Circuit Lab Test

School Name:

Competitor Names:

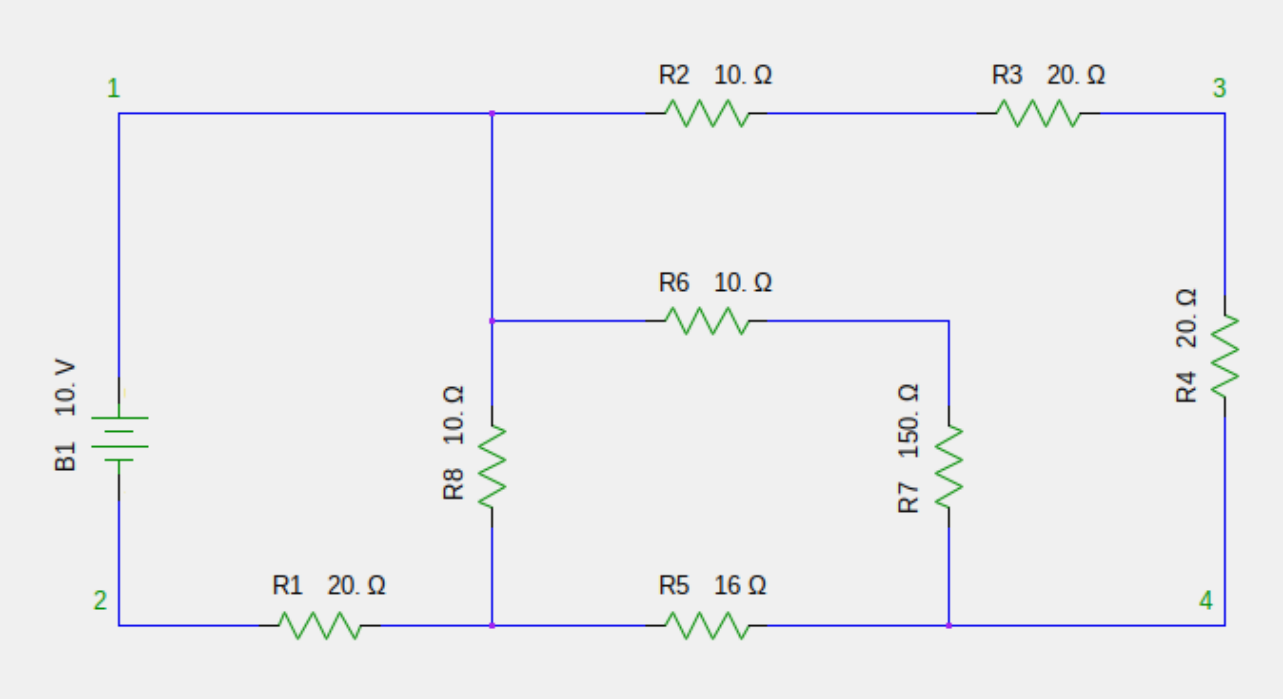
For this test:

- Use SI units, except when specified otherwise. Make sure not to forget the units when recording your answers.
- Use positive numbers for voltage differences, current, etc. no matter the polarity/direction.
- When a question asks for a name, full names are not necessary to receive full credit but do demonstrate your knowledge and may be required on future tests.
- Assume all components are ideal unless otherwise specified.
- The answers in the answer key are given with proper significant digits. Significant digits are not required on this test, but keep in mind that they may be required on future tests, so using proper significant digits on this test may be helpful practice. A decimal point written after a number indicates that the ones digit is significant, e.g. 100. has three significant digits, and 50. has two when normally, they would both have one significant digit.
- Write your answers on the answer sheet so that they may be more easily graded. You can write on the test or use scrap paper to work out your answers.
- Point values are marked on the answer sheet.
- The first tiebreaker question is marked **T1**, the second is marked **T2**, and so on.

This test is not for tournament use.

Part One

Use the following circuit for questions 1-5:



1) Find the voltage
   a) between nodes 1 and 2 (½ point).
   b) between nodes 2 and 4 (½ point).
   c) between nodes 4 and 3 (½ point).
   d) between nodes 3 and 1 (½ point).

2) Find the effective resistance of all of the resistors (1 point).

3) Find the current flowing through R1 (1 point).

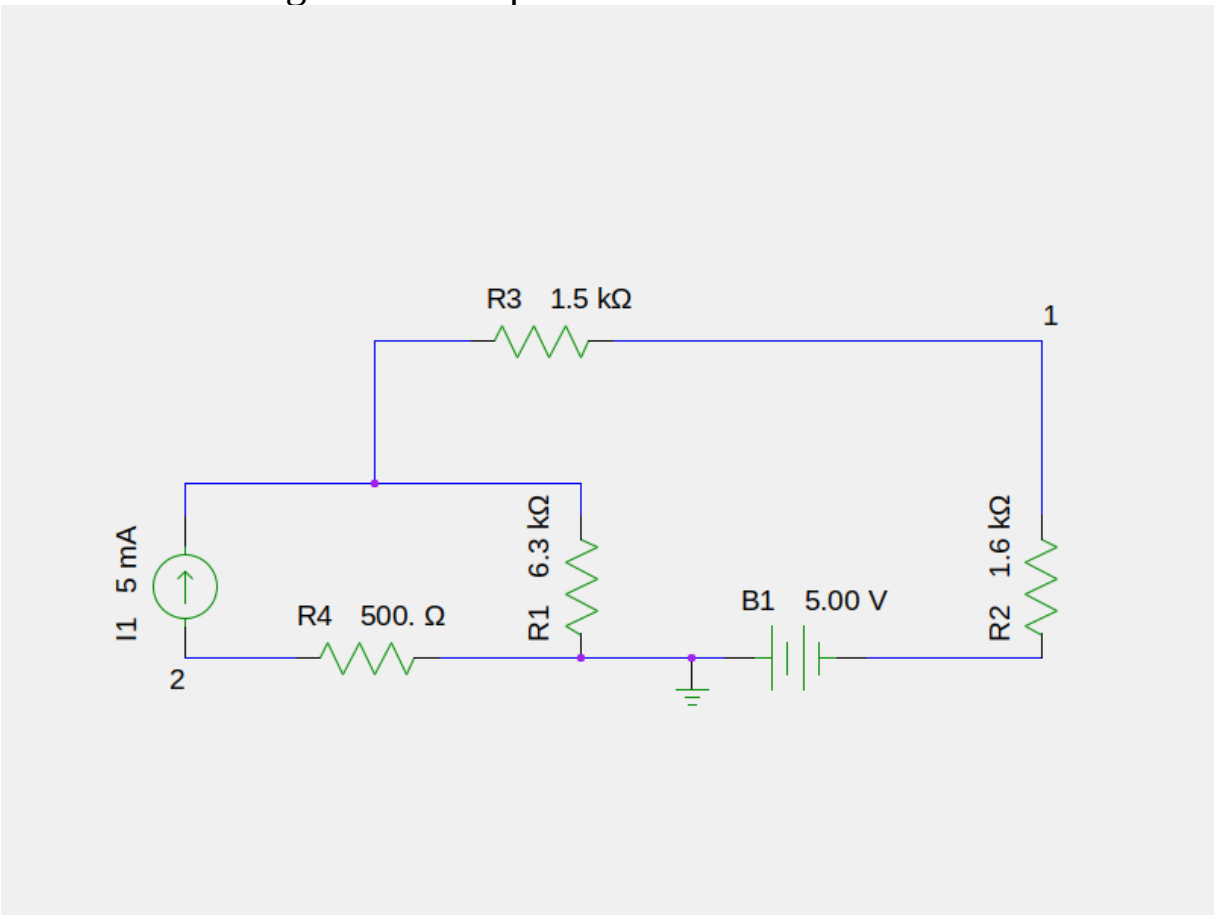
4a-d) Color code R7, which has a 10% tolerance, using the standard 4-band system (½ point each, max 2 points).

5) Find the power dissipated by R7 (2 points).

Available points for part one: 8 points

Part Two

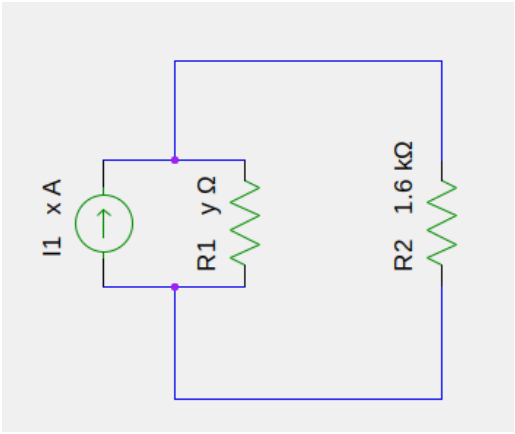
Use the following circuit for questions 6-10:



6)
   a) What is the potential difference between nodes 1 and 2? (1 point)
   b) What is the current through R1? (1 point)

7) Find the Thévenin equivalent of the circuit with R2 as the load (2 points).

8) Find the maximum power that R2 could dissipate if its resistance were to be changed (1 point).

9) 

a) Find values for x and y such that the new circuit is identical to the old circuit for R2 (½ point each, max 1 point).
b) Fill in the blank: This new circuit is the ___ equivalent circuit (1 point).

10) Find what the current going through would be R2 if its resistance were:
a) exactly 0 Ω (½ point).
b) 100. Ω (½ point).
c) 5000. Ω (½ point).
d) 8.37×10^{18} Ω (½ point).

Available points for part two: 9 points

Part Three

11)
a) What do ammeters measure? (½ point)
b) Are ammeters connected in series or parallel to the circuit? Why? (½ point for correct answer, 1.5 points for correct reasoning, max 2 points; **T4**)
c) Is it better for the internal resistance of an ammeter to be very high or very low? Why? (½ point for correct answer, 1 point for correct reasoning, max 1.5 points; **T6**)

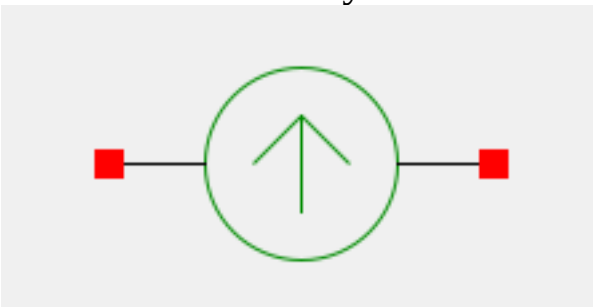
12)
a) What do voltmeters measure? (½ point)

b) Are voltmeters connected in series or parallel to the circuit? Why? (½ point for correct answer, 1.5 points for correct reasoning, max 2 points; **T5**)

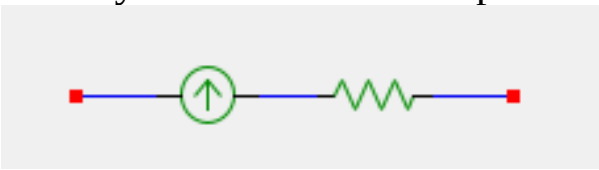
c) Is it better for the internal resistance of a voltmeter to be very high or very low? Why? (½ point for correct answer, 1 point for correct reasoning, max 1.5 points; **T7**)

13)

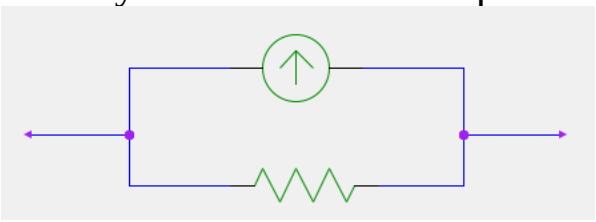
a) What instrument's symbol is shown below? (½ point)



b) Identify the instrument composed of the elements below (½ point).



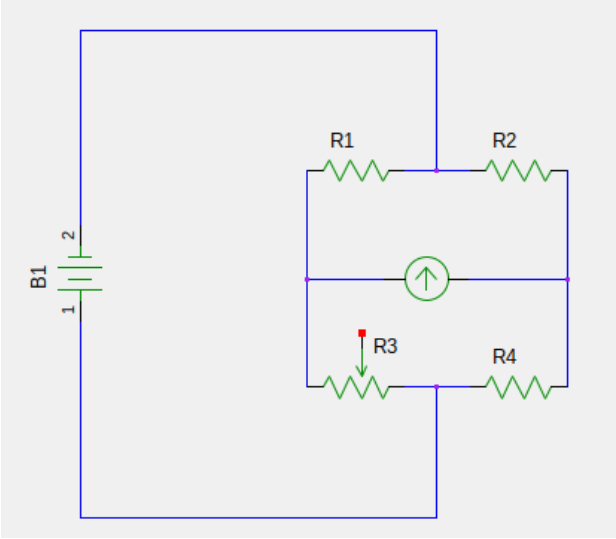
c) Identify the instrument composed of the elements below (½ point).



d) What is the function of the resistor in part c)? (½ point)

14)

a) What instrument is shown below? (½ point)



b) What does it measure? (½ point)
c) Suppose there is no voltage difference across the device that is represented on the diagram by a circle with an arrow in the middle. If R1=5.30 kΩ, R2=2.30 kΩ, and R3 is set at 1.225 kΩ, what is the resistance of R4? (1 point)
d) What is the name of the component R3? (½ point)

15) Rewrite the following units in terms of base SI units:
a) C (½ point)
b) V (½ point)
c) F (½ point)
d) S (½ point)
e) Ω (½ point)

Available points for part three: 15 points

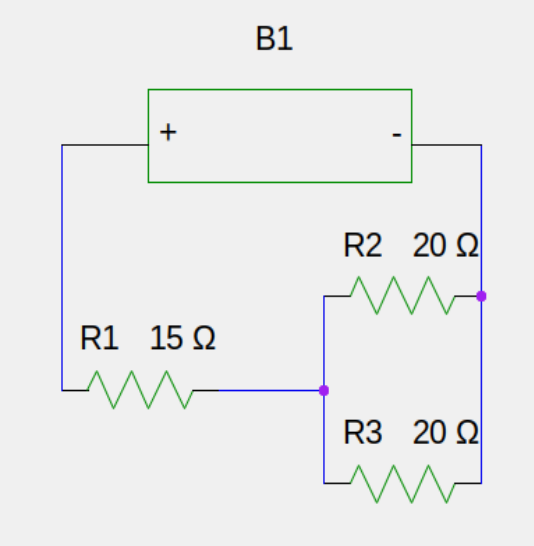
Part Four

Use the following scenario for questions 16-20:
A non-ideal battery has an EMF of 10.0 V and an internal resistance of 0.100 Ω.

16)

a) What does EMF stand for? (½ point)
b) In the context of a voltaic cell, define EMF and explain how it is produced (½ point for correct definition, 1 points for correct explanation, max 1.5 points; **T1**).

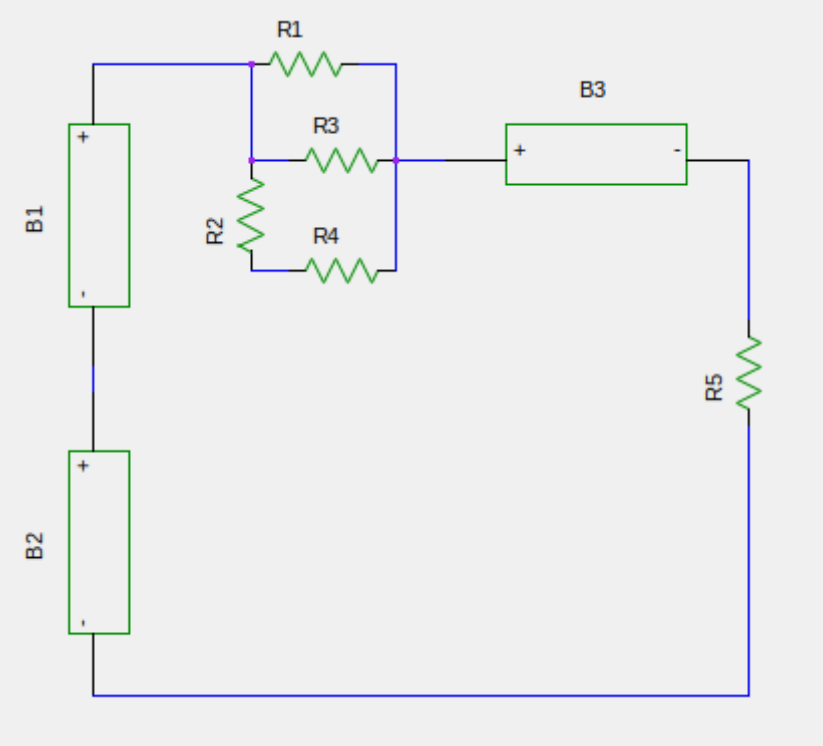
17) What is the maximum current the battery can put out? (½ point)



18) The battery is connected to a circuit as shown above. What is the voltage between the terminals of the battery, factoring in the internal resistance? (1 points)

19) Suppose the battery (with internal resistance) is connected in series to a capacitor with capacitance 25.0 μF and a resistor with resistance 5.00 Ω.
a) What is the time constant of the circuit? (1 point)
b) How long does it take for the resistor to reach a voltage of 2.50 V across its terminals? (3 points)

20) Three such batteries are connected to a circuit as shown:



All of the resistors have a resistance of 1.000 kΩ.

a) Find the voltage drops of all of the resistors. (½ point each, max 2.5 points)
b) What is the % error of the current through R5 due to the internal resistance, i.e. how much is the current less than the ideal current due to the internal resistance of the batteries as a percentage of the ideal current? (2 points)
c) Recalculate part b) with 1.000-Ω resistors instead of 1.000-kΩ resistors. (2 points)

Available points for part four: 14 points

Part Five

21)

a) A cylindrical wire has a resistance of 0.112 Ω, with a diameter of 5.00 mm and a length of 6.30 m. What is its resistivity? (1 point)
b) Does the wire have more or less resistance than a copper wire of the same size at 20 degrees Celsius? (½ point)

c) The wire is bent, with no sharp edges, and cut in two, then connected to an 8.001 V voltage source with internal resistance 0.157 Ω and a 0.824 Ω resistor. Find the current through the wire. (1 point)
d) Given a diameter of a cylindrical wire in mils, how would you calculate the area of the circular base in cmils? (1 point; **T3**)

22) What resistivity does an ideal wire have? (½ point)

23)
a) Define drift velocity. (1 point)
b) Calculate the magnitude of the drift velocity of an electron in copper wire with a diameter of 3.0 mm, assuming a current of 5.0 A. Copper has 8.5×10^{28} electrons per cubic meter. (2 points)

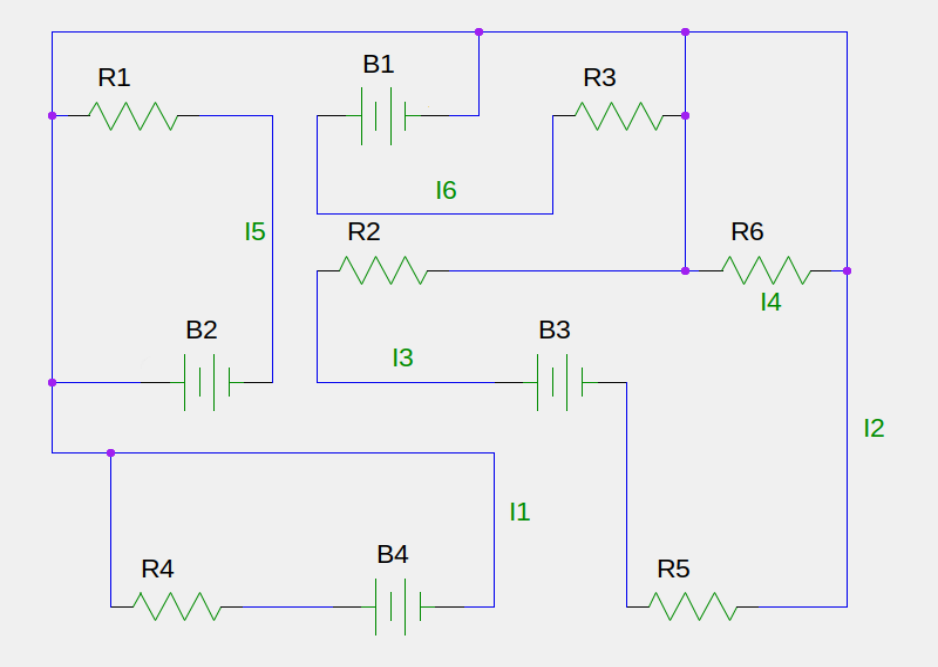
24) If an electricity-conducting wire has in it a conventional current of 2 A east, are the electrons in it moving north, east, south, west, or in no net direction? (½ point)

25) Who assigned the direction of conventional current? (½ point)

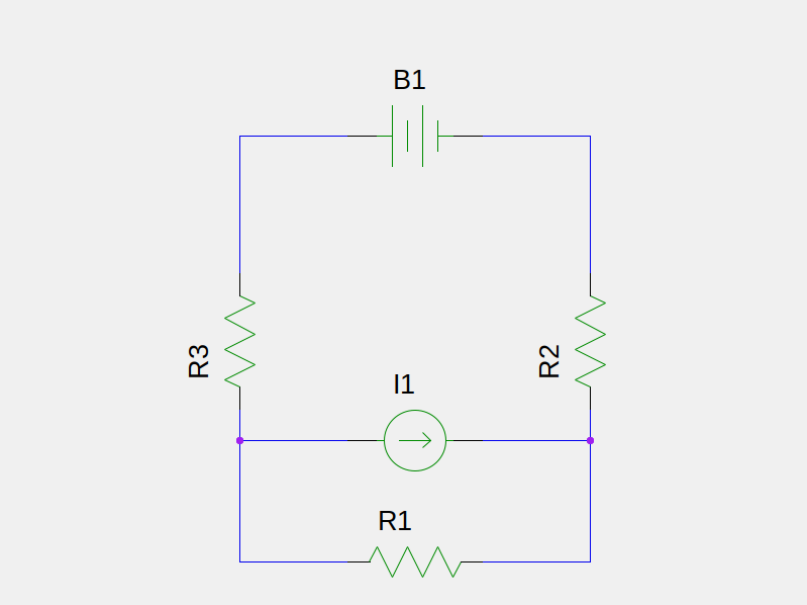
Available points for part five: 7 points

Part Six

26) Given the circuit schematic below, solve for $I_1..I_6$ in terms of $E_1..E_4$ and $R_1..R_6$. All values should be positive (½ point each, max 3 points).



27) Calculate I_1, in terms of E_1, R_1, R_2, R_3, and the voltage across the current source V (5 points).



28)

a) What is the insulating material between the two plates of a capacitor called? (½ point)

b) The permittivity of free space is around 8.854 Farads per meter. What is the approximate capacitance of a capacitor consisting of two 0.400 mm x 0.200 mm plates separated by 1.00 cm? (½ point)

c) The dielectric constant of paper is 3.85. What is the approximate capacitance of an identical capacitor with paper between the plates? (1 point)
d) Consider the capacitor described in part c). Suppose you have, in parallel, one of these capacitors, two of these capacitors in series, four of these capacitors in series, eight of these capacitors in series, ad infinitum. This parallel network is connected in series to a resistor of resistance 6.00 kΩ and a battery of voltage 8.50 V. What is the voltage across the network in 2.00 seconds? (4 points)

29) What is the term for a 0-voltage reference point from which other voltages are measured? (½ point)

30)
a) Are household appliances connected in series or parallel? Why? (½ point for correct answer, 1 point for explanation, max 1.5 points; **T2**)
b) What is a fuse? Is it connected in series or parallel? (½ point each, max 1 point)

Available points for part six: 17 points

Part Seven

31) Make a truth table for the AND logic gate (1 point).

32) Make a truth table for the XOR logic gate (1 point).

33) Make a boolean algebra formula for the following truth table: (2 points)

x	y	f(x,y)
0	0	0
0	1	0
1	0	1
1	1	0

34) Simplify the following expression to have only AND, OR, and NOT operations with no parentheses: (3 points; **T9**)

$(\overline{ae} \oplus \bar{a}\,\bar{c}) + \overline{(c+a)}\, m\, (e + \bar{a}\, c) + \bar{e}$

35) Rewrite (X AND (Y AND Z)) using only NAND operations and parentheses. Use (a ~ b) to represent A NAND B (3 points).

Available points for part seven: 10 points

Part Eight

36)

a) Who determined mathematically a formula for the magnitude of the force between two point charges? (1 point)?
b) When was the law published (½ point)?
c) What was the name of the paper in which it was published? (½ point)

37) On 1840, the Royal Society of London rejected a paper that reported that the heat generated by a voltaic current is proportional to the square of the current multiplied by the resistance. This paper later appeared in the Philosophical Magazine. What was the name of this paper, and who authored it? (1 point each, max 2 points; **T8**)

38)

a) When was the watt defined in the “International System” of Electrical and Magnetic Units? (1 point)
b) How many “international” watts are there in one joule per second?

39)

a) What two electrical units are named after Michael Faraday? (½ point each, max 1 point)
b) When was the unit with the shorter name coined? (1 point)

40)

a) Who suggested the term mho for the reciprocal of the Ohm? (1 point)
b) What year was the mho renamed to the siemens? (½ point)

c) Who is the siemens named after (full name)? (½ point)

Available points for part eight: 10 points

Credits:

This test was created using LibreOffice Writer. The pictures are taken from the program gschem, part of the gEDA project, and have been edited using GIMP.