1. Consider a hybrid car that has 400 kJ of kinetic energy at a certain speed. The car’s regenerative braking is 40% efficient ($\eta = 0.4$) at converting kinetic energy ($E = \frac{1}{2}mv^2$) to energy stored in a battery. When the car slows down to half of its original speed, what is the energy, $\Delta E$, added to the car’s battery?

a. $\Delta E = 40 \text{ kJ}$
b. $\Delta E = 80 \text{ kJ}$
c. $\Delta E = 120 \text{ kJ}$
d. $\Delta E = 160 \text{ kJ}$
e. $\Delta E = 200 \text{ kJ}$

2. The energy of a certain charged capacitor is 5 J. What is the new energy stored in that capacitor, if its charge decreases to 1/3 of its original value?
(Hint: The capacitance does not change. Consider what happened to the voltage across the capacitor.)

a. Stays the same: 5 J
b. Decreased to 2/3 of original: 10/3 J
c. Decreases to 4/9 of original: 20/9 J
d. Decreases to 1/3 of original: 5/3 J
e. Decreases to 1/9 of original: 5/9 J

3. What is the maximum voltage that can be applied across a 400 $\Omega$ resistor without risking damage, if the resistor’s maximum power rating is $\frac{1}{4}$ W?

a. 10 V
b. $10\sqrt{2}$ V
c. 20 V
d. $20\sqrt{2}$ V
e. 40 V

$\text{Power dissipated in resistor}$

$P = \frac{V^2}{R} \leq \frac{1}{4} \text{ W}$

$= \frac{V^2}{400} \leq \frac{1}{4}$

$\Rightarrow V \leq 10V$
4. If $V_1 = 0.7 \, V$, $V_4 = 0.3 \, V$, $V_5 = 0.4 \, V$ in the circuit below, what is $V_2$?
   a. $1.4 \, V$
   b. $0.8 \, V$
   c. $0.6 \, V$
   d. $0 \, V$
   e. $-0.6 \, V$

   
   use KVL around loop with enough information to solve for $V_2$

   $-0.7 + V_2 + 0.3 + 0.4 = 0$
   $\Rightarrow V_2 = 0$

5. If $I_1 = -10 \, mA$ (yes, $I_1$ is negative), $I_3 = 6 \, mA$, $I_6 = 8 \, mA$ in the circuit below, what is $I_4$?
   a. $-0 \, mA$
   b. $-4 \, mA$
   c. $-6 \, mA$
   d. $-10 \, mA$
   e. $-20 \, mA$

   Using the supernode $I_1 + I_6 + I_4 + I_3 = 0$
   $-10 + 8 + I_4 + 6 = 0$
   $I_4 = -4 \, mA$

6. Which of the following KCL and KVL equations is incorrect for this circuit?
   a. $I_1 = I_4$
   b. $I_2 = I_3 + I_4$
   c. $I_2 R_2 + I_3 R_3 - V_2 = 0$
   d. $I_1 R_1 + I_2 R_2 + I_4 R_4 = V_1$
   e. $V_1 - I_1 R_1 - I_3 R_3 - V_2 - I_4 R_4 = 0$

   The correct equation is
   $V_1 - I_1 R_1 + I_3 R_3 - I_4 R_4 = 0$
7. What is the value of resistance between a and b?

a. R = 9 Ω  

b. R = 16 Ω  

c. R = 24 Ω  

d. R = 35 Ω  

e. R = 70 Ω  

Combine \( R_2 \) and \( R_3 \) in series

\[
\text{finally } R_{ab} = \frac{1}{\frac{1}{60} + \frac{1}{40}} = 24 \Omega
\]

8. What is the expression for resistance between a and b?

a. \( R = R_1\left(\frac{R_2}{R_1 + R_2} + \frac{R_3}{R_1 + R_3}\right) \)

b. \( R = R_1 + R_2 + R_3 + R_4 \)

c. \( R = \frac{(R_1 + R_2)(R_1 + R_3)}{2R_1 + R_2 + R_3} \)

d. \( R = \frac{R_1(R_2 + R_3)}{2R_1 + R_2 + R_3} \)

e. \( R = \frac{R_1R_2R_3}{R_1 + R_2 + R_3} \)

\[
R_{ab} = \frac{(R_1 + R_2)(R_1 + R_3)}{(R_1 + R_2)(R_1 + R_3)} = \frac{(R_1 + R_2)(R_1 + R_3)}{(R_1 + R_2)(R_1 + R_3)}
\]

9. What are the voltages \( V_1 \) and \( V_2 \) in the circuit below?

a. \( V_1 = 10 \) V and \( V_2 = 5 \) V

b. \( V_1 = 9 \) V and \( V_2 = 6 \) V

c. \( V_1 = 7.5 \) V and \( V_2 = 7.5 \) V

d. \( V_1 = 6 \) V and \( V_2 = 9 \) V

e. \( V_1 = 5 \) V and \( V_2 = 10 \) V

\[
V_{AB} = 15 \text{ V} \text{ so ignoring the } 6 \Omega \text{ resistor can use voltage divider rule}
\]

\[
V_1 = \frac{3}{3+2} \cdot 15 = 9 \text{ V} \quad V_2 = \frac{2}{3+2} \cdot 15 = 6 \text{ V}
\]
10. What are the voltages $V_1$ and $V_2$ in the circuit below?

- a. $V_1 = 2\, V$ and $V_2 = 4\, V$
- b. $V_1 = 3\, V$ and $V_2 = 3\, V$
- c. $V_1 = 4\, V$ and $V_2 = 2\, V$
- d. $V_1 = 6\, V$ and $V_2 = 3\, V$
- e. Not enough info to tell

$$ -6 + V_1 + V_2 = 0 $$
$$ -6 + V_1 + 3 = 0 \Rightarrow V_1 = 3\, V $$

11. What are the values of the currents $I_1$ and $I_2$ in the circuit below?

- a. $I_1 = 30\, mA$ and $I_2 = 10\, mA$
- b. $I_1 = 10\, mA$ and $I_2 = 30\, mA$
- c. $I_1 = 45\, mA$ and $I_2 = 15\, mA$
- d. $I_1 = 15\, mA$ and $I_2 = 45\, mA$
- e. $I_1 = 15\, mA$ and $I_2 = 5\, mA$

Using the Current Divider Rule:
$$ I_1 = \frac{3}{3+3} \times 60 = 45\, mA $$
$$ I_2 = \frac{1}{3+3} \times 60 = 15\, mA $$

12. What is the value of resistance $R$ needed to make $V_o = 4\, V$?

- a. $1\, k\Omega$
- b. $1.2\, k\Omega$
- c. $1.5\, k\Omega$
- d. $2\, k\Omega$
- e. $3\, k\Omega$

For $V_o = 4\, V$ $I_o$ needs to be $\frac{V_o}{R} = \frac{4}{6\, k\Omega}$

Using KVL around the larger loop:
$$ -12 + 2000I + 4 = 0 \Rightarrow I = \frac{8}{2000} $$

At node A $I = I_1 + I_o$. Solving for $I_1$ gives $I_1 = \frac{20}{6\, k\Omega}$

Using Ohm's Law $R = \frac{V_o}{I_1} = \frac{4}{(20/6\, k\Omega)} = 1.2\, k\Omega$
13. How much power is being absorbed by the 6 Ω resistor if the 3 Ω resistor is absorbing 60 W?

a. 120 W  
b. 90 W  
c. 60 W  
d. 30 W  
e. 20 W

The voltage across both resistors is the same. The relative currents can be found using CDR.  
\[
I_1 = \frac{6}{3+6} = \frac{6}{9} = \frac{2}{3} \quad \text{and} \quad I_2 = \frac{3}{9} = \frac{1}{3}
\]

\[
P_{3\Omega} = 90W \Rightarrow V \cdot \frac{2}{3}I = 90W \Rightarrow V = \frac{135}{2}W
\]

14. How can one describe the IV characteristics line of an ideal ammeter (aka ideal current meter)?

a. Horizontal line going through the origin  
b. Vertical line going through the origin  
c. Any line going through the origin  
d. Any horizontal line  
e. Any vertical line

15. Which is the correct IV equation for the circuit below?

a. \[I = -\frac{1}{5}V + 0.60\]  
b. \[I = -\frac{1}{5}V + 0.20\]  
c. \[I = -\frac{1}{20}V + 0.20\]  
d. \[I = -\frac{1}{20}V + 0.15\]  
e. \[I = 0.20\]

\[V_{oc} = 15 \cdot 0.2 = 3V \quad \text{(Ohm's Law)}\]

\[I_{sc} = \frac{15}{20} \cdot 0.2 = 0.15A \quad \text{(CDR)}\]

\[R_{eq} = 15 + 5 = 20Ω \quad \text{(set current source to zero)}\]

\[I = -\frac{1}{20}V + 0.15\]
16. If the open circuit voltage of a circuit containing a source and some resistors is measured at 15 V, while the current through the short circuit across the circuit is 300 mA, what would be the power absorbed by a 100 Ω resistor placed across the terminals?

a. 0.5 W  

b. 1.0 W  

c. 1.2 W  

d. 1.5 W  

e. 4.5 W

Using $V_{oc}$ and $I_{sc}$ to get the circuit

\[ I = \frac{-1}{50} V + 0.3 \]

The voltage across a 100 Ω resistor attached to this subcircuit $V_{100Ω} = \frac{100}{100+50} \cdot 15 = 10$ V

using the VDR. $P = \frac{V^2}{R} = \frac{10^2}{100} = 1$ W.

17. What is the resistance, represented by the dashed line, which intersects the IV line of the circuit C at the voltage value of 12 V?

a. 300 Ω  

b. 450 Ω  

c. 600 Ω  

d. 900 Ω  

e. 1200 Ω

The IV curve of the solid line is

\[ I = -\frac{I_{sc}}{V_{oc}} V + I_{sc} = -\frac{50}{15} V + 50. \text{ When } V = 12 \text{ V} \]

\[ I = -\frac{10}{3}, 12 + 50 = 10 \text{ mA} \Rightarrow \text{ the slope of the dashed line is } \frac{10}{12} \cdot 10^3 = \frac{1}{R} \]

\[ R = 1.2 \, k\Omega \]
18. Find the Thevenin equivalent of the circuit below.

- a. $V_T = 9\, \text{V}, R_T = 900\, \Omega$
- b. $V_T = 9\, \text{V}, R_T = 200\, \Omega$
- c. $V_T = 6\, \text{V}, R_T = 300\, \Omega$
- d. $V_T = 4\, \text{V}, R_T = 200\, \Omega$
- e. $V_T = 2\, \text{V}, R_T = 200\, \Omega$

Use the equivalence of Thevenin and Norton Equivalents to transform circuit:

$\frac{V}{I} = \frac{6}{600} = 10\, \text{mA}$

19. What is the node voltage $V_A$?

- a. 6.0 V
- b. 4.2 V
- c. 3.0 V
- d. 2.4 V
- e. 2.0 V

Nodal Analysis — Apply KCL at Node in terms of Voltage:

$$\frac{V_A - 6}{15\,000} + \frac{V_A - 0}{15\,000} + \frac{V_A - 2}{5\,000} = 0$$

$$V_A = 2.4\, \text{V}$$
20. What is the node voltage $V_A$ if $V_1 = 15 \, V$?

a. 8.5 V  
b. 8.0 V  
c. 7.5 V  
d. 7.0 V  
e. 6.5 V

Apply KCL at supernode:

$\frac{V_A - 15}{3000} + \frac{V_A}{2000} + \frac{V_B}{3000} = 0$

$V_B$ is related to $V_A$:

$V_B = V_A + 2$

$\frac{10}{6} V_A = \frac{65}{6} \Rightarrow V_A = 6.5 \, V$

21. What is the current, $I_S$, going through both voltage sources, given $V_S = 4.5 \, V$?

a. 0 A  
b. 0.5 A  
c. 1 A  
d. 1.5 A  
e. 2 A

Replace with Thevenin's equivalent:

$-10 + 2 + 4.5 + 7I_S = 0$

$I_S = \frac{3.5}{7} = 0.5 \, A$
22. If a certain PWM waveform with a 20% duty cycle has an RMS voltage of 3 V, what will be the RMS voltage if the duty cycle increases to 40%?

a. 3 V  
b. $3\sqrt{2}$ V  
c. $3\sqrt{3}$ V  
d. 6 V  
e. 12 V

$$V_{\text{RMS}} = \sqrt{\frac{V_0^2 T_{\text{on}}}{T}} = 3 = V_0 \sqrt{\frac{2}{\sqrt{2}}} \quad 20\% \text{ duty cycle}$$  
so $V_0 = 3 / \sqrt{2}$

For 40% duty cycle $V_{\text{RMS}} = \frac{3}{\sqrt{2}} \cdot \sqrt{4} = 3\sqrt{2}$ V

23. What is the approximate resistance of a light bulb which consumes 40 W when the AC voltage (in volts) is given by $v(t) = 200\sqrt{2} \cos (100\pi t)$.

a. 1.0 kΩ  
b. 1.4 kΩ  
c. 2.0 kΩ  
d. 2.4 kΩ  
e. 4.0 kΩ

For a time-varying signal

$$P_{\text{AVG}} = V_{\text{RMS}} \cdot I_{\text{RMS}} \quad \text{as in the case of power dissipated in a resistive load}$$

$$P_{\text{AVG}} = \frac{V_{\text{RMS}}^2}{R} = 40 \text{ W}$$

$$V_{\text{RMS}} = \frac{A}{\sqrt{2}} = \frac{200\sqrt{2}}{\sqrt{2}} = \frac{(200)^2}{R} = 40 \Rightarrow R = 1000 \Omega.$$
24. If a light-emitting diode (LED) has the turn on voltage $V_{on} = 2 \, \text{V}$, what is the resistance R needed to set the current through the LED to 50 mA (assuming the offset ideal model)?

- a. 20 $\Omega$
- b. 30 $\Omega$
- c. 40 $\Omega$
- d. 50 $\Omega$
- e. 60 $\Omega$

![Diagram of LED circuit with 3 V source and 2 V diode voltage drop]

$I = 0.05 = \frac{3-2}{R} \Rightarrow R = 200 \Omega$

25. Assuming an offset ideal model, what is the current, I, through the voltage source if the diodes have the turn on voltage $V_{on} = 0.7 \, \text{V}$?

- a. 120 mA
- b. 50 mA
- c. 40 mA
- d. 30 mA
- e. 10 mA

![Diagram of circuit with 1.1 V source and two diodes]

Both of the diodes cannot be on. If neither diode is conducting, $I = 10 \, \text{mA}$ driven by the current source.

Condition for $D_1$ to be on $V_{D1} > 0.7 \, \text{V}$

$D_2$ to be on $V_{D2} > 0.7 \, \text{V}$

$V = 1.1 - 0.1 = 1 \, \text{V}$

Voltage drop across res.
Condition for diode D1 to be on is met.

\[
I = \frac{1.1 - 0.7}{10} = 40 \text{ mA}
\]