Additional Homework Problems for ECEN 2250

These homework problems are referred to in homework assignments using the prefix: “EK”.

**EKD-1** A voltage source $v_{in}(t) = 20 \sin \omega t \text{ V}$ is applied to the half-wave rectifier circuit shown in the notes on diodes, where the load resistor $R = 1 \text{ k}\Omega$ and $f = 1 \text{ kHz}$. If the fluctuating voltage $\Delta V$ is filtered out by a capacitor, what is the voltage $V_{DC}$ that appears across the load resistor? How much power is delivered by this circuit to the resistor? Compare this result to the time-average power $P$ that would be delivered to the resistor if it was connected directly to the AC voltage source $v_{in}(t)$.

**EKD-2** Repeat problem EKD-1 for the full-wave rectifier circuit shown in the notes on diodes. Comment on the difference from the result of problem EKD-1.

**EK1-1** A 12 V car battery is rated as capable of delivering 15 ampere-hours (Ah). Assuming the battery’s voltage remains constant, for how long can this battery illuminate a 50 W headlamp?

**EK1-2** A battery is supplying a voltage to a light bulb. As the battery wears out, its voltage decreases with time $t$ starting at $t = 0$ as $v(t) = 9e^{-10^{-3}t} \text{ V}$, and as it does so, the current it supplies is $i(t) = 0.1e^{-10^{-3}t} \text{ A}$. Calculate the total energy delivered to the light bulb between $t = 0$ and when the battery is totally exhausted at $t = \infty$.

**EK1-3** A wire connects two reservoirs of charge, equal but opposite in sign as shown.

The charge $q(t)$ in the upper reservoir varies with time as shown. Compute and sketch the current in the wire as a function of time.
EK2-1 A source supplies the currents $i_1$, $i_2$ and $i_3$ to the interconnected elements shown below.

If you know the values of $i_1$, $i_2$ and $i_3$, but nothing about the elements, which of the element currents $i_4$, $i_5$ and $i_6$ can be determined in terms of $i_1$, $i_2$ and $i_3$? Give expression(s) for any currents that can be so expressed. Can you say anything about the currents that cannot be expressed in terms of $i_1$, $i_2$ and $i_3$, and if so, what?

EK2-2 Using the figure for problem 2-21 in the text, if $v_2 = 20$ V, $v_5 = 10$ V and $v_6 = 15$ V, find the values of $v_1$, $v_3$ and $v_4$.

EK2-3 For the circuit shown in the figure below, find the voltages $v_1$, $v_2$, $v_3$ across, and the currents $i_1$, $i_2$ and $i_3$ through, each of the resistors.

Choose the current reference directions according to the passive sign convention and sketch them on a circuit schematic.
EK2-4 For the circuit in problem EK2-3, find the power absorbed in each resistor, and the power delivered by the current source. Verify that the power delivered by the source is equal to the sum of the powers absorbed by the resistors.

EK2-5 For the practical voltage sources shown in the figure, determine the maximum currents $I_{1\text{max}}$ and $I_{2\text{max}}$ that can be supplied to an external circuit.

```
R_1
V_{S1} + _

I_{1\text{max}}

R_2
V_{S2} + _

I_{2\text{max}}

R_1
R_2
V_{S1} + _

I_{\text{max}}

V_{S2} + _
```

Compute the maximum current $I_{\text{max}}$ that can be supplied when the two practical sources are connected in parallel as shown.

EK2-6 Determine a practical current source equivalent circuit (an ideal current source in parallel with a resistor) for the circuit shown below.

```
40 V + _

100 \Omega

100 \Omega
```

Be sure to label polarities and component values on your schematic diagram.
EK2-7 Use the voltage divider principle to determine $v_x$ in the circuit shown below.

\[
\begin{align*}
9 \text{ V} & \quad 20 \ \Omega \\
1.5 \text{ V} & \quad 30 \ \Omega \\
& \quad 40 \ \Omega \\
& \quad + \\
& \quad - \\
& \quad v_x
\end{align*}
\]

EK2-8 Use circuit reduction to determine $i_1$ in the circuit shown below.

\[
\begin{align*}
1.2 \ \text{k\Omega} & \quad 5.1 \ \text{k\Omega} \\
20 \ \text{V} & \quad + \\
2.7 \ \text{k\Omega} & \quad 1 \ \text{k\Omega} \\
& \quad 2.2 \ \text{k\Omega} \\
& \quad i_1
\end{align*}
\]

EK3-1 Three nodes A, B and C exist in a circuit, in addition to the reference node 0. The node-voltage equations for this circuit are

\[
\begin{align*}
v_A &= V_G \\
\frac{v_B - v_A}{R_1} + \frac{v_B - v_C}{R_3} - I_S &= 0 \\
\frac{v_C - v_A}{R_2} + \frac{v_C - v_B}{R_3} + \frac{v_C}{R_4} + I_S &= 0
\end{align*}
\]

where $V_G$ and $I_S$ are a given voltage and a given current respectively. Draw the circuit, labeling each source and resistor together with the nodes and any pertinent reference directions.
**EK3-2** For the circuit shown below, with the indicated labeling of nodes, and reference node 0:

(a) Set up the node-voltage equations for the node voltages \( v_1 \) and \( v_2 \) in this circuit.

(b) From the equations found in part (a), find an expression for \( R_4 \) in terms of the remaining resistances that will guarantee that \( v_1 = v_2 \).

**EK3-3** For the circuit shown below, with the indicated reference node 0:

(a) Label the nodes at which node voltages are defined, and write down the equations of the node-voltage method.

(b) Solve the node-voltage equations and determine the voltage \( v_x \) in the figure.
**EK3-4** For the circuit shown below, with the indicated reference node 0:

(a) Label the nodes at which node voltages are defined, and write down the equations of the node-voltage method.

(b) Solve the node-voltage equations and determine the voltage \( v_x \) in the figure.

**EK4-1** Find the current \( i_O \) and the power \( p_L \) being delivered to the load resistor \( R_L \) in the circuit below. Calculate also the voltage gain \( v_O/v_i \).

**EK4-2** Obtain an expression for the voltage gain \( v_O/v_i \) in the circuit shown below.
**EK4-3** To what passive circuit element is the circuit below equivalent, and why?

![Circuit Diagram](image)

**EK4-4** Find the Thévenin equivalent of the circuit shown below.

![Circuit Diagram](image)

**EK4-5** In the circuit shown below, the resistor $R_F$ has an adjustable value.

![Circuit Diagram](image)

Find an expression for the voltage gain $v_O/v_S$ of this network, if the op-amp is ideal. If $v_S = 1$ V, plot $v_O$ versus $R_F$, starting at $R_F = 0$ and ending when $v_O$ reaches its maximum. Do the same thing if $v_S = 10$ V.
EK4-6 In Example 4-20 on page 200 of the text, suppose that a resistor $R_4$ is connected between nodes B and E of the circuit. What effect does this have on the expression for the output voltage $v_O$?

EK4-7 Repeat Example 4-20 on page 200 of the text for the circuit shown below.

How is $v_O$ different in this case?

EK5-1 A voltage with waveform $v(t) = 25 \cos(120\pi t)$ V and a current with waveform $i(t) = 0.1 \sin(120\pi t)$ A appear at the terminals of a circuit element (passive sign convention assumed). Write an expression for the power $p(t)$ being delivered to the element, and plot the result as a function of time (you may sketch the plot or use mathematical software as you please, but cover the range of $0 < t < \frac{1}{30}$ sec).

EK6-1 A voltage $v(t)$ given by

\[
v(t) = \begin{cases} 
0 \text{ V} & \text{for } t < 0 \\
500t \text{ V} & \text{for } 0 < t < 1 \text{ msec} \\
1 - 500t \text{ V} & \text{for } 1 \text{ msec} < t < 2 \text{ msec} \\
0 \text{ V} & \text{for } t > 2 \text{ msec}
\end{cases}
\]

appears across the terminals of a capacitor with $C = 1\mu F$. Find an expression for the current through this capacitor, and plot the result versus time $t$. 

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**EK6-2** Express the output $v_O(t)$ of the circuit below in terms of the input $v_S(t)$. Draw a block diagram indicating the function of the circuit.

\[ \begin{align*}
\text{20 k\Omega} & \quad \text{10 \mu F} \\
\text{+} & \quad \text{10 k\Omega} \\
\text{−} & \quad \text{30 k\Omega} \\
\end{align*} \]

**EK6-3** Express the output $v_O(t)$ of the circuit below in terms of the input $v_S(t)$.

\[ \begin{align*}
\text{20 k\Omega} & \quad \text{10 \mu F} \\
\text{+} & \quad \text{10 k\Omega} \\
\text{−} & \quad \text{30 k\Omega} \\
\end{align*} \]

**EK7-1** In the circuit below, the switch has been in position A for a very long time, and is changed to position B at time $t = 0$.

\[ \begin{align*}
10 \text{ V} & \quad \text{100 \Omega} \\
\text{+} & \quad \text{A} \\
\text{−} & \quad \text{B} \\
\text{50 \Omega} & \quad v_L(t) \\
\text{5 mH} & \quad + \\
\text{−} & \quad \text{v_L(t)} \\
\end{align*} \]

Obtain an expression for $v_L(t)$ when $t > 0$. 

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**EK7-2** In the circuit below, obtain an expression for $v_1(t)$ when $t > 0$, and determine the time $t_5$ when $v_1(t_5) = 5$ V.

\[ v_C(0) = 18 \text{ V} \]

**EK7-3** In the circuit below, the switch has been in position A for a long time, and is changed to position B at time $t = 0$. Find $v(t)$ for $t > 0$.

**EK7-4** In the circuit below, the switch has been open for a long time, and is closed at time $t = 0$. Find an expression for $i(t)$ for $t > 0$. 

\[ V_A \]
**EK7-5** In the circuit below, the inductor current at $t = 0$ is $i(0) = 0$.

Compute and plot the current $i(t)$ as a function of $t$ for $0 < t < 30 \mu\text{sec}$.

**EK7-6** In the circuit below, the voltage $v$ at $t = 0$ is $v(0) = 0$.

Obtain an expression for $v(t)$ for $t > 0$.

**EK7-7** In the circuit below, the source voltage is

$$v_s(t) = \begin{cases} 
10 \text{ V} & (t < 0) \\
10e^{-100t} \text{ V} & (t > 0)
\end{cases}$$

Obtain an expression for $v(t)$ for $t > 0$.

**EK8-1** Obtain a formula for the equivalent impedance of an inductor $L$ and a capacitor $C$ connected in parallel and operating at an angular frequency $\omega$. What happens to this impedance when $\omega = 1/\sqrt{LC}$?
**EK8-2** Compute the equivalent impedance for the circuit shown below, when the operating frequency is \( f = 2 \) GHz.

![Circuit Diagram](image)

Note that 1 GHz = \( 10^9 \) Hz, 1 nH = \( 10^{-9} \) H and 1 pF = \( 10^{-12} \) F.

**EK8-3** In the circuit shown below, when the radian operating frequency is \( \omega = 10^7 \) rad/sec, for what value of capacitance \( C \) will the equivalent impedance of the circuit be real? What is the value of this real impedance?

![Circuit Diagram](image)

**EK8-4** In the circuit shown below, use the phasor node-voltage method to determine the voltage \( v_x(t) \).

![Circuit Diagram](image)

**EK8-5** In the circuit shown in Figure P8-58 on page 442 of the text, use node-voltage analysis to find the phasor voltage across the inductor (passive sign convention with respect to \( i_2 \)).

200 cos (2000t - 30°) mA
EK8-6 Find the phasor Thévenin equivalent of the circuit in the shaded box shown below.

Use this equivalent circuit to find the voltage $v(t)$ that results when a 500 Ω resistor is connected to the terminals of the box.

EK8-7 The source circuit shown in Figure P8-48 on page 441 of the text has an open circuit voltage of $V_{oc} = 150 - j30$ V, while when a load impedance $Z_L = j300$ Ω is connected, a voltage $V = 100 + j0$ results. Find the phasor Norton equivalent of this circuit.

EK8-8 In the circuit shown below, calculate the time-average powers $P_L$ absorbed by the 100 Ω resistor and $P_{Th}$ absorbed by the 10 Ω resistor, as well as the efficiency

$$\eta = \frac{P_L}{P_L + P_{Th}}$$

with which the power is delivered to the 100 Ω resistor.
**EK15-1** In the circuit below, obtain an expression for the phasor voltage \( V \) and the equivalent impedance \( Z_{eq} \) seen by the current source \( I_0 \).

![Circuit Diagram]

What happens when the coupling coefficient \( k = 1 \)?

**EK15-2** In Fig. 15-13 on page 817 of the text, let \( L_1 = L_2 = 10 \text{ mH}, M = 5 \text{ mH}, \omega = 120\pi \text{ rad/sec}, \) and let \( Z_L \) consist of the series combination of a 50 \( \Omega \) resistor and a capacitor \( C \). For what value of \( C \) will the input impedance \( Z_{IN} \) be real?