3.10 Problems

(Assume zero initial condition unless specified otherwise. Passive sign convention is assumed.)

1. A voltage source is first connected across A-B in the circuit in Fig. 3.10-1. Later it is moved and connected across C-D. Find the ratio of power delivered by the voltage source in the two cases.

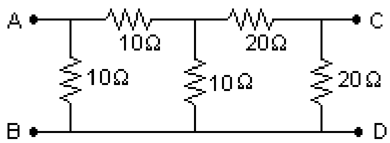

Fig. 3.10-1

2. Find i_x in Fig. 3.10-2.

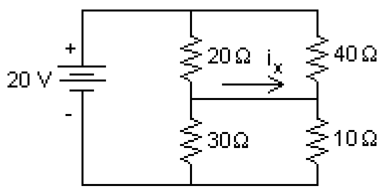

Fig. 3.10-2

3. The power dissipated in the 4Ω resistor is 1W in the circuit in Fig. 3.10-3. Find the power dissipated in the 3Ω resistor, power delivered by the dc source and the value of source voltage.

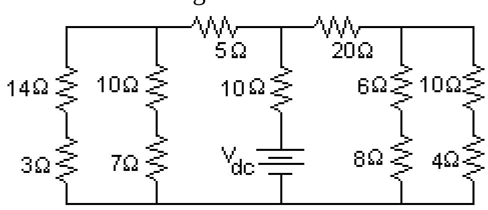

Fig. 3.10-3

4. A voltage of 5V is to be produced from a dc voltage source of 24V by a potential divider arrangement. The 5V output will be loaded by a resistance in the range 1 kΩ - 10 kΩ. The output voltage should not vary by more than 2% when the load varies in this range. Design the potential divider such that the no-load power dissipation in it is at minimum possible value.

5. The power dissipated in 15Ω resistor is 15W and power dissipated in R_2 is 5W in the circuit in Fig. 3.10-4. (i) Find R_1 and R_2. (ii) Solve the circuit completely and mark voltage, current and power dissipated for all elements.

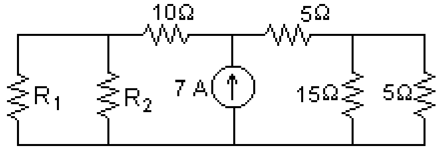

Fig. 3.10-4

6. (i) Find the value of R in the circuit in Fig. 3.10-5 such that R dissipates 200W of power.(ii) What is the additional resistor to be connected in parallel to R such that total power dissipated by R and the additional resistor will be 400W?

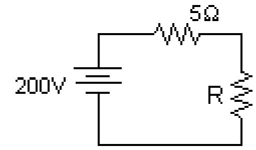

Fig. 3.10-5

7. What must be the value of R such that i_x is zero in the circuit in Fig. 3.10-6.

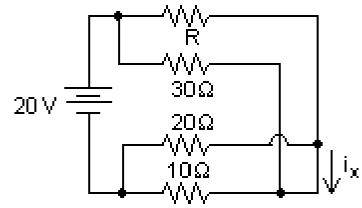

Fig. 3.10-6

8. What must be the value of R in Fig. 3.10-7 such that shorting A to B will not affect the current through R ?

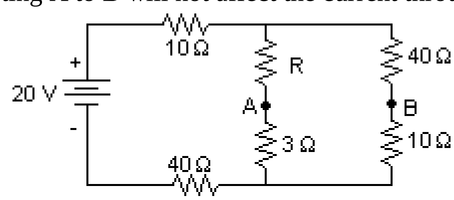

Fig. 3.10-7

9. The *unit step function* was described in Eqn. 3.2-4. The function $u(t\text{-}t_0)$ is termed as a *delayed unit step function*.

$$u(t-t_0)=\begin{cases} 0 \text{ for } (t-t_0)\le 0^- \\ \textit{undefined} \text{ for } 1 \text{ for } (t-t_0)=0 \\ 1 \text{ for } (t-t_0)\ge 0^+ \end{cases}$$

Therefore the jump from 0 to 1 takes place at t_0 *i.e.*, after a delay of t_0 sec. What is the applied voltage function across an inductor of 0.5H if its current is $2u(t\text{-}2)$?

10. Another standard test signal frequently used in Electrical and Electronics Engineering is the *unit ramp function* defined as

$$r(t)=\begin{cases} 0 & \text{for } t<0 \\ t & \text{for } t\ge 0 \end{cases}.$$

(i) Show that unit ramp is the integral of unit step function. (ii) Find the voltage across a 0.25H inductor when its current is $(5+25t)$ for $t\ge 0^+$ and 0 A for $t\le 0^-$.

11. The voltage applied across an inductor of 0.3H is a rectangular pulse of height 10V and duration 30 ms. The pulse starts at t = 20 ms. (i) Express the voltage waveform in terms of scaled and delayed unit step functions. (ii) Obtain an expression for the current in the inductor as a function of time for $t \ge 10$ ms if the initial current at 10 ms is 1A. (iii) Plot the current in inductor, power delivered to the inductor and energy storage in inductor as functions of time.

12. The value of $i_L(t)$ is found to be 10A at 18 sec in the circuit in Fig. 3.10-8. Find the ratio of initial energy storage in the inductor to stored energy in it at 17 sec.

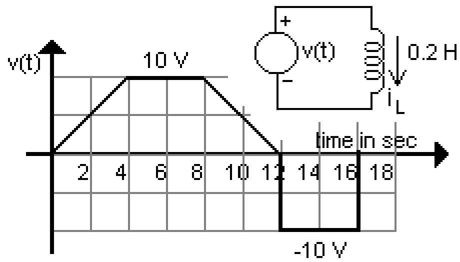

Fig. 3.10-8

13. A periodic ramp voltage waveform applied across the 2 mH inductor in Fig. 3.10-9 from t = 0. (i) What must be the initial current and initial energy storage in the inductor such that there is no dc component in the inductor after t = 0? (ii) Calculate and plot the inductor current and stored energy for one period with initial current at the value calculated above. (iii) Find the average power delivered by the source, the average being taken over a cycle.

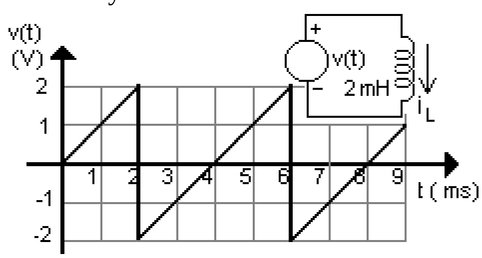

Fig. 3.10-9

14. A sinusoidal voltage $v_S(t) = 10 \sin(400t + \pi/3)$ is applied to a 25 mH inductor from t = 0. (i)Plot the current, power and stored energy in the inductor as functions of time for one period of input voltage. (ii) What is the dc content in the inductor current? (iii) What is the initial current to be specified at t = 0- such that the dc content in the inductor current will be zero? (iv) What is the frequency of power variation with this value of initial current?
15. A voltage source $v_S(t) = 5e^{0.5\,t}\,[u(t) - u(t\text{-}2)]$ volts is connected across an inductor of 0.5H. The initial current specified at t = 0- is 2A.(i) Plot the applied voltage and inductor current for t =0 to 3 sec. (ii) What is the value of current and stored energy in the inductor at t = 4 sec ?
16. An arbitrary voltage is applied across a 0.4H inductor from t = 0. The current in inductor was observed to be 3A at 1.5 s. The stored energy in it was found to quadruple in the next 0.2 seconds. Explain why the applied voltage could not have been less than 6V in the entire interval [1.5s, 1.7s].
17. An inductor used as a smoothing inductor in a dc power supply is expected to carry a dc current of 10A. At the same time a periodic voltage with a waveform shown in Fig. 3.10-10 will get applied across it. Find the minimum value of inductance such that the current in inductor will not get perturbed by more than ± 2% of its dc value. Assume that the value of dc current given includes the dc component due to this periodic voltage also.

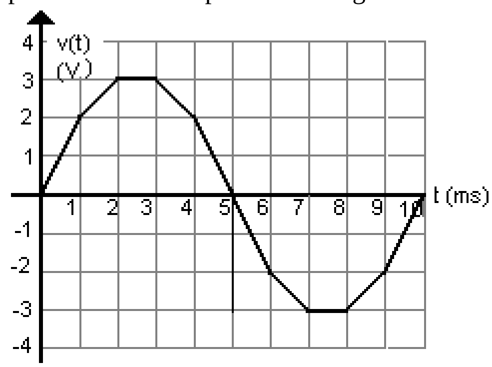

Fig. 3.10-10

18. The switch S in Fig. 3.10-11 starts at position-1 at t = 0 with initial current in 1 mH at zero. It remains at position-1 for 1 ms and then goes to position-2 and remains there for 0.1 ms. After that it is brought back to position-1 and the entire cycle is repeated. (i) Find the value of V_{dc} such that the inductor current reaches zero just prior to the switch going back to position-1. (ii) With this value of V_{dc} , calculate and plot v_L , i_L , i_S and i_{dc} for two switching cycles. (iii) Calculate the average values of v_L, i_L, i_S, i_{dc} and power flow from 10 V source to the second source. Averaging is to be done over a switching cycle.(iv) Assume that the first switching cycle was 1.5 ms/0.1 ms and all the subsequent cycles were 1ms/0.1 ms. Repeat step (iii) for a cycle after the first one. (v) Suggest a method to control the power flow to the second source.

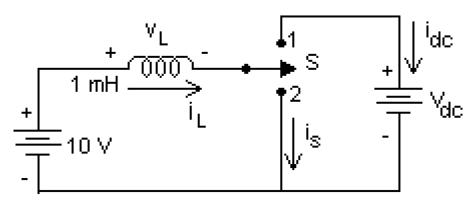

Fig. 3.10-11

19. The switch S in Fig. 3.10-12 starts at position-1 at t = 0 with initial current in 1mH at zero. It remains at position-1 for 1 ms and then goes to position-2 and remains there for 0.02 ms. After that it is brought back to position-1 and the entire cycle is repeated. (i) Find the value of V_{dc} such that the inductor current reaches zero just prior to the switch going back to position-1. (ii) With this value of V_{dc} , calculate and plot v_L , i_L ,i_{s1} and i_{s2} for two switching cycles. (iii) Calculate the average values of v_L , i_L ,i_{s1}, i_{s2} and power flow from 10 V source to the second source. Averaging is to be done over a switching cycle.

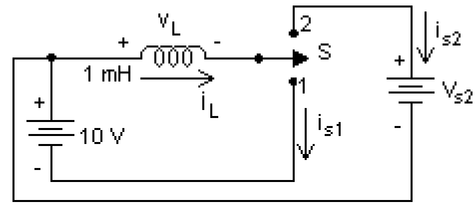

Fig. 3.10-12

20. All the inductors in the circuit in Fig. 3.10-13 had zero initial energy. The applied source voltage is $v_S(t)$ = (10 sin 2000πt)$u(t)$ volts. Find and plot the waveform of current drawn from the source, current in $L_4$and voltage across L_4.

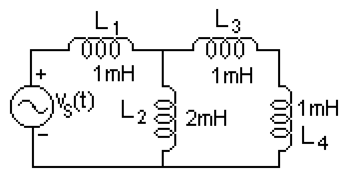

Fig. 3.10-13

21. Three inductors of 0.1H, 0.05H and 0.15H with equal initial current of 3A are connected in series at t = 0. $v(t)$ from $t = 0^-$ is 0.5δ(t-2) + $v_S(t)$ where $v_S(t)$ is not known. The total flux linkage in the circuit is found to double in the first 3 seconds. and $v(t)$ at t = 3 s is found to be 12V. (i) Find the voltage across each inductor and flux linkages in them at t = 3 s (ii) The average value of $v_S(t)$ in the first 3 s (iii) Stored energy in the circuit and each inductor at t = 3 s (iv) Total energy delivered by the applied voltage source in 3 s and average power delivered by the source over 3 s?
22. Three inductors – 0.02H, 0.05H and 0.0333H-with same initial current of 2A are connected in parallel and a voltage of 0.1δ (t-0.002)+$v_S(t)$ is applied across them. The flux linkage in the 0.05 H inductor is found to be 0.3 Wb-T at t = 5 ms. (i) Find the trapped energy in the parallel combination (ii) Find the current through each inductor and flux linkages in them at t = 5 ms (iii) The average value of $v_S(t)$ in the first 5 ms (iv) Stored energy in the circuit and in each inductor at t = 5 ms (v) Total energy delivered by the applied voltage source in 5 ms and average power delivered by the source over 5 ms?
23. What is the applied current into a capacitor of 0.02 F if its voltage is 5u(t-3)?
24. What must be the charging current function if the voltage across an initially uncharged 10 μF capacitor is to vary as (5+2t) $u(t)$ volts ?
25. The current applied into a capacitor of 10 mF is a rectangular pulse of height 10 A and duration 25 ms. The pulse starts at t = 10 ms. (i) Express the current waveform in terms of scaled and delayed unit step functions. (ii) Obtain voltage across the capacitor as a function of time for $t \geq$ 10 ms if the initial voltage at 10 ms is –10 V. (iii) Plot the voltage across capacitor, power delivered to the capacitor and energy storage in it as functions of time.
26. The value of $v_C(t)$ is found to be 10 V at 18 ms in the circuit in Fig. 3.10-14. Find the ratio of initial energy storage in the capacitor to stored energy in it at 17 ms.

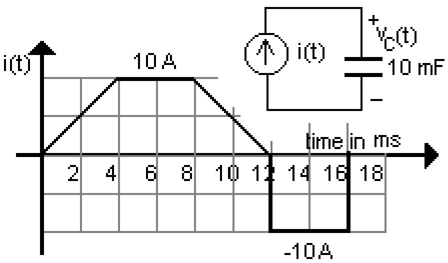

Fig. 3.10-14

27. The periodic ramp current waveform in Fig. 3.10-15 is applied into a 100pF capacitor from t = 0. (i) What must be the initial voltage and initial energy storage in the capacitor such that there is no dc component in the capacitor voltage after t = 0? (ii) Calculate and plot the capacitor voltage and stored energy for one period with initial voltage at the value calculated above. (iii) Find the average power delivered by the source, the average being taken over a cycle.

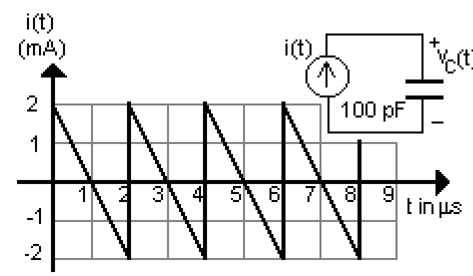

Fig. 3.10-15

28. A sinusoidal current $i_S(t)$ = 2 sin(400t + π/3) A is applied to a 20 μF capacitor from t = 0. (i)Plot the voltage, power and stored energy in the capacitor as functions of time for one period of input current. (ii) What is the dc content in the capacitor voltage? (iii) What is the initial voltage to be specified at t = 0- such that the dc content in the capacitor voltage will be zero? (iv) What is the frequency of power variation with this value of initial voltage?
29. A current source $i_S(t) = 5e^{1.5\,t}$ [$u(t)$ - u(t-1)] mA is connected across capacitor of 470 μF. The initial voltage specified at t = 0- is 2 V.(i) Plot the applied current and capacitor voltage for t =0 to 2 sec. (ii) What is the value of voltage and stored energy in the capacitor at t = 4 sec ?
30. An arbitrary current is applied to a 0.1F capacitor from t = 0. The voltage across capacitor was observed to be 10V at 2 s. The stored energy in it was found to quadruple in the next 0.5 seconds. Explain why the applied current could not have been less than 2 A in the entire interval [2s, 2.5s].
31. The circuit in Fig. 3.10-16 shows an idealized model for the output of a dc power supply. The output is taken across the bulk capacitor C. Load on the supply is

modeled as a current source of value i_L. i_L has a dc component and pure ac component. Its ac component is shown in the same figure. The voltage across the capacitor is found to have a dc component of 12 V and rest of the power supply circuit is in effect delivering a constant current of 5A to the capacitor node. (i) What must be the value of dc component in load current i_L? (ii) What must be the minimum value of C such that the peak-to-peak ripple voltage at output will be less than 2% of its dc value?

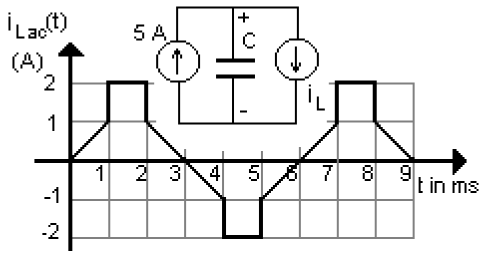

Fig. 3.10-16

32. The capacitance values of C_1 , C_2 , C_3 and C_4 in Fig. 3.10-17 are 20μF, 10μF, 20μF and 20μF respectively. They had zero initial energy at $t = 0^-$. The applied source is (200 sin 300t)u(t) volts. Find and plot (i) the current drawn from the source (ii) the voltage across C_4 and current through it.

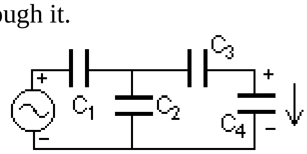

Fig. 3.10-17

33. The source in the circuit in Fig. 3.10-18 is (2 cos 300t)u(t) amps. Find and plot (i) the voltage across the source (ii) the voltage across C_4 and current through it. $C_1 = C_3 = C_4 = 10\ \mu$F, $C_2 = 5\mu$F

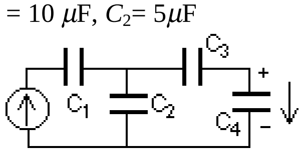

Fig. 3.10-18

34. All the three capacitors in Fig. 3.10-19 had equal initial voltages at $t = 0^-$. The source current is zero for $t > 8$ ms. The voltage across the 10μF capacitor is observed to be 4V at t= 2 ms.(i) What was the initial voltage across the capacitors and what were the initial stored energy in them ? (ii) Calculate and plot the voltage across the capacitors and the voltage across the current source as functions of time for 0 to 9 ms range. (iii) Calculate the total energy delivered by the current source, total energy dissipated in the resistor and change in stored energy of all the capacitors.

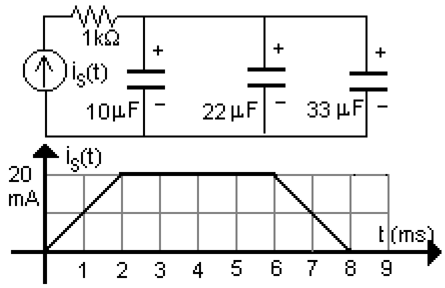

Fig. 3.10-19

35. Three capacitors – 0.02 mF, 0.05 mF and 0.0333 mF – with same initial voltage of 10V are connected in series. The applied current source is $i_S(t)$ mA where $i_S(t)$ is not known. The charge in the 0.05 mF capacitor is found to be 0.3 mC at t = 3 s. (i) Find the trapped energy in the series combination (ii) Find the voltage across each capacitor and charges in them at t = 3 s (iii) The average value of $i_S(t)$ in the first 3 s (iv) Stored energy in the circuit and in each capacitor at t = 3 s (v) Total energy delivered by the applied current source in 3 s and average power delivered by the source over 3 s?