Instructions
You must sketch correct pictures and vectors, you must show all calculations, and you must explain all
answers for full credit. Neatness and organization is required. Points will be taken off for sloppy work.

Section 1. Multiple Choice

Questions 1–4: A single wire is connected across the
terminals of a battery as shown below.

1. The surface charge density is most negative
at
(a) point A
(b) point B
(c) point C
(d) point D
(e) point E

2. The surface charge density is least negative
at
(a) point A
(b) point B
(c) point C
(d) point D
(e) point E

3. At which point is the electric field within the
wire due to surface charge the greatest?
(a) point A
(b) point B
(c) point C
(d) point D
(e) point E
(f) None of the above, because it is the
same at all points.

4. At which point is the current the greatest?
(a) point A
(b) point B
(c) point C
(d) point D
(e) point E
(f) None of the above, because it is the
same at all points.

A circuit is connected as shown below. The volt-
age across $R_1$ is 0.5 V. The voltage across $R_2$ is 0.8
V.

5. What is the voltage across $R_3$?
(a) 0.5 V
(b) 1.0 V
(c) 2.0 V
(d) 2.5 V
(e) 3.0 V

6. What is the current through $R_1$ if $R_1 =
100 \, \Omega$?
(a) 0.005 A
(b) 0.02 A
(c) 0.03 A
(d) 0.5 A
(e) 50 A
7. In what direction (in the diagram) does conventional current flow through $R_3$?
   (a) to the left
   (b) to the right

8. In what direction (in the diagram) does electron current flow through $R_3$?
   (a) to the left
   (b) to the right

A circuit is connected as shown below. The voltage across $R_2$ is 1.0 V. The resistances are $R_1 = 10 \, \Omega$, $R_2 = 10 \, \Omega$, and $R_3 = 20 \, \Omega$.

9. What is the voltage across $R_1$?
   (a) 2 V
   (b) 5 V
   (c) 4 V
   (d) 1 V
   (e) 3 V

10. What is the voltage across $R_3$?
    (a) 5 V
    (b) 4 V
    (c) 3 V
    (d) 2 V
    (e) 1 V

11. What is the current through $R_1$?
    (a) 0.075 A
    (b) 0.15 A
    (c) 0.1 A
    (d) 0.3 A
    (e) 0.4 A

12. What is the current through $R_3$?
    (a) 0.05 A
    (b) 0.4 A
    (c) 0.15 A
    (d) 0.2 A
    (e) 0.1 A

13. The filament in bulb A as twice the length and twice the radius as the filament in bulb B. The filaments are made of the same material. Which bulb has the greatest resistance?
    (a) Bulb A
    (b) Bulb B
    (c) Neither, because they have the same resistance

In the circuit below, bulb 1 has a resistance of 10 $\Omega$ and bulb 2 has a resistance of 30 $\Omega$.

14. What is the voltage across bulb 1?
    (a) 1 V
    (b) 1.33 V
    (c) 3.33 V
    (d) 2.5 V
    (e) 3.5 V

15. Which bulb has the greatest current?
    (a) Bulb 1
    (b) Bulb 2
    (c) Neither, because they have the same current.

16. Which bulb will be brightest?
    (a) Bulb 1
    (b) Bulb 2
    (c) Neither, because they will have the same brightness.
In the circuit below, bulb 1 has a resistance of 10 Ω and bulb 2 has a resistance of 30 Ω.

17. Which bulb has the greatest current?
   (a) Bulb 1
   (b) Bulb 2
   (c) Neither, because they have the same current.

18. Which bulb has the greatest voltage?
   (a) Bulb 1
   (b) Bulb 2
   (c) Neither, because they have the same voltage.

19. Which bulb will be brightest?
   (a) Bulb 1
   (b) Bulb 2
   (c) Neither, because they will have the same brightness.

A capacitor and resistor are connected to a battery as shown below. At \( t = 0 \), the circuit is connected. The charge on the capacitor plates is initially zero.

20. What is the direction of the electron current through the resistor?
    (a) to the left (as shown in the diagram)
    (b) to the right (as shown in the diagram)

21. In what direction is the electric field due to surface charge on the wire at point P?
    (a) down, toward the bottom of the diagram
    (b) up, toward the top of the diagram

22. In what direction is the electric field due to the capacitor at point P after some charge builds up on the capacitor?
    (a) down, toward the bottom of the diagram
    (b) up, toward the top of the diagram

23. Which capacitor plate becomes negatively charged?
    (a) the bottom plate shown in the diagram
    (b) the top plate shown in the diagram

24. As the temperature of a wire increases, the mobility of the wire
    (a) remains the same.
    (b) decreases.
    (c) increases.

25. As temperature of a wire increases, the resistance of the wire
    (a) remains the same.
    (b) decreases.
    (c) increases.

26. Which of the following changes will increase the capacitance of a capacitor?
    (a) increase the separation distance, \( s \)
    (b) decrease the area of the capacitor plates, \( A \)
    (c) increase the dielectric constant, \( K \)
    (d) all of the above
    (e) none of the above

A thin wire and a thick wire are connected in parallel to the terminals of a battery as shown below. Wire 2 has twice the radius as wire 1.
27. The voltage across wire 2 is
   (a) \( \frac{1}{2} \Delta V_1 \)
   (b) \( 2 \Delta V_1 \)
   (c) \( \frac{1}{4} \Delta V_1 \)
   (d) \( 4 \Delta V_1 \)
   (e) \( \Delta V_1 \)

28. The electric field in wire 2 is
   (a) \( \frac{1}{2} E_1 \)
   (b) \( 2 E_1 \)
   (c) \( \frac{1}{4} E_1 \)
   (d) \( 4 E_1 \)
   (e) \( E_1 \)

29. The current through wire 2 is
   (a) \( \frac{1}{2} I_1 \)
   (b) \( 2 I_1 \)
   (c) \( \frac{1}{4} I_1 \)
   (d) \( 4 I_1 \)
   (e) \( I_1 \)

30. A 100 \( \Omega \) resistor is connected to a battery and the current through the battery is 0.01 A. If you add another resistor in parallel with this one, the current through the battery will be
   (a) greater than 0.01 A.
   (b) less than 0.01 A.
   (c) the same, 0.01 A.
   (d) it depends on the resistance of the second resistor; the current might be greater than 0.01 A or less than 0.01 A or equal to 0.01 A, depending on the value of this resistor.
Section 2. Problem Solving

31. An RC circuit has a 1.5-V battery, a 100kΩ resistor, and a 5 µF capacitor. At $t = 0$, there is no charge on the capacitor plates. At $t = 0$, the switch is closed, and the capacitor begins to charge.

(a) Sketch the charge on the capacitor plates in the picture above.

(b) What is the time constant $\tau$ of the RC circuit?

(c) What is the voltage across the capacitor at $t = \infty$?

(d) What is the magnitude of the charge on each capacitor plate at $t = \infty$?
(e) Sketch a graph of $Q$ vs. $t$ for the charging capacitor.

(f) Sketch a graph of $I$ vs. $t$ for the charging capacitor.

(g) What is the voltage across the capacitor at $t=0.25\ s$?

(h) What is the voltage across the resistor at $t=0.25\ s$?

(i) What is the voltage across the resistor at $t = \infty$?
32. What is the current through $R_4$ in the circuit below?
Section 3. LAB

33. (a) Which of the resistors shown in the circuit below are in series? If none are in series, then say this explicitly.

(b) Which of the resistors shown in the circuit above are in parallel? If none are in parallel, then say this explicitly.

34. Two meters are shown in the picture below. Label the meter that is used as an ammeter to measure current and label the meter that is used as a voltmeter to measure voltage.

35. In an RC circuit, you measure the decay constant to be $\beta = 0.5 \text{ s}^{-1}$. What is the time constant $\tau$?

36. For an RC circuit where the capacitor is discharging, describe what you would change in order to discharge the capacitor in less time?

37. What is the underlying physical principle that is the basis for Kirchhoff’s voltage law?

38. What is the underlying physical principle that is the basis for Kirchhoff’s current law?