Circuit Lab Key

Answers (**bold**) are given with work, but work is not required to earn credit. Answers without the proper units can only receive half credit. Accept any equivalent answers. Answers marked with asterisks were determined by hand and then checked using ngspice, part of the gEDA project.

1)
Simplifying the circuit:
R2+R3+R4 = 50 (2 sigfigs) Ω
R6+R7 = 160 (3 sigfigs) Ω
(R2+R3+R4)||(R6+R7) = 38.095 (2 sigfigs) Ω
((R2+R3+R4)||(R6+R7))+R5 = 54.095 (2 sigfigs) Ω
(((R2+R3+R4)||(R6+R7))+R5)||R8 = 8.439 (2 sigfigs) Ω
((((R2+R3+R4)||(R6+R7))+R5)||R8)+R1 = 28.439 (2 sigfigs) Ω

a) ***1.0 × 10¹ V** or **10. V**
b) * $10\,V\left(\frac{20\,\Omega}{28.439\,\Omega}+\frac{8.439\,\Omega}{28.439\,\Omega}\cdot\frac{16\,\Omega}{54.095\,\Omega}\right)$ = **7.9 × 10⁰ V** or **7.9 V**
c) * $10\,V\left(\frac{8.439\,\Omega}{28.439\,\Omega}\cdot\frac{38.095\,\Omega}{54.095\,\Omega}\cdot\frac{20\,\Omega}{50\,\Omega}\right)$ = **8.4 × 10⁻¹ V** or **0.84 V** or **840 mV**
d) * $10\,V\left(\frac{8.439\,\Omega}{28.439\,\Omega}\cdot\frac{38.095\,\Omega}{54.095\,\Omega}\cdot\frac{30\,\Omega}{50\,\Omega}\right)$ = **1.3 × 10⁰ V** or **1.3 V**

(n.b.: the answers to b) through d) add up to 10.04 V instead of 10 V because of rounding)

2) ***2.8 × 10¹ Ω** or **28 Ω**

3) * $\frac{10\,V}{28.439\,\Omega}$ = **3.5 × 10⁻¹ A** or **0.35 A** or **350 mA**

4)
a) **Brown**
b) **Green**
c) **Brown**
d) **Silver**

5) * $\frac{\left(10\,V\left(\frac{8.439\,\Omega}{28.439\,\Omega}\cdot\frac{38.095\,\Omega}{54.095\,\Omega}\cdot\frac{150\,\Omega}{160\,\Omega}\right)\right)^2}{150\,\Omega}$ = **2.6 × 10⁻² W** or **0.026 W** or **26 mW**

6)

a) * $(5\,mA \cdot 500\,\Omega) + \left(-5.00\,V \cdot \frac{6.3\,k\Omega}{6.3\,k\Omega + 1.5\,k\Omega + 1.6\,k\Omega} + 5\,mA \cdot \frac{6.3\,k\Omega \cdot (1.5\,k\Omega + 1.6\,k\Omega)}{6.3\,k\Omega + 1.5\,k\Omega + 1.6\,k\Omega}\right) + \left(-5.00\,V \cdot \frac{1.5\,k\Omega}{6.3\,k\Omega + 1.5\,k\Omega + 1.6\,k\Omega} - 5\,mA \cdot \frac{1.5\,k\Omega \cdot 6.3\,k\Omega}{6.3\,k\Omega + 1.5\,k\Omega + 1.6\,k\Omega}\right)$ = **4 × 10^0 V** or **4 V**

b) * $\left(-5\,V \cdot \frac{6.3\,k\Omega}{6.3\,k\Omega + 1.5\,k\Omega + 1.6\,k\Omega} + 5\,mA \cdot \frac{6.3\,k\Omega \cdot (1.5\,k\Omega + 1.6\,k\Omega)}{6.3\,k\Omega + 1.5\,k\Omega + 1.6\,k\Omega}\right) \div 6.3\,k\Omega$ = **1 × 10^{-3} A** or **1 mA**

7)
*V_{th} = $5\,V + 5\,mA \cdot 6.3\,k\Omega$ = **3.650 × 10^1 V** or **36.500 V**
*R_{th} = $6.3\,k\Omega + 1.5\,k\Omega$ = **7.8 × 10^3 Ω** or **7800 Ω** or **7.8 kΩ**

8) * $\left(\frac{36.5\,V}{2 \cdot 7800\,\Omega}\right)^2 \cdot 7800\,\Omega$ **4.3 × 10^{-2} W** or **0.043 W** or **43 mW**

9)
a) *x = $\frac{36.5\,V}{7.8\,k\Omega} * 1\,A^{-1}$ = **4.7 × 10^{-3}** or **0.0047**
*y = **7800**
b) **Norton**

10)
a) ***4.7 × 10^{-3} A or 4.7 mA**
b) * $\frac{36.5\,V}{7800\,\Omega + 100\,\Omega}$ = $4.7\,mA * \frac{7800\,\Omega}{7800\,\Omega + 100\,\Omega}$ = **4.6 × 10^{-3} A** or **4.6 mA**
c) * $\frac{36.5\,V}{7800\,\Omega + 5000\,\Omega}$ = $4.7\,mA * \frac{7800\,\Omega}{7800\,\Omega + 5000\,\Omega}$ **2.9 × 10^{-3} A** or **3.230 mA**
d) * $\frac{36.5\,V}{7800\,\Omega + 8.37 \times 10^{18}\,\Omega}$ = $4.7\,mA * \frac{7800\,\Omega}{7800\,\Omega + 8.37 \times 10^{18}\,\Omega}$ = **4.4 × 10^{-18} A** or **4.4 aA**

11)
a) **Current**
b) **Series; accept any valid explanations, e.g.**
   - **Objects in series experience the same current while parallel circuits are current dividers.**
c) **Very low so the ammeter does not substantially change the current.**

12)
a) **Voltage**
b) **Parallel; accept any valid explanations, e.g.**

- **Objects in parallel experience the same voltage drop while series circuits are voltage dividers.**
- **If voltmeters were connected in series, they would not be able to measure across a component.**

c) **Very high so that the voltmeter does not substantially change the path of electricity and therefore the voltage drop across the device.**

13)

a) **A galvanometer**
b) **A voltmeter**
c) **An ammeter**
d) **Both the term (to provide shunt resistance) and the definition (to create a low resistance path for the majority of the current to run through, allowing the galvanometer to precisely measure the current without getting overloaded) are acceptable.**

14)

a) **A Wheatstone bridge**
b) **Resistance**
c) $\frac{1.225\,k\Omega}{5.30\,k\Omega}\cdot 2.30\,k\Omega$ = **5.3 × 10^2 Ω** or **530 Ω**
d) **Variable resistor** (but varistor is unacceptable) or **rheostat** or **potentiometer**

15)

a) **A•s**
b) **A^{-1}•kg•m^2•s^{-3}**
c) **A^2•kg^{-1}•m^{-2}•s^4**
d) **A^2•kg^{-1}•m^{-2}•s^3**
e) **A^{-2}•kg•m^2•s^{-3}**

16)

a) **Electromotive force**
b) **EMF is the maximum potential difference between the two electrodes (i.e. when no current is flowing). An oxidation reaction occurs at the anode, and a reduction reaction occurs at the cathode, producing a potential difference.**

17) * $\frac{10.0\,V}{0.100\,\Omega}$ = **1.00 × 10^2 A** or **100. A**

18) * $10.0\,V-\left(\frac{10.0\,V}{0.100\,\Omega+15.0\,\Omega+10.0\,\Omega}\right)(0.100\,\Omega)$ = **9.96 × 10^0 V** or **9.96 V**

19)

a) $25.0\,\mu F\cdot(5.00\,\Omega+0.100\,\Omega)$ = **1.28 × 10^{-4} s** or **0.128 ms** or **128 µs**

b) * $-25.0\,\mu F\cdot(5.00\,\Omega+0.100\,\Omega)\cdot\ln\left(\frac{2.50\,V}{10.0\,V}*\frac{5.10\,\Omega}{5.00\,\Omega}\right)$ = **1.74 × 10^{-4} s** or **0.174 ms** or **174 µs**

20)

a)

*V_{R1} = $(20.0\,V-10.0\,V)\left(\frac{400.0\,\Omega}{1400.3\,\Omega}\right)$ = **2.86 × 10^0 V = 2.86 V**

*V_{R2} = $\frac{1}{2}(20\,V-10\,V)\left(\frac{400\,\Omega}{1400.3\,\Omega}\right)$ = **1.43 × 10^0 V = 1.43 V**

*V_{R3} = $(20\,V-10\,V)\left(\frac{400\,\Omega}{1400.3\,\Omega}\right)$ = **2.86 × 10^0 V = 2.86 V**

*V_{R4} = $\frac{1}{2}(20\,V-10\,V)\left(\frac{400\,\Omega}{1400.3\,\Omega}\right)$ = **1.43 × 10^0 V = 1.43 V**

*V_{R5} = $(20\,V-10\,V)\left(\frac{1000\,\Omega}{1400.3\,\Omega}\right)$ = **7.14 × 10^0 V = 7.14 V**

b) * $-\left(\frac{10.0\,V}{1400.3\,\Omega}-\frac{10.0\,V}{1400.\,\Omega}\right)\div\frac{10.0\,V}{1400.\,\Omega}\cdot 100\,\%$ = **2.14 × 10^{-2} %** or **0.0214%**

c) * $-\left(\frac{10.0\,V}{1.700\,\Omega}-\frac{10.0\,V}{1.400\,\Omega}\right)\div\frac{10.0\,V}{1.400\,\Omega}\cdot 100\,\%$ = **1.76 × 10^1 %** or **17.6%**

21)

a) $0.112\,\Omega\left(\frac{\pi\cdot(2.50\,mm)^2}{6.30\,m}\right)$ = **3.49 × 10^{-7} Ω·m**

b) **More**

c) $\frac{8.001\,V}{0.112\,\Omega+0.157\,\Omega+0.824\,\Omega}$ = **7.32 × 10^0 A = 7.32 A**

d) **A = d^2**

22) **0**

23)

a) **The average velocity that a particle attains due to an electrical field**

b) $\frac{5.0\,A}{8.5\times10^{28}\,electrons\cdot m^{-3}\cdot\pi\cdot(1.5\,mm)^2\cdot q\,C\cdot electron^{-1}}$ = **5.2 × 10^{-5} m/s = 52 µm/s**

24) **West**

25) **Benjamin Franklin**

26)

$*I_1 = E_4/R_4$
$*I_2 = E_3/(R_2+R_5)$
$*I_3 = E_3/(R_2+R_5)$
$*I_4 = 0$
$*I_5 = E_2/R_1$
$*I_6 = E_1/R_3$

27) **$*I_1 = (VR_1+VR_2+VR_3+E_1R_1)/(R_1R_2+R_1R_3)$**

28)
   a) **Dielectric**
   b) $8.854\frac{F}{m}\cdot\frac{(0.400\,mm)(0.200\,mm)}{1.00\,cm}$ = **7.08×10^{-5} F** = **70.8 µF**
   c) $8.854\frac{F}{m}\cdot\frac{(0.400\,mm)(0.200\,mm)}{1.00\,cm}\cdot 3.85$ = **2.73×10^{-4} F** = **0.273 mF** = **273 µF**
   d) $8.50\,V\left(1-e^{-(2.00\,s)/(6000\,\Omega\cdot(2.727\times10^{-4}F+\frac{1}{2}\cdot2.727\times10^{-4}+\frac{1}{4}2.727\times10^{-4}\ldots))}\right)$ = **3.89×10^{0} V** = **3.89 V**

29) **Ground** or **earth**

30)
   a) **Parallel; accept any valid explanations, e.g.**
      - **So that if one appliance is not connected, the whole circuit does not become open.**
      - **So that different currents can be supplied to different outlets.**
   b) **A fuse is a device that prevents overheating by melting and breaking the circuit if the current exceeds a safe level; series.**

31) **The following table (with the rows in any particular order; the heading row is not required):**

x	y	x AND y
0	0	0
0	1	0
1	0	0
1	1	1

32) **The following table (with the rows in any particular order; the heading row is not required):**

x	y	x XOR y
0	0	0
0	1	1
1	0	1
1	1	0

33) **f(x,y) =** $\mathbf{x\bar{y}}$ or anything equivalent

34) $\mathbf{\bar{a}c + \bar{a}e\bar{c}m + \bar{e}}$

35) **(X ~ ((Y ~ Z) ~ (Y ~ Z))) ~ (X ~ ((Y ~ Z) ~ (Y ~ Z)))**

36)

a) **(Charles-Augustin de) Coulomb**
b) **1785**
c) **“Second Mémoire sur l’Électricité et le Magnétism”**, or **“Second Report on Electricity and Magnetism”** (or any other viable translation of the title)

37) **(James Prescott) Joule’s “On the Production of Heat by Voltaic Electricity”**

38)

a) **1908**
b) **1.00019**

39)

a) The **farad** and the **faraday**
b) **1861**

40)

a) **Lord Kelvin/(William) Thomson**
b) **1881**
c) **Ernst Werner von Siemens**

Credits:

This answer key was created using LibreOffice Writer. Answers, once obtained, were checked using gEDA.