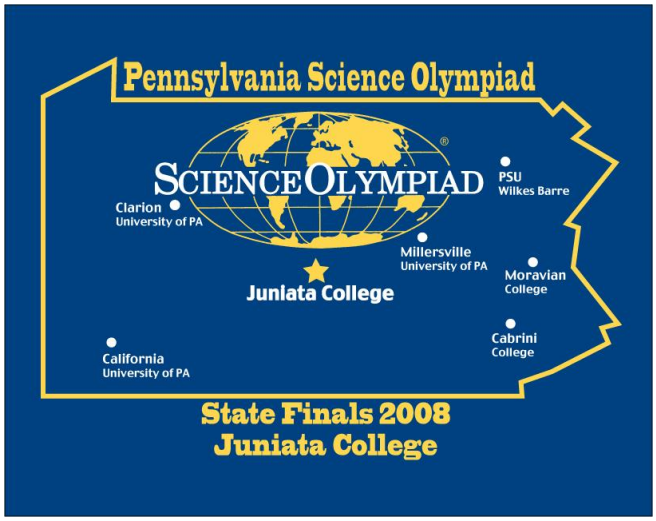
SCIENCE OLYMPIAD

Exploring the World of Science

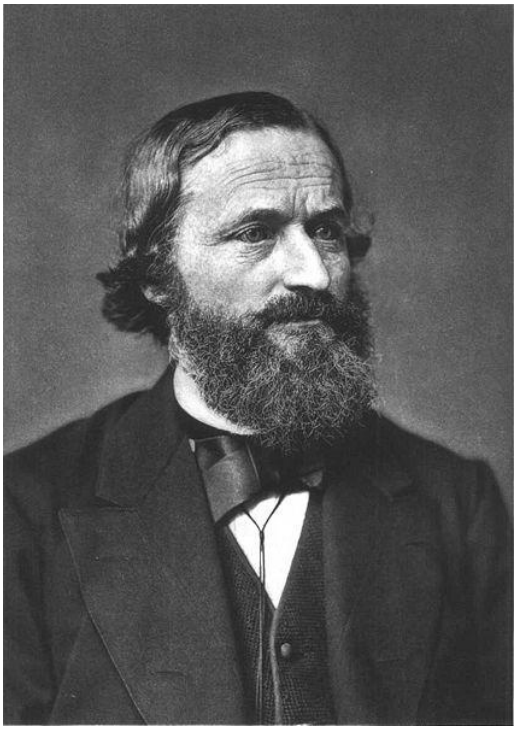



# PENNSYLVANIA SCIENCE OLYMPIAD
# STATE FINALS 2008

## CIRCUIT LAB C DIVISION

## APRIL 25, 2008

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.**

**2. You may separate the exam pages. Re-staple them as you submit your materials to the supervisor. Keep the answer sheet 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. Answers that can't be read can't be correct. Include units where applicable.**

**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. Tiebreaker questions are identified with a (T#) where the number indicates the sequence of consultation. In the event of a tie, the supervisor will first look at T1, then T2, etc. until the tie is broken. *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. Mocking, nonsensical, and/or inappropriate answers WILL RESULT IN DISQUALIFICATION.**

**8. Who is the gentleman pictured on the cover page, and what does he have to do with this event? Put your answer in the bonus box on the *back* of the answer sheet for 3 bonus points.**

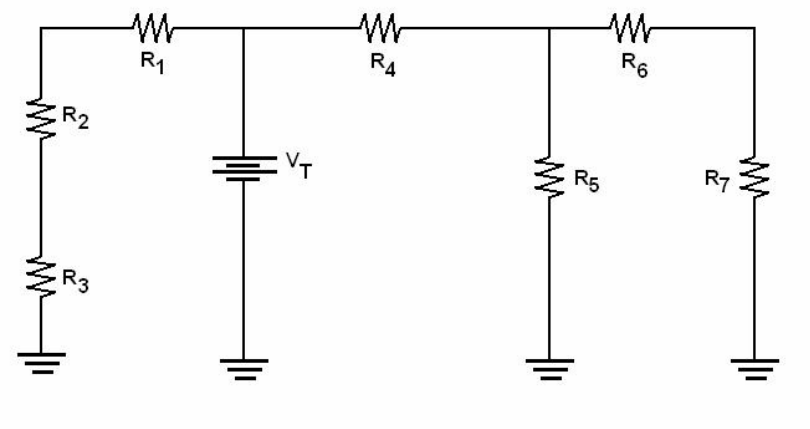
**9. NON-PROGRAMMABLE CALCULATORS ONLY. DON'T ASK, THE ANSWER IS NO.**

**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 schematic diagram below shows a circuit consisting of 7 color-coded resistors and an ideal voltage source ($V_T$ = 24 volts). You may ignore the tolerance values (that is, the three stripes indicate the *actual* resistance). The 1st three colored stripes on each resistor are listed in the table.**



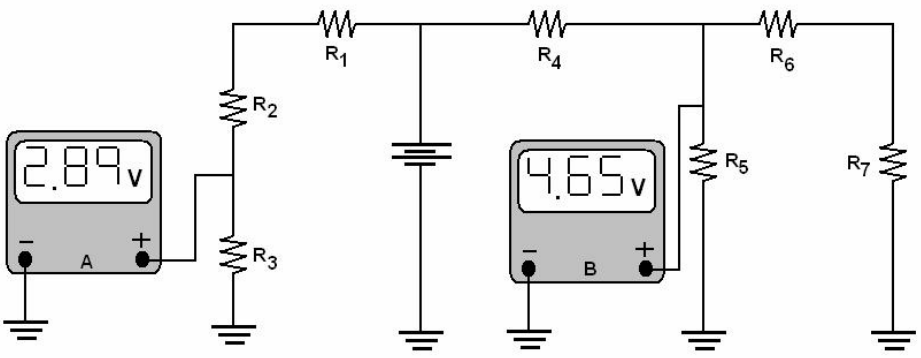

| | |
|---|---|
| $R_1$ | green green black |
| $R_2$ | brown grey black |
| $R_3$ | brown black black |
| $R_4$ | violet green black |
| $R_5$ | brown black brown |
| $R_6$ | brown green black |
| $R_7$ | red red black |

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

**(3) 2. What is the power dissipated by $R_5$?**

**(3) 3. How much energy is dissipated by $R_3$ over 5.00 seconds?**

**Now the circuit is constructed, and ideal voltmeters are used to measure the voltage drops across $R_3$ and $R_5$ as shown below.**



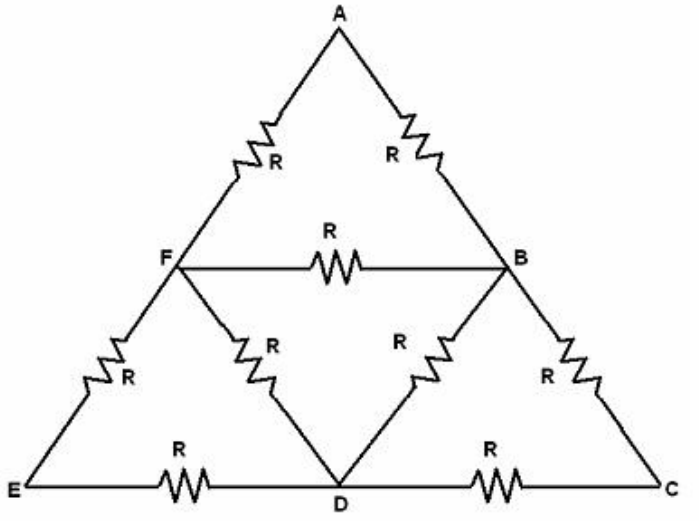

**(6) 4. (T6) The voltmeter readings indicate a problem in the circuit. Which resistor is the problem, and what is the nature of the problem?**

**(3) 5. If $R_2$ was open-circuited, what would the voltmeter across $R_3$ display?**

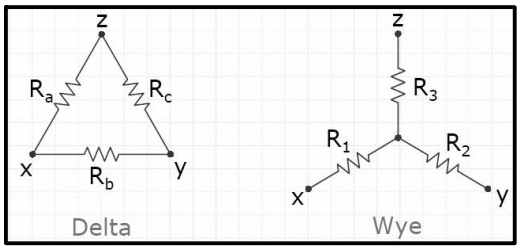
**(3) 6. If $R_2$ was short-circuited, what would the voltmeter across $R_3$ display?**

## SECTION 2

**The circuit shown below consists of 9 identical ideal resistors, each with a resistance of 10 Ω. Use this diagram for numbers 1-4.**




**HINT: Use the transformation equations shown below.**




**Delta-to-wye transformation equations**

$$R_1 = \left(\frac{R_a R_b}{R_a + R_b + R_c}\right)$$

$$R_2 = \left(\frac{R_b R_c}{R_a + R_b + R_c}\right)$$

$$R_3 = \left(\frac{R_c R_a}{R_a + R_b + R_c}\right)$$

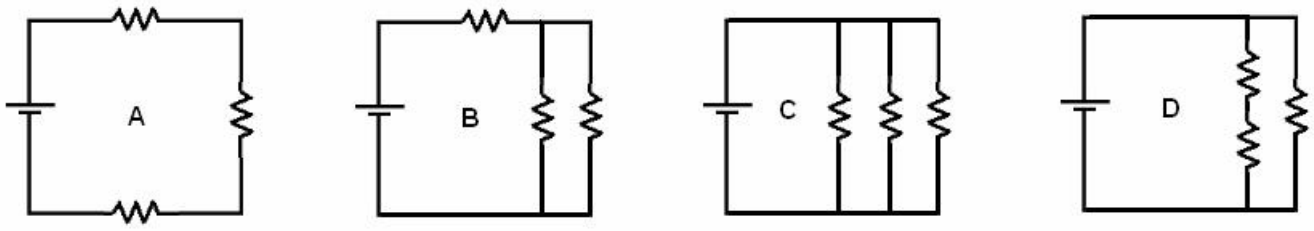
**(3) 1. What is the resistance across terminals A and F?**

**(3) 2. What is the resistance across terminals F and D?**

**(3) 3. What is the resistance across terminals F and B?**

**(3) 4. (T7) What is the resistance across terminals A and D?**

**The circuits shown below consist of three identical resistors (each with resistance R) and a battery (voltage V) with internal resistance $\frac{R}{3}$. Use these diagrams for numbers 5-14. Descending order means greatest first.**




**(4) 5. Rank the circuits in descending order in terms of the equivalent resistance of the circuit.**

**(2) 6. What is the equivalent resistance (including the battery) of circuit C in terms of R?**

**(4) 7. Rank the circuits in descending order in terms of the total current produced by the battery.**

**(2) 8. What is the total current produced by the battery in circuit B, in terms of V and R?**

**(4) 9. Rank the circuits in descending order in terms of the power supplied by the battery.**

**(2) 10. What is the power supplied by the battery in circuit D, in terms of V and R?**

**(4) 11. (T5) Rank the circuits in descending order in terms of the terminal voltage available to the circuit.**

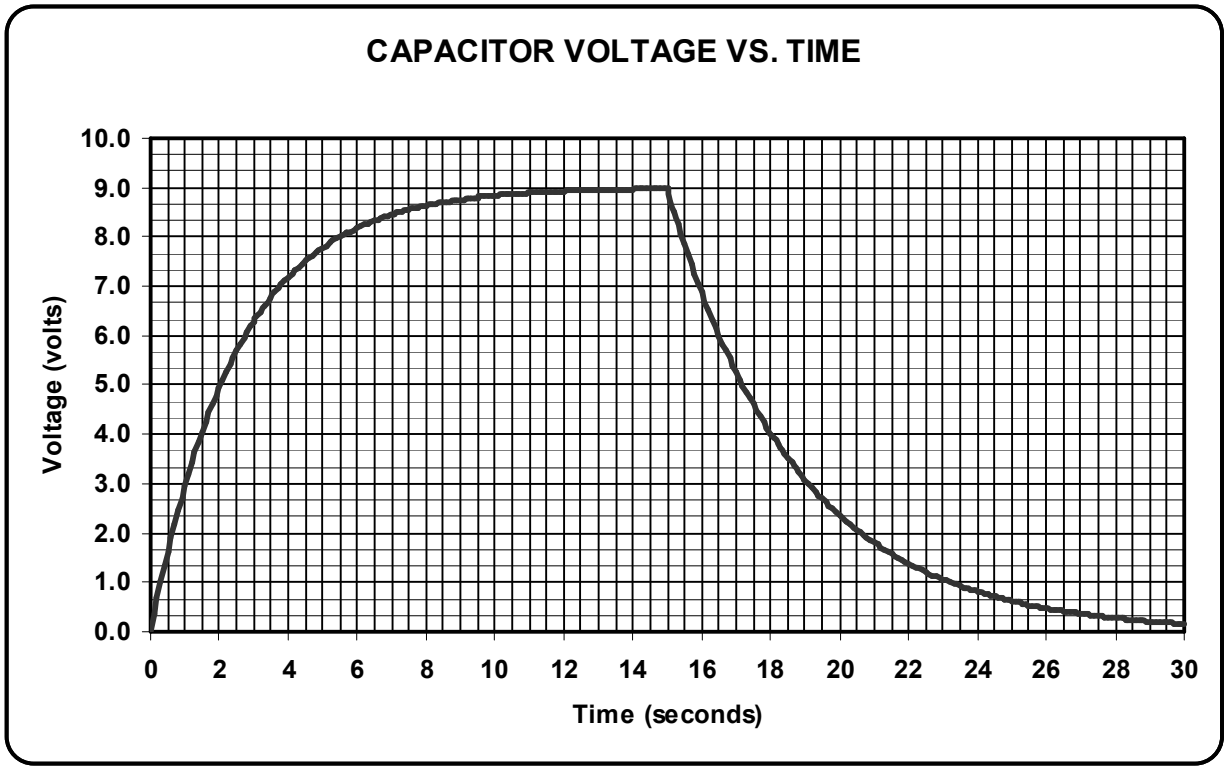
**(2) 12. What is the terminal voltage in circuit A, in terms of V?**

**(4) 13. Rank the circuits in descending order in terms of the voltage drop across the battery.**

**(2) 14. What is the voltage drop across the battery in circuit B, in terms of V?**

## SECTION 3

**The circuit shown schematically at below right contains an ideal battery, two ideal resistors, and an ideal capacitor (C = 250 μF). The switch is closed at time t = 0, and the voltage across the capacitor is recorded as a function of time, producing the graph shown below.**




**(2) 1. What is the voltage of the battery?**

**(3) 2. What is the time constant for this circuit when the switch is closed?**

**(3) 3. What is the time constant for this circuit when the switch is open?**

**(3) 4. What is the resistance of resistor $R_1$?**

**(3) 5. What is the resistance of resistor $R_2$?**

**(3) 6. What is the voltage across resistor $R_1$ at t = 2.0 seconds?**

**(3) 7. What is the voltage across resistor $R_2$ at t = 2.0 seconds?**

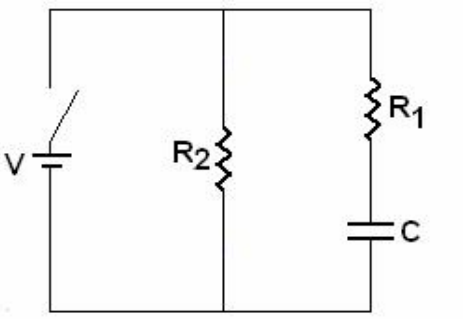
**(3) 8. What is the total current produced by the battery at t = 0?**

**(3) 9. What is the current through resistor $R_1$ at t = 5.0 seconds?**

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

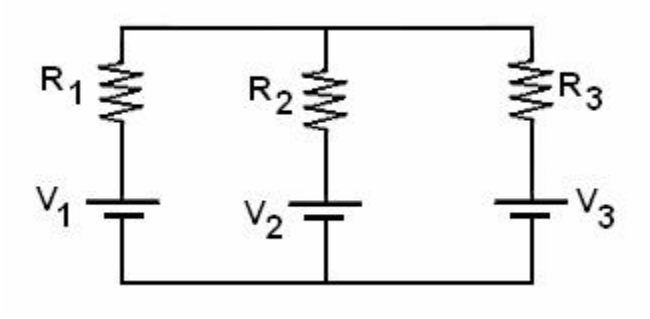
**(3) 11. When is the switch opened?**

**(6) 12. (T4) Sketch the graph (on the answer sheet) of the total current in the circuit as a function of time.**



## SECTION 4

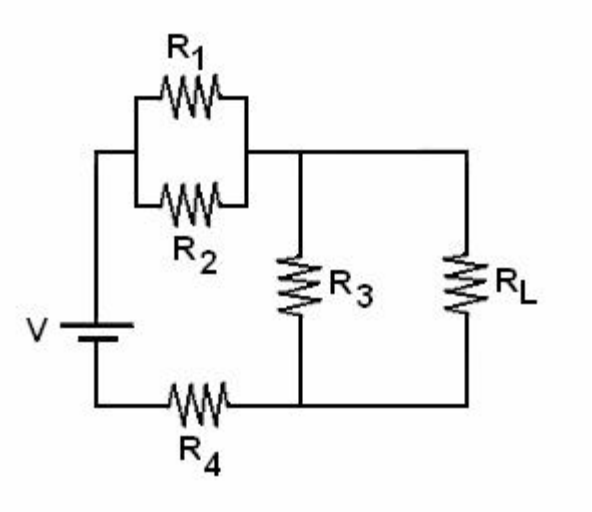
**(15) 1. (T2) The circuit shown below has three ideal voltage sources and three resistors arranged as shown. Solve for the current and voltage drop across each of the resistors, and include the direction of conventional current (up or down) through each resistor. The resistances $R_1$, $R_2$, and $R_3$ and voltages $V_1$, $V_2$, and $V_3$ are listed in the table.**




| VOLTAGES, V | |
|---|---|
| $V_1$ | 12 |
| $V_2$ | 6 |
| $V_3$ | 9 |

| RESISTANCES, Ω | |
|---|---|
| $R_1$ | 5 |
| $R_2$ | 10 |
| $R_3$ | 20 |

**Find the Thevenin equivalent circuit from the perspective of the load resistor $R_L$.**




| V | 110 | volts |
|---|---|---|
| $R_1$ | 16 | ohms |
| $R_2$ | 24 | ohms |
| $R_3$ | 50 | ohms |
| $R_4$ | 33 | ohms |

**(4) 2. What is the value of $V_{TH}$?**

**(4) 3. (T3) What is the value of $R_{TH}$?**

**(4) 4. Sketch the Thevenin equivalent circuit from the perspective of $R_L$ on the answer sheet.**

## SECTION 5

**List the units *in base SI* for each of the following quantities. For example, Force would be recorded as $\frac{kg\ m}{s^2}$.**

**(2) 1. Resistance**

**(2) 2. Power**

**(2) 3. Potential difference**

**(2) 4. Charge**

**(2) 5. Energy**

**(2) 6. Capacitance**

**(2) 7. Current**

**(2) 8. Electric field strength**

**(2) 9. Conductance**

**(2) 10. Electrostatic force**

**(10) 11. (T1) You have a circuit consisting of six identical light bulbs wired to a battery. You are unable to see the wiring, but each light bulb is capable of being unscrewed from its housing. When each bulb is unscrewed, it is no longer part of the circuit. The experimental results when each bulb is *separately* unscrewed from its housing are shown in the table below.**

| CONDITION | EXPERIMENTAL OBSERVATIONS |
|---|---|
| All bulbs functional | Bulb 1 is brightest; bulb 3 dimmer; bulbs 5 and 6 equal brightness and dimmer than 3; bulbs 2 and 4 equal brightness, but dimmer than 5 and 6 |
| bulb 1 removed | All bulbs dark |
| bulb 2 removed | Bulbs 1 and 3 equally bright; bulb 4 is dark; bulbs 5 and 6 equally bright but dimmer than 1 and 3 |
| bulb 3 removed | Bulbs 1, 2, and 4 are equally bright; bulbs 5 and 6 are equally bright and dimmer than the others |
| bulb 4 removed | Bulbs 1 and 3 equally bright; bulb 2 is dark; bulbs 5 and 6 equally bright but dimmer than 1 and 3 |
| bulb 5 removed | Bulbs 1 and 6 equally bright; bulb 3 dimmer; bulbs 2 and 4 equally bright but dimmer than 3 |
| bulb 6 removed | Bulbs 1 and 5 equally bright; bulb 3 dimmer; bulbs 2 and 4 equally bright but dimmer than 3 |

**On the back of the answer sheet, indicate the wiring of the circuit by drawing in the proper connections.**