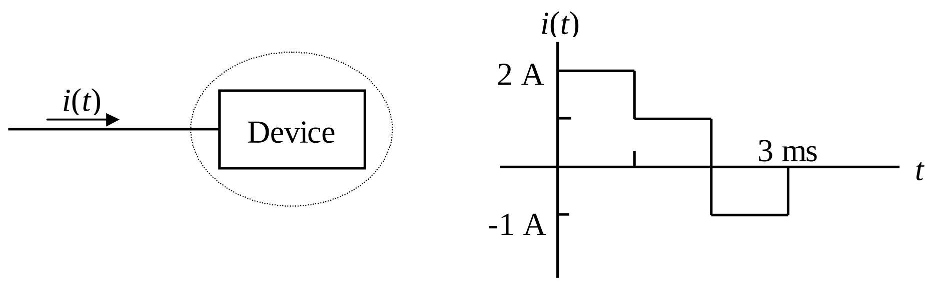
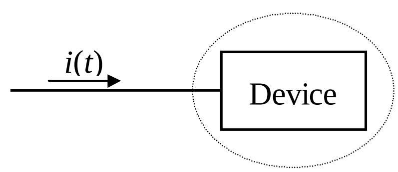
1. Problems

1. The diagram below shows part of a circuit in which a wire carries current into a device. The current is plotted as a function of time. A system boundary is drawn around the device.



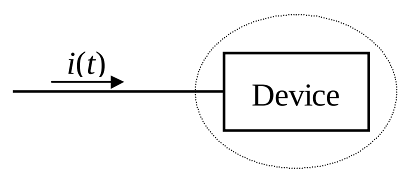
Suppose that the charge stored in the device is zero at time zero. Find and plot the stored charge as a function of time.

2. The diagram below shows part of a circuit in which a wire carries current into a device. The current is given as a function of time by $i(t) = -5e^{-10^3 t}$ mA, $t \geq 0$. A system boundary is drawn around the device. Suppose at time $t = 0$ there is $q_0 = 2\ \mu\text{C}$ of charge stored in the device.



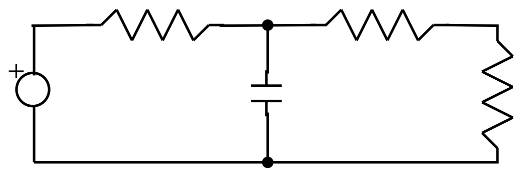
Find the charge stored in the device as a function of time. Plot your result, labeling all significant charge values and times.

3. The diagram below shows part of a circuit in which a wire carries current into a device. A system boundary is drawn around the device. Suppose that the charge stored in the device is given as a function of time by $q_{sys}(t) = 50\cos(2\pi 60 t)$ mC.

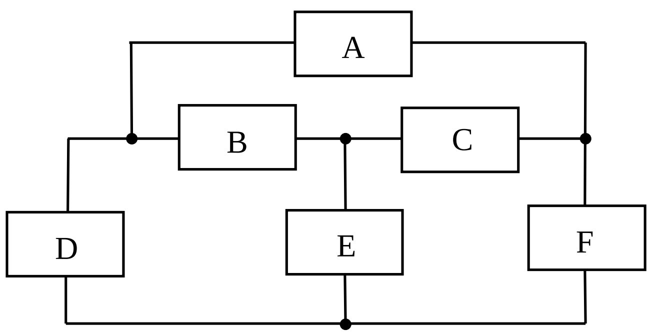


Find the current $i(t)$ as a function of time. Plot your result, showing all significant current values and times.

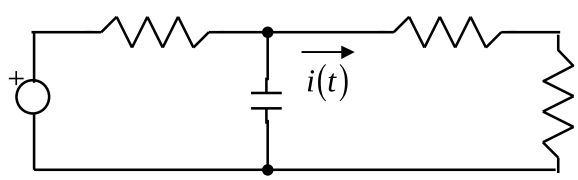
4. The circuit shown below contains five circuit elements including the source.
   A. Label the voltages and currents in the circuit using the passive sign convention.
   B. Now repeat part A, but use the active sign convention for the voltage source.



5. The circuit shown below contains six elements.
   A. Label the element voltages and currents using the passive sign convention.
   B. Repeat part A, but change at least one of your voltage reference directions.

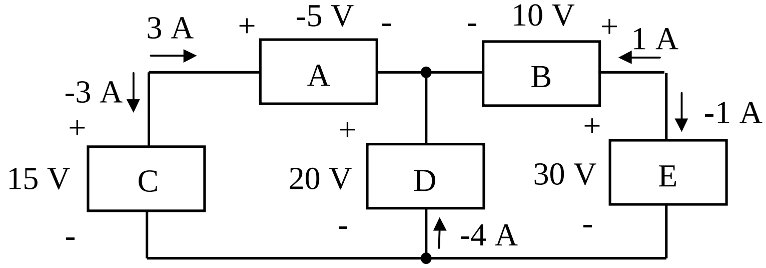


6. In the circuit shown below the current $i(t)$ is given by $i(t) = 2\cos(2\pi 1000t)$ mA .



   A. In which direction (right or left) is the current flowing at time $t = 0$?
   B. In which direction is the current flowing at time $t = 0.5$ ms ?
   C. In copper wire current is caused by the motion of free electrons. In which direction are the electrons responsible for $i(t)$ moving at time $t = 0.5$ ms ?

7. The voltages and currents in the circuit shown below are constant with time.



A. Which elements are labeled using the passive sign convention?
B. Find the power *absorbed* by each element.
C. Determine which elements are sources.

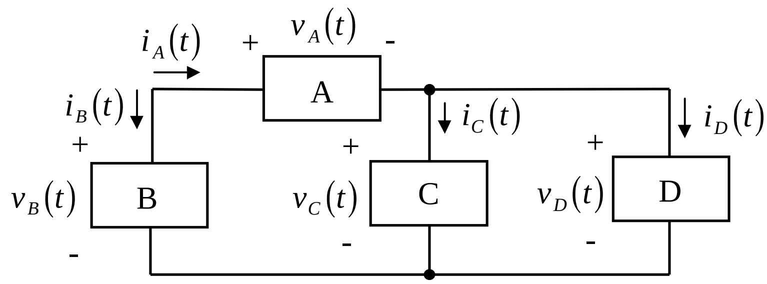
8. In the circuit shown below the voltages and currents are given by

$v_A(t) = 50\cos(2\pi 60t)$ V $\qquad i_A(t) = 4\cos(2\pi 60t)$ mA

$v_B(t) = 150\cos(2\pi 60t)$ V $\qquad i_B(t) = -4\cos(2\pi 60t)$ mA

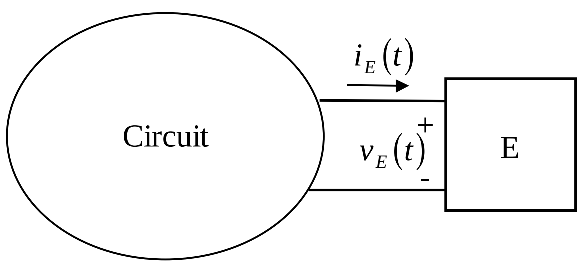
$v_C(t) = 100\cos(2\pi 60t)$ V $\qquad i_C(t) = 10\cos(2\pi 60t)$ mA

$v_D(t) = 100\cos(2\pi 60t)$ V $\qquad i_D(t) = -6\cos(2\pi 60t)$ mA .



A. Find the instantaneous power absorbed by each element.
B. Verify that the sum of the powers absorbed by each element is identically zero.
C. Which of the elements are *always* sources?

9. The diagram below shows a circuit containing an element E whose voltage and current are given by $v_E(t) = 150\left(1 - e^{5000t}\right)$ V and $i_E(t) = 25e^{-5000t}$ mA , respectively.

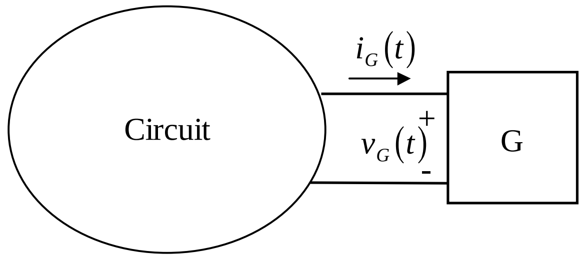


A. Find the instantaneous power absorbed by element E.
B. Find the total energy absorbed by element E.
C. Can you tell what happens to the energy after it has been absorbed by element E?

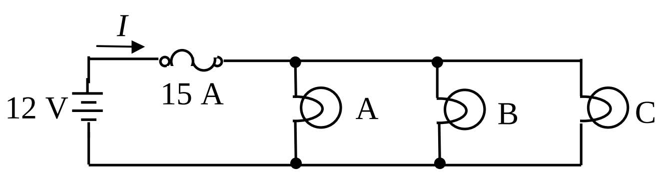
10. The diagram below shows a circuit containing an element G whose voltage and current are given by $v_G(t) = 0.2\cos\left(2\pi 5\times 10^6 t + \frac{\pi}{6}\right)$ V and $i_G(t) = 15\cos\left(2\pi 5\times 10^6 t + \frac{\pi}{3}\right)$ μA , respectively.

A. Find the instantaneous power absorbed by element G.

B. During the interval $0 \le t \le 200$ ns, find the times during which element G absorbs power.
C. During the interval $0 \le t \le 200$ ns, find the times during which element G is a source of power.
D. On the average, is element G a source or a load?

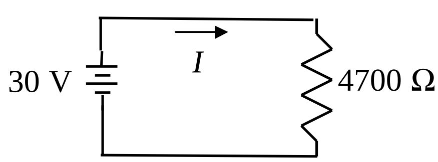


11. The diagram below is a simplification of a part of an automotive lighting circuit. Three light bulbs are connected in a parallel with a 12 V battery. The "15 A" fuse is normally a short circuit, but the metal element inside it will melt causing the fuse to become an open circuit if more than 15 A flows through it. Suppose bulb A draws 36 W, bulb B draws 24 W, and bulb C draws 18 W.



A. How much current is drawn by bulb A? by bulb B? by bulb C?
B. How much power must the battery supply?
C. Using your answer to part B, find the current I.
D. Suppose instead of three dissimilar bulbs as shown, the circuit consists of n type B bulbs in parallel. Find the maximum value of n for which the circuit will operate without blowing the fuse.

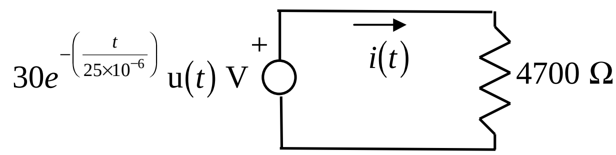
12. In the circuit shown below



A. Find the current I.
B. Find the power delivered to the resistor.

13. A 10 kV power line 5 km long has a total resistance of 0.5 Ω. The current flowing is 15 A. Find the power loss in the line.

14. In the circuit shown below

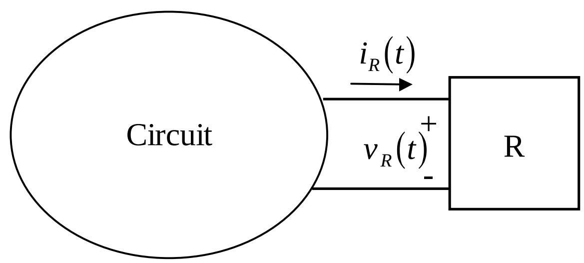


A. Find the current $i(t)$.
B. Find the total energy delivered to the resistor.

15. In the circuit of Problem 11, find the resistance of a light bulb of type A, of type B, of type C.

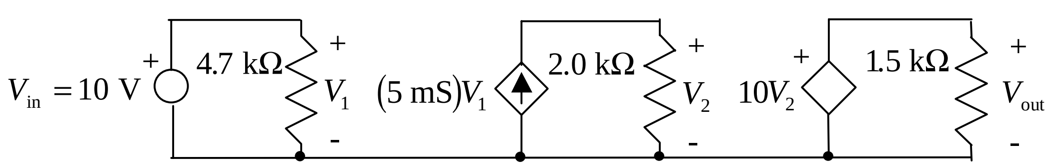
16. In the circuit shown below $v_R(t) = 10\cos\left(2\pi 100t + \frac{\pi}{6}\right)$ V and

$i_R(t) = 0.001\cos\left(2\pi 100t - \frac{\pi}{6}\right)$ A .



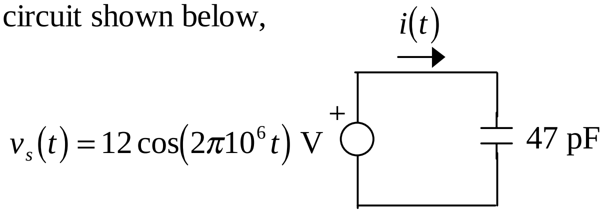
A. Find the instantaneous power delivered to the element R.
B. Could the element R be a resistor? Explain.

17. The circuit shown below is a simplified model of an amplifier.



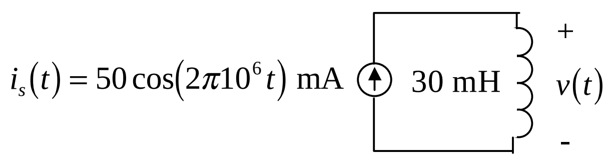
A. Find the output voltage V_{out}.
B. Find the voltage gain $\frac{V_{out}}{V_{in}}$.

18. In the circuit shown below,



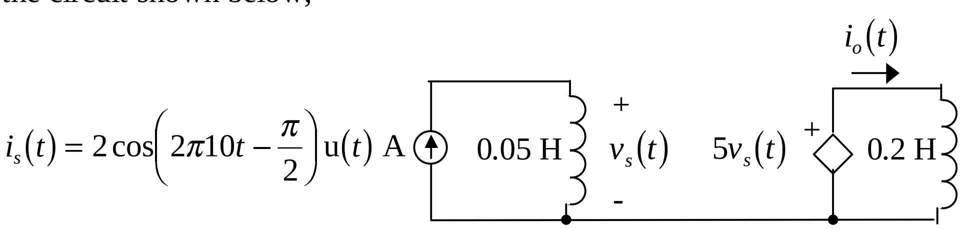
A. Find the current $i(t)$.
B. Plot the voltage $v_s(t)$ and the current $i(t)$ on the same axes. Plot a few cycles, so that the shapes and relationships are clear. You may have to scale one of the quantities to make the plot easy to read.
C. Find the instantaneous power $p(t)$ delivered to the capacitor. Find the energy $W_e(t)$ stored in the capacitor as a function of time. Plot $p(t)$ and $W_e(t)$ on the same axes. Verify that your result satisfies the accounting equation for electrical energy.
D. Plot the stored energy $W_e(t)$ and the voltage $v_s(t)$ on the same axes. Verify that the stored energy is zero whenever the voltage across the capacitor is zero.

19. In the circuit shown below,



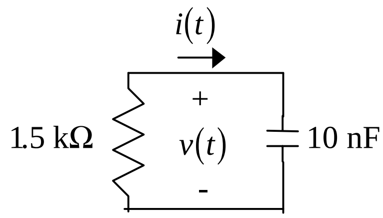
A. Find the voltage $v(t)$.
B. Plot the current $i_s(t)$ and the voltage $v(t)$ on the same axes. Plot a few cycles, so that the shapes and relationships are clear. You may have to scale one of the quantities to make the plot easy to read.
C. Find the instantaneous power $p(t)$ delivered to the inductor. Find the energy $W_m(t)$ stored in the capacitor as a function of time. Plot $p(t)$ and $W_m(t)$ on the same axes. Verify that your result satisfies the accounting equation for electrical and magnetic energy.
D. Plot the stored energy $W_m(t)$ and the current $i_s(t)$ on the same axes. Verify that the stored energy is zero whenever the current through the inductor is zero.

20. In the circuit shown below,



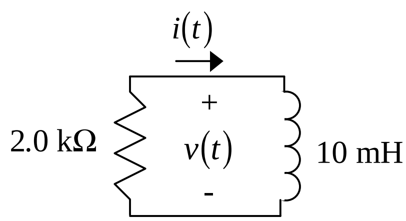
A. Find the output current $i_o(t)$. Assume $i_o(t) \equiv 0$ for $t < 0$. Plot your result, showing all significant current values and times.
B. Find the instantaneous power delivered by the dependent source.
C. Find the energy stored in the 0.2 H inductor as a function of time. Plot your result, showing all significant energy values and times.

21. In the circuit shown below $v(t) = 25e^{-\left(\frac{t}{15\times10^{-6}}\right)}$ V, $t \geq 0$.



A. Find the current $i(t)$. Be careful about the reference direction.
B. Find the instantaneous power $p(t)$ flowing into the capacitor.
C. For $t \geq 0$ is power actually flowing from the capacitor to the resistor or from the resistor to the capacitor?
D. Find the energy $W_e(0)$ stored in the capacitor at time $t = 0$.
E. Find the total energy turned into heat in the resistor during the interval $0 \leq t < \infty$.

22. In the circuit shown below $i(t) = 5.00e^{-\left(\frac{t}{5\times10^{-6}}\right)}$ mA, $t \geq 0$.



A. Find the voltage $v(t)$. Be careful about the reference direction.
B. Find the instantaneous power $p(t)$ flowing into the inductor.
C. For $t \geq 0$ is power actually flowing from the inductor to the resistor or from the resistor to the inductor?
D. Find the energy $W_m(0)$ stored in the inductor at time $t = 0$.
E. Find the total energy turned into heat in the resistor during the interval $0 \leq t < \infty$.