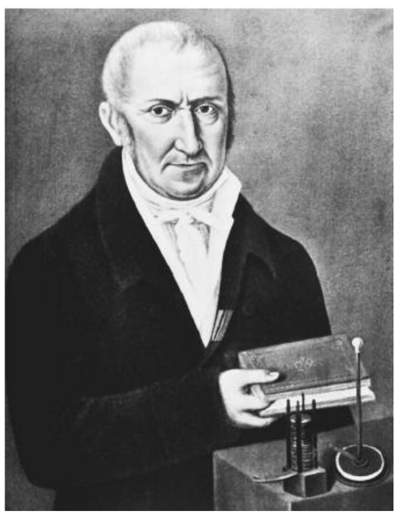
PENNSYLVANIA SCIENCE OLYMPIAD

STATE FINALS 2007

CIRCUIT LAB C DIVISION

APRIL 27, 2007

JUNIATA COLLEGE



SCHOOL NAME_______________________________ **SCHOOL CODE**____________

INSTRUCTIONS

1. Turn in all exam materials at the end of this event. *Missing exam materials will result in immediate disqualification of the team in question*. There is an exam packet and a blank answer sheet. There is also scrap paper for your calculations, should you need it; turn it in as well.

2. You may separate the exam pages. Re-staple them as you submit your materials to the supervisor. Keep the answer sheet and scrap paper separate.

3. *Only* the answers provided on the answer page will be considered. Do not write outside the designated spaces for each answer. Write LEGIBLY. Include standard SI units.

4. Write your school name and school code in the appropriate locations on the answer sheet as well as on the title page. Indicate the names of the participants at the bottom of the answer sheet. Write LEGIBLY.

5. Point values for each question are in parentheses. Proper SI units typically are worth a single point. The five tiebreaker questions are identified with a number indicating the first, second, third, etc. They do not appear in numerical order. *Tiebreaker questions count toward the overall grade, and are only used as tiebreakers in the event of a tie.*

6. When the time is up, *the time is up*. Continuing to write after the time is up risks immediate disqualification.

7. There is an image of a serious-looking fellow on the title page. Who is he and what is his connection to this event? Put the answer in the "Bonus" box on the answer sheet for 5 bonus points.

8. NON-PROGRAMMABLE CALCULATORS ONLY. DON'T ASK, THE ANSWER IS NO.

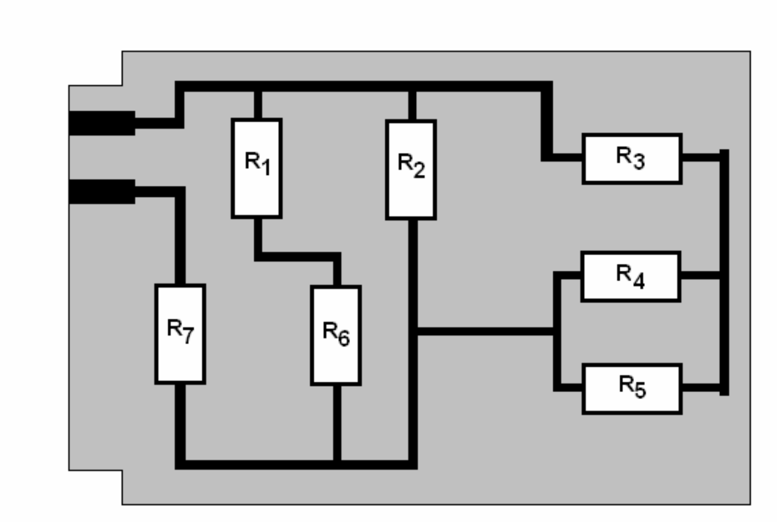
9. Nonsensical, mocking, or inappropriate answers WILL RESULT IN DISQUALIFICATION.

10. Use this table for the resistance of color-coded resistors.

COLOR	1st stripe 1st digit	2nd stripe 2nd digit	3rd stripe multiplier
Black	0	0	X 1
Brown	1	1	X 10
Red	2	2	X 100
Orange	3	3	X 1000
Yellow	4	4	X 10000
Green	5	5	X 100000
Blue	6	6	X 1000000
Violet	7	7	
Grey	8	8	
White	9	9	

SECTION 1

The image below shows a circuit consisting of 7 color-coded resistors on a PC board. You may ignore the tolerance values (that is, the three stripes indicate the *actual* resistance). The three colored stripes are listed in the table. The leads will be connected to a 75.0 volt DC power source.



RESISITOR	STRIPE COLORS
R_1	red violet black
R_2	yellow brown black
R_3	brown orange brown
R_4	black green black
R_5	brown green black
R_6	red brown red
R_7	orange yellow black

(21) 1. List the resistance of each resistor and solve for the theoretical current and voltage drop for each resistor in the circuit. Assume the voltage source is ideal.

(3) 2. What is the equivalent resistance of R_4 and R_5?

(3) 3. What is the equivalent resistance of R_3, R_4, and R_5?

(3) 4. What is the equivalent resistance of the entire circuit?

(3) 5. What is the power dissipated by R_2?

(2) 6. If R_6 is shorted, will the total current through the battery increase, decrease, or remain the same?

(2) 7. If R_4 is opened, will the total current through the battery increase, decrease, or remain the same?

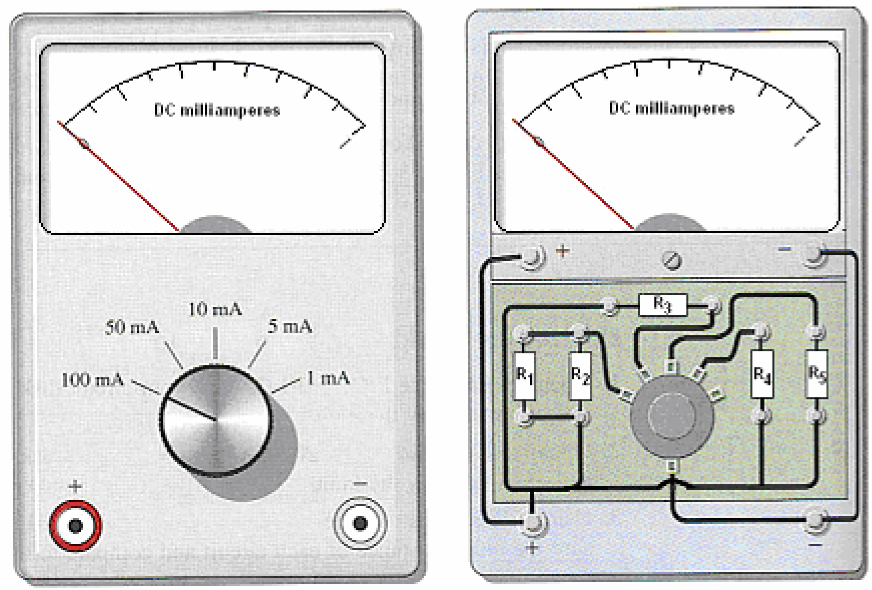
The current through R_7 is *experimentally* determined to be 927 mA. The voltage drop across R_2 is experimentally determined to be 28.7 volts.

(3) 8. What is the internal resistance of the battery?

(3) 9. (Tiebreaker 5) What is the terminal voltage of the battery?

SECTION 2

A variable-range ammeter is shown below. The galvanometer itself has a resistance of 500 Ω, and is intended to show a full-scale deflection when the current through the galvanometer is 1.00 mA. The view at right is the ammeter with the selector switch and the cover removed. R_1 and R_2 have the same value.



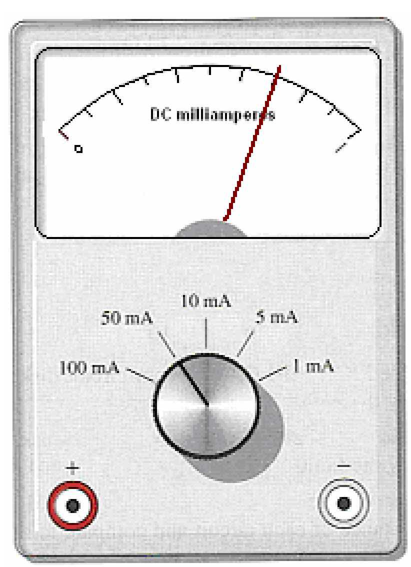
(10) 1. Solve for the values of each resistor, R_1 through R_5, such that the ranges displayed on the dial are accurate.

(2) 2. The ammeter measures a current of 4.25 mA on the 5 mA setting. Which resistor is the shunt resistor?

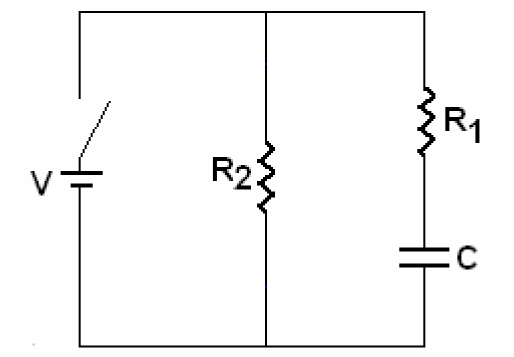
(3) 3. How much current goes through the shunt resistor in #2 above?

(3) 4. What is the equivalent resistance of the *entire ammeter* when the dial is on the 10 mA setting?

(3) 5. What current is being measured by the ammeter shown below?



SECTION 3



You are provided with the schematic diagram of a circuit consisting of an ideal battery (V = 20.0 volts), two resistors wired in parallel (R_1 = 150 Ω, R_2 = 250 Ω) and a capacitor (C = 12.5 milliFarads) in series with R_1 as shown. The switch is closed at time t = 0, and the capacitor is initially uncharged.

(3) 1. What is the time constant for this circuit with the switch closed?

(3) 2. What is the current through R_1 at t = 0?

(3) 3. What is the current through R_2 at t = 0?

(3) 4. What is the charge on the capacitor at t = ∞?

(3) 5. What is the current through R_1 at t = ∞?

(3) 6. What is the current through R_2 at t = ∞?

(3) 7. What is the voltage across the capacitor at t = ∞?

(3) 8. What is the voltage across the capacitor at t = 3.00 seconds?

(3) 9. What is the current through R_1 at t = 3.00 seconds?

(3) 10. How much energy is stored in the capacitor at t = 3.00 seconds?

(5) 11. (Tiebreaker 4) Construct the graph that shows the *total current produced by the battery* as a function of time.

After the capacitor has reached its full charge, the switch is opened (at t = 0).

(3) 12. What is time constant for this circuit with the switch open?

(3) 13. What is the current in the circuit at t = 0?

(3) 14. What is the voltage across R_1 at t = 3.00 seconds?

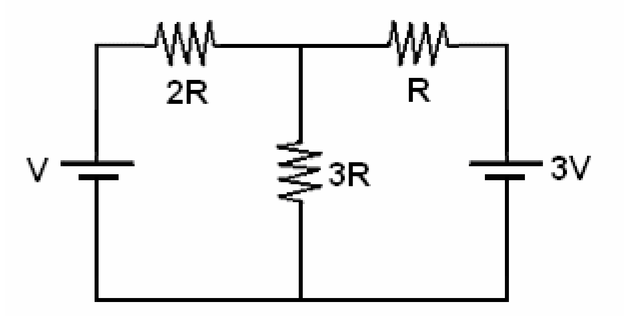
(3) 15. What is the charge on the capacitor at t = 3.00 seconds?

SECTION 4

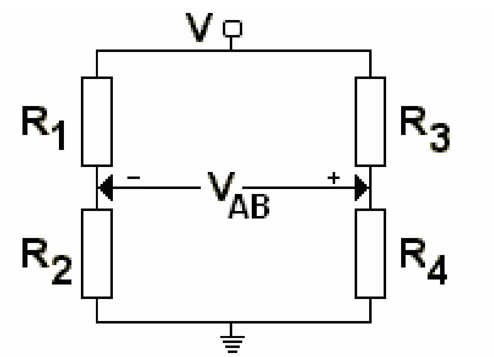
(18) 1. (Tiebreaker 3) The circuit shown below has two ideal voltage sources and three resistors arranged as shown. Solve for the current and voltage drop across each of the resistors in terms of R and V.

(3) 2. Indicate the direction of *conventional* current through 2R (right or left).

(3) 3. What is the power dissipated by resistor 3R in the circuit (in terms of V and R)?



(3) 4. (Tiebreaker 2) What is the value of R_4 in the bridge circuit shown below such that $V_{AB} = 0$?



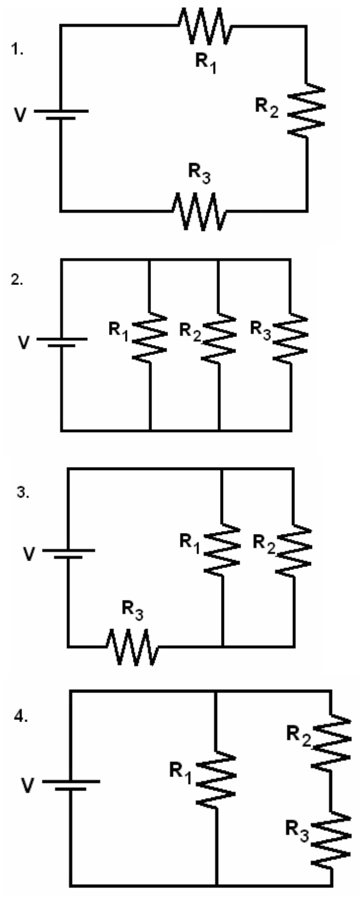
Resistor	Resistance, kΩ
R_1	13.5
R_2	40.2
R_3	21.7
R_4	

(24) 5 – 16. Match the terms listed in column 1 with the descriptions in column 2. Each description is used once.

5. Ampere	A. Potential drop is proportional to current
6. Battery	B. Also defined as Coulomb/Volt
7. Coulomb	C. Converts electromagnetic radiation into electrical energy
8. Coulomb's Law	D. Also defined as Joule/Coulomb
9. DC generator	E. Converts electrical energy into mechanical energy
10. DC motor	F. Electric potential energy per unit charge
11. EMF	G. Also defined as Coulomb/second
12. Farad	H. Converts chemical energy into electrical energy
13. Ohm's Law	I. Force is proportional to charge and inversely proportional to distance^2
14. Potential difference	J. SI units of charge
15. Solar cell	K. Converts mechanical energy into electrical energy
16. Volt	L. Any device that can establish a potential difference across a circuit

SECTION 5

(8) 1 – 4. For each of the circuits shown below, an ideal battery (voltage V) is wired with four different combinations of the same three resistors ($R_3 > R_2 > R_1$). The table contains two columns; the left column lists *relative* relationships among the voltage drops across each of the resistors, and the right column lists *relative* relationships among the currents through each of the resistors. For numbers 1 through 4, Select from the letters A – H regarding the voltage drops, and select from the letters J – Q regarding the currents, and list both letters on the answer sheet next to the number of the circuit to which they apply. Clearly, all the letters are *not* used. Each correct *letter* is worth 2 points.



Relative Voltage Drops	Relative Currents
A. $V_1 = V_2 = V_3$	J. $I_1 > I_2 > I_3$
B. $V_1 = V_3 > V_2$	K. $I_1 < I_2 < I_3$
C. $V_1 < V_2 < V_3$	L. $I_2 < I_1 < I_3$
D. $V_3 > V_2 = V_1$	M. $I_1 = I_2 > I_3$
E. $V_1 > V_2 > V_3$	N. $I_1 < I_2 = I_3$
F. $V_1 > V_3 > V_2$	O. $I_1 > I_2 = I_3$
G. $V_2 < V_3 = V_1$	P. $I_1 = I_2 < I_3$
H. $V_2 = V_3 > V_1$	Q. $I_1 = I_2 = I_3$

(4) 5. Rank the four circuits in order of descending equivalent resistance (highest first).

(4) 6. Rank the four circuits in order of descending total current (highest first).

(4) 7. Rank the four circuits in order of descending power dissipation (highest first).

(10) 8. (Tiebreaker 1) An infinite array of resistors is constructed as shown below. All individual resistors in the array have a value of R. Write an expression for the total resistance R_{eq}, measured between points A and B.