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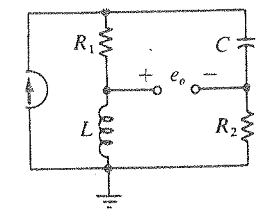

Figure P6.23

***6.24.** Repeat Problem 6.19 for the circuit shown in Figure P6.24.

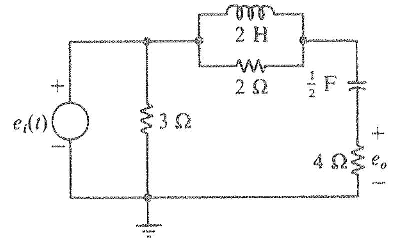

Figure P6.24

6.25. For the circuit shown in Figure P6.25, find a set of state-variable equations and write an algebraic output equation for i_o. Define the variables and show their positive senses on the diagram.

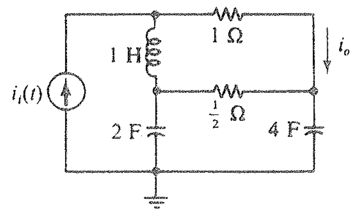

Figure P6.25

6.26. Repeat Problem 6.25 for the circuit shown in Figure P6.26.

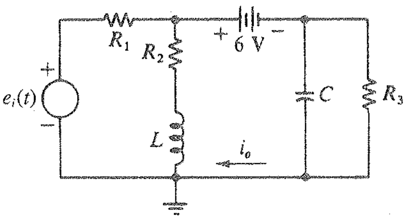

Figure P6.26

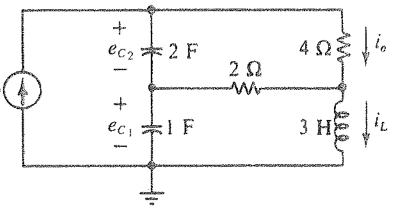

Figure P6.27

***6.27.** Find a set of state-variable equations for the circuit shown in Figure P6.27. Write the algebraic output equation for i_o.

6.28. Find the state-variable equation for the circuit shown in Figure 6.28(a) when the initial choice of the state variable is e_B rather than e_A. Write an algebraic output equation for e_A.

***6.18.**

a. Find a set of state-variable equations describing the circuit shown in Figure P6.18. Define the variables and show their positive senses on the diagram.

b. Write an algebraic output equation for i_o, which is the current through the 6-V source.

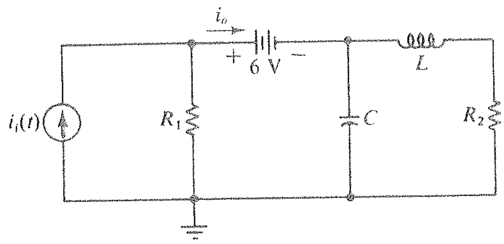

Figure P6.18

6.19. For the circuit shown in Figure P6.6, find a set of state-variable equations and an algebraic output equation for e_o.

6.20. Repeat Problem 6.19 for the circuit shown in Figure P6.7.

***6.21.** Repeat Problem 6.19 for the circuit shown in Figure P6.9.

6.22. Repeat Problem 6.19 for the circuit shown in Figure P6.22.

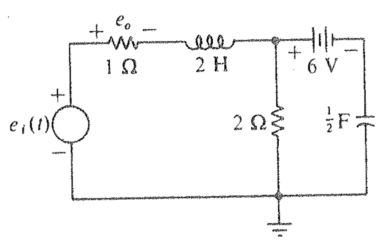

Figure P6.22

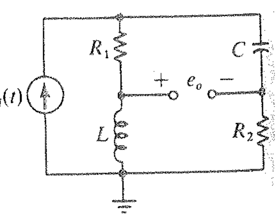

Figure P6.23

6.23. Repeat Problem 6.19 for the circuit shown in Figure P6.23.

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$e_i(t)$.

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6.15. For the circuit shown in Figure P6.15, use the rules for series and parallel resistors to find e_o and the equivalent resistance connected across the source.

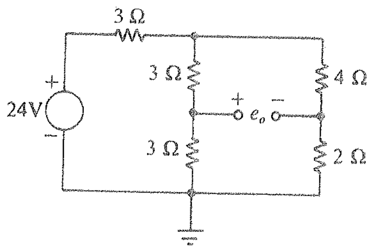

Figure P6.15

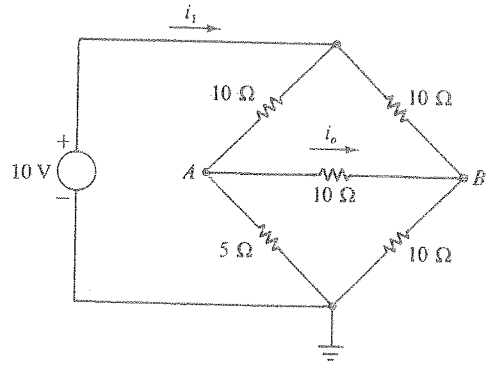

Figure P6.16

6.16.

a. Explain why the rules for series and parallel resistors cannot be used for the circuit shown in Figure P6.16.

b. Use the node-equation method to find the voltages of nodes A and B with respect to the ground node.

c. Find the currents i_o and i_1 and the equivalent resistance connected across the source.

***6.17.** Find e_o for the circuit shown in Figure P6.17.

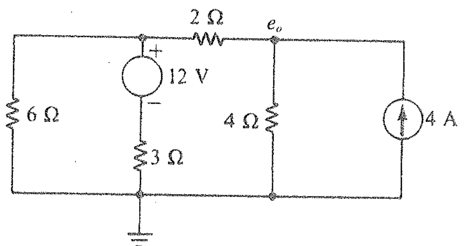

Figure P6.17

6.11.

a. For the circuit shown in Figure P6.11, write current-law equations at nodes A and B to obtain a pair of coupled differential equations in the variables e_A, e_o, and $e_i(t)$.

b. Find the input-output differential equation relating e_o and $e_i(t)$.

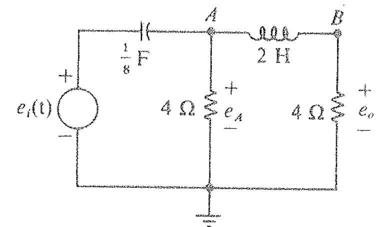

Figure P6.11

***6.12.** For the circuit shown in Figure P6.12, use the node-equation method to find the input-output differential equation relating e_o and $e_i(t)$.

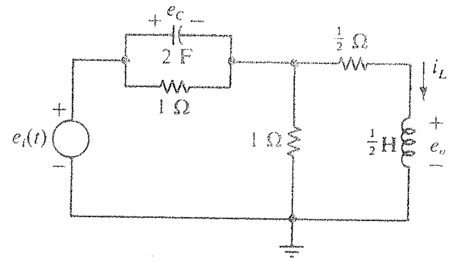

Figure P6.12

6.13. Repeat Example 6.5 with the capacitor C replaced by an inductor L.

6.14. For the circuit shown in Figure P6.14, use the rules for series and parallel combinations of resistors to find i_o and the equivalent resistance connected across the source.

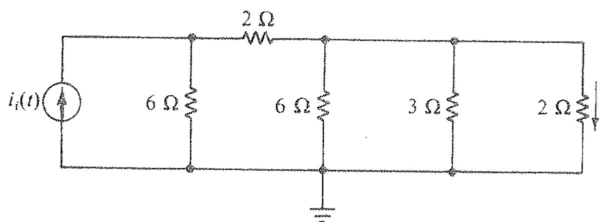

Figure P6.14

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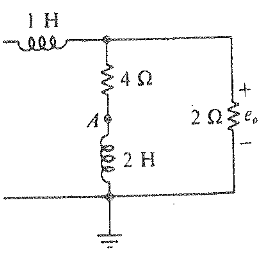

Figure P6.6

*6.7. Repeat Problem 6.5 for the circuit shown in Figure P6.7.

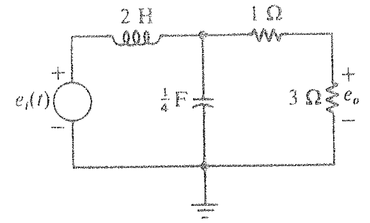

Figure P6.7

6.8. Repeat Problem 6.5 for the circuit shown in Figure P6.8.

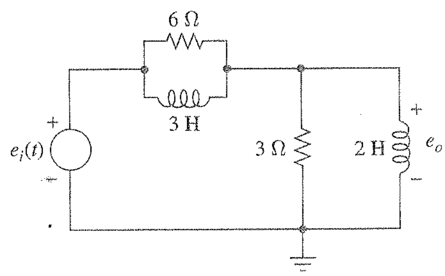

Figure P6.8

*6.9. Repeat Problem 6.5 for the circuit shown in Figure P6.9.

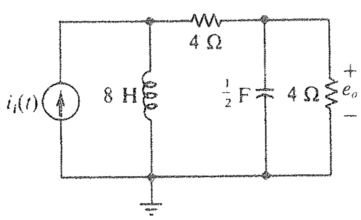

Figure P6.9

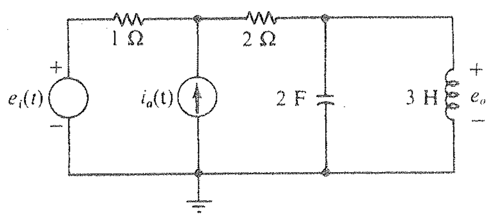

Figure P6.10

6.10. Find the input-output differential equation relating e_o to $e_i(t)$ and $i_a(t)$ for the circuit shown in Figure P6.10.

*6.3. Repeat Problem 6.2 for the circuit shown in Figure P6.3.

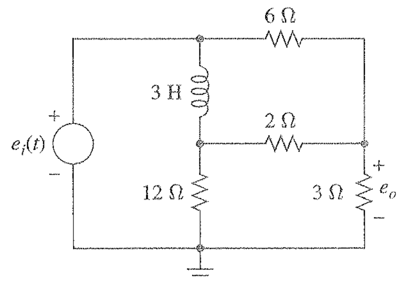

Figure P6.3

6.4. Find the input-output differential equation for the circuit shown in Figure P6.4.

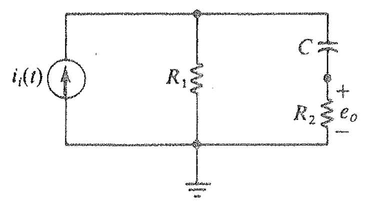

Figure P6.4

6.5. For the circuit shown in Figure P6.5, use the node-equation method to find the input-output differential equation.

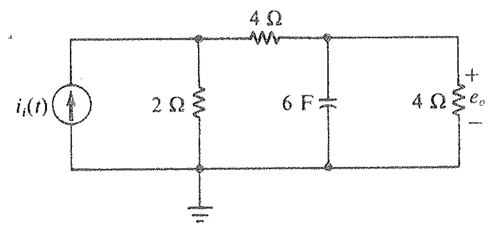

Figure P6.5

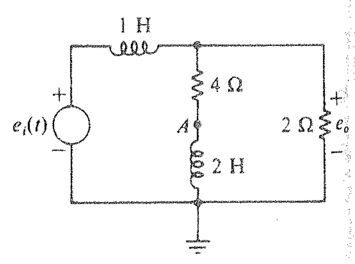

Figure P6.6

6.6. Repeat Problem 6.5 for the circuit shown in Figure P6.6.

SUMMARY

After introducing the element and interconnection laws for electrical circuits, we developed systematic procedures for obtaining both the input-output differential equation and the set of state-variable equations. For the general node-equation method, we select a ground node and label the voltages of the other nodes with respect to ground. We then write current-law equations at the nodes whose voltages are unknown, using the element laws to express the currents through the passive elements in terms of the node voltages. If it becomes necessary to sum currents at a node to which a voltage source is connected, keep in mind that the current through such a source is another unknown variable.

For a state-variable model, we normally choose as state variables the voltage across each capacitor and the current through each inductor. Two types of exceptions to this choice were illustrated in Figure 6.28. As far as possible, unknown variables are labeled on the diagram in terms of state variables and inputs. By using Ohm's law and Kirchhoff's laws, we then express the capacitor currents, the inductor voltages, and any other outputs as algebraic functions of the state variables and inputs. Inserting these expressions into the element laws $\dot{e}_C = (1/C)i_C$ and $di_L/dt = (1/L)e_L$ yields the state-variable model.

The important special case of resistive circuits, including the rules for series-parallel combinations, was treated in Section 6.5. Operational amplifiers were explained in Section 6.7. For an ideal op-amp, no current flows into the input terminals, but the output current is unknown. The op-amp gain is usually large enough so that the voltage between the two input terminals can be assumed to be zero.

PROBLEMS

6.1. Find the input-output differential equation relating e_o and $i_i(t)$ for the circuit shown in Figure P6.1.

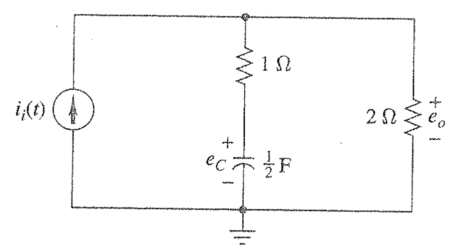

Figure P6.1

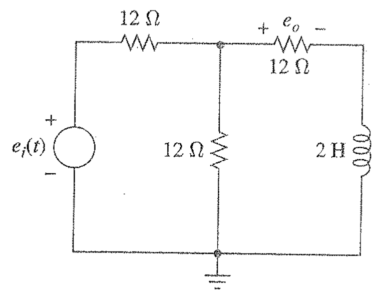

Figure P6.2

6.2. Find the input-output differential equation relating e_o and $e_i(t)$ for the circuit shown in Figure P6.2.