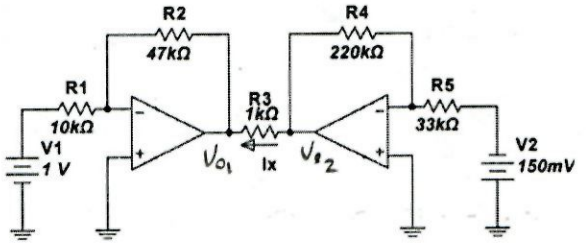
34. Determine the current through R3 (I_x) and the necessary value of the left voltage source (V_1) for which $I_x = 0$. Provide your answer to 3 significant figures. [2] **(12 pts; 6, 6)**

$V_{o1} = -4.7\ V$

$V_{o2} = 1.0\ V$

$I_x = \frac{1.0 - -4.7}{1000} = 5.7mA$

*For $I_x = 0$, $V_{o1} = V_{o2} = 1.0\ V$



$I_X =$ 5.70 mA $V_1 =$ −2.13 mV

35. Consider a point charge $2q$ located at the origin and a point charge $-q$ located at $x = a$ with a >0. Refer to the diagram below to answer the following questions.[2] **(12 pts; 3, 3, 3, 3)**

(a) Where would we need to put a point charge Q in order for the total force on Q to be zero?

(b) What is the work done on Q in order to place the charge at this location?

(c) What is the assembling energy, U, for this configuration of charges?

(d) What value of Q is needed to make the force on each charge equal to 0? Use only your expression for U.

a.) $(2+\sqrt{2})a = 3.41a$

b.) $W = (3-2\sqrt{2})\frac{kqQ}{a} = 0.17\frac{kqQ}{a}$

c.) $U = \frac{kq}{a}\left[(3-2\sqrt{2})Q - 2q\right]$

d.) $Q = 2(3+2\sqrt{2})q$

36. A thin wire with uniform linear charge density λ_1 lies along the z axis. An infinite conducting cylinder with uniform linear charge density λ_2 has its axis of symmetry aligned with the z axis. The inner and outer radii of the cylinder are a and b respectively. A second infinite conducting cylinder with uniform linear charge density λ_3 also has its axis of symmetry along the z axis. Its inner and outer radii are c and d with c >b. Find the electric field $E(r)$ everywhere in terms of $\lambda_1, \lambda_2, \lambda_3$, r, and any relevant physical constants.[2] **(10 pts)**

$r<a: E(r) = \frac{\lambda_1}{2\pi\varepsilon_0 r}$

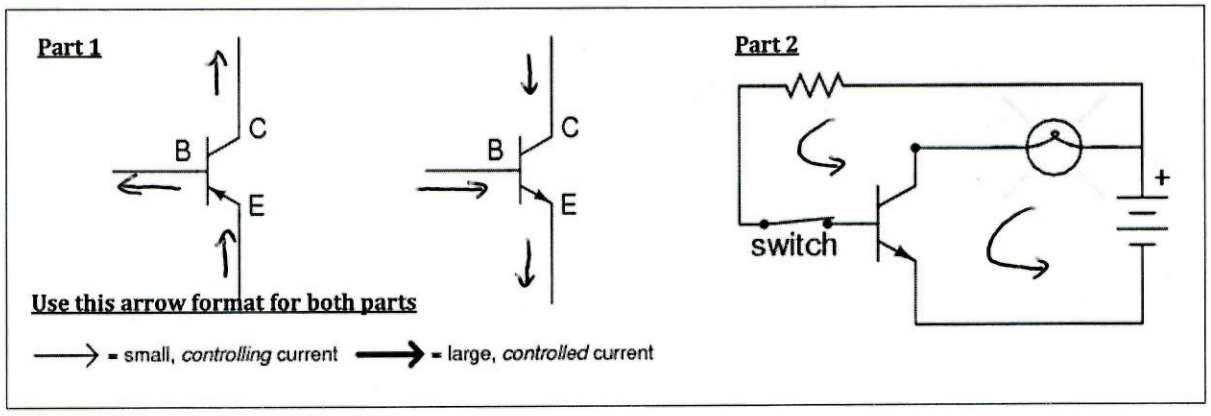
$a<r<b: E(r) = 0$

$b<r<c: E(r) = \frac{\lambda_1+\lambda_2}{2\pi\varepsilon_0 r}$

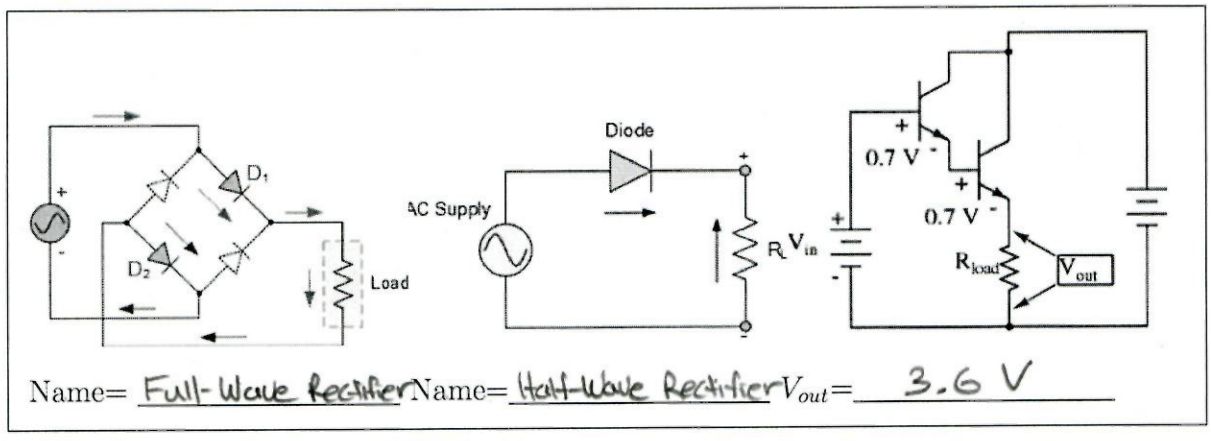
$c<r<d: E(r) = 0$

$r>d: E(r) = \frac{\lambda_1+\lambda_2+\lambda_3}{2\pi\varepsilon_0 r}$

37. Part 1: Show the direction of current travel at each terminal by drawing arrows pointing towards or away from each of the terminals in the PNP and NPN transistor diagrams provided below. There should be a total of 8 arrows drawn, 4 on each schematic. Answer the questions. Part 2: Show the direction of current travel in each of the 2 loops. This can be accomplished with a minimum of 2 arrows, but you will not be penalized for using more. [1] **(12 pts; 8, 4)**



38. Identify the name of the first two circuits; find V_{out} given $V_{in} = 5.0V$.[1] **(8 pts; 2, 2, 4)**



Name= Full-Wave Rectifier Name= Half-Wave Rectifier V_{out}= 3.6 V

39. What are two properties of the combinatorial gate abstraction?[2] **(4 pts; 2, 2)**

- Outputs are a function of inputs alone
- The static discipline is satisfied

40. Simplify the following Boolean expressions.[2] **(6 pts; 2, 2, 2)**

Unsimplified A = $(x + z)(\bar{x} + y)(z + y)$

Unsimplified B = $\bar{w}\overline{(wxyz)}$

Unsimplified C = $(a\bar{d})(\bar{b}c)(c\bar{d})$

$A =$ $Xy + \bar{X}z$ $B =$ $\bar{W}$ $C =$ $a\bar{b}c\bar{d}$

41. Given $\overline{a}cd + abc\overline{d}$,

(a) Create a truth table

(b) Create a Karnaugh map with correct loops

(c) Find the equivalent minimum product of sums expression
Credit: MIT 6.111

[2] **(20 pts; 6,10,4)**

a	b	c	d	Q
X				0
	X			0
		X		0
			X	1
X	X			0
X		X		0
X			X	0
	X	X		0
	X		X	1
		X	X	0
X	X	X		1
X	X		X	0
X		X	X	0
	X	X	X	0
X	X	X	X	0

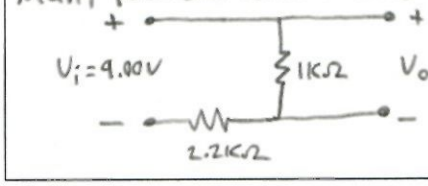
CD \ AB	00	01	11	10
00	0	0	0	0
01	1	1	0	0
11	0	0	0	0
10	0	0	1	0

Equivalent Minimum Product of Sums= $(c+d)(\bar{a}+b)(\bar{a}+\bar{d})(a+z)$ OR $(c+d)(d+b)(\bar{a}+\bar{d})(a+z)$

Hands-On Task Practice: For the following questions, your circuit diagrams and calculations MUST be composed of components that are provided (e.g., use the resistor values provided). You will have 10 minutes to complete the questions in this section.

42. Draw a simple circuit diagram such that its input is about 9 V (V_i) and output is about 3 V (within +/- 10%). Calculate its theoretical output voltage (V_o). Provide your answer to 3 significant figures. HINT: Your answer should NOT be 3.00 V.[1] **(10 pts)**

Many possible circuit diagram solutions



$V_o = 9\left(\frac{1}{3.2}\right) = 2.8125\,V$

Note: This answer will vary depending upon the components provided.

Theoretical V_0 = Varies, V_o = 2.81 V

43. Construct the circuit from Q42. Record V_i and V_o to 3 significant figures. [1] **(10 pts; 5,5)**

V_i = Varies V_o = Varies

44. Determine the resistance and tolerance of the following theoretical resistors. You should be able to do each of these in seconds.[2] **(20 pts; 1 pt. each)**

A	Red-Orange-Yellow-Brown-Red	F	Violet-Blue-Pink-Violet
B	Orange-Grey-White-Green	G	White-Black-White-Silver
C	Blue-Yellow-Gold-Blue	H	Red-Green-Blue-Gold
D	Purple-Blue-White	I	Red-Orange-Yellow-Brown
E	Brown-Brown-Brown-Brown-Brown	J	Blue-Violet-Grey-Brown

	Resistance	Tolerance		Resistance	Tolerance
A	234e1 Ω	2 %	F	76e-3	0.1 %
B	38e9	0.5 %	G	90e9	5 %
C	64e-1	0.25 %	H	256	10 %
D	76e9	NA	I	234	1 %
E	111e1	1 %	J	678	1 %

45. Sketch a possible schematic diagram for the following breadboard configuration with correct resistor values and a 10 uF capacitor.[2] **(20 pts)**