

$$1. \quad i = C \frac{dv}{dt}$$

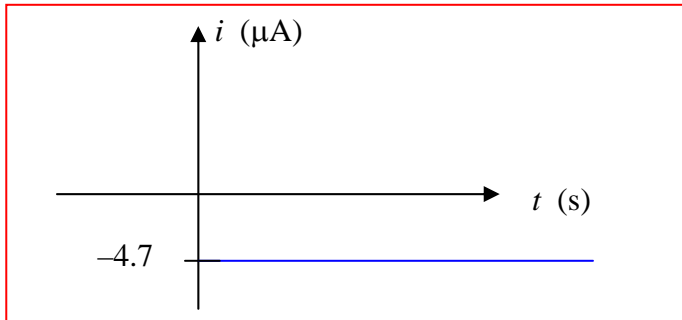
$$(a) \quad i = 0 \quad (\text{DC})$$

$$(b) \quad i = C \frac{dv}{dt} = -(10 \times 10^{-6})(115\sqrt{2})(120\pi) \sin 120\pi t = -613 \sin 120\pi t \text{ mA}$$

$$(c) \quad i = C \frac{dv}{dt} = -(10 \times 10^{-6})(4 \times 10^{-3})e^{-t} = -40e^{-t} \text{ nA}$$

$$2. \quad i = C \frac{dv}{dt}$$

$$v = \frac{6-0}{0-6}t + 6 = 6 - t, \text{ therefore } i = C \frac{dv}{dt} = -4.7 \times 10^{-6} \mu\text{A}$$



$$3. \quad i = C \frac{dv}{dt}$$

$$(a) \quad \frac{dv}{dt} = 30[e^{-t} - te^{-t}] \quad \text{therefore} \quad i = 10^{-3} \frac{dv}{dt} = 30(1-t)e^{-t} \text{ mA}$$

(b)

$$\frac{dv}{dt} = 4[-5e^{-5t} \sin 100t + 100e^{-5t} \cos 100t]$$

$$\text{therefore} \quad i = 10^{-3} \frac{dv}{dt} = 4e^{-5t} (100 \cos 100t - 5 \sin 100t) \text{ mA}$$

$$4. \quad W = \frac{1}{2}CV^2$$

$$(a) \quad \left(\frac{1}{2}\right)(2000 \times 10^{-6})1600 = \boxed{1.6 \text{ J}}$$

$$(b) \quad \left(\frac{1}{2}\right)(25 \times 10^{-3})(35)^2 = \boxed{15.3 \text{ J}}$$

$$(c) \quad \left(\frac{1}{2}\right)(10^{-4})(63)^2 = \boxed{198 \text{ mJ}}$$

$$(d) \quad \left(\frac{1}{2}\right)(2.2 \times 10^{-3})(2500) = \boxed{2.75 \text{ J}}$$

$$(e) \quad \left(\frac{1}{2}\right)(55)(2.5)^2 = \boxed{171.9 \text{ J}}$$

$$(f) \quad \left(\frac{1}{2}\right)(4.8 \times 10^{-3})(50)^2 = \boxed{6 \text{ J}}$$

$$5. \quad (a) \quad C = \frac{\epsilon A}{d} = \frac{8.854 \times 10^{-12} (78.54 \times 10^{-6})}{100 \times 10^{-6}} = 6.954 \text{ pF}$$

$$(b) \quad \text{Energy, } E = \frac{1}{2} CV^2 \therefore V = \sqrt{\frac{2E}{C}} = \sqrt{\frac{2(1 \times 10^{-3})}{6.954 \times 10^{-12}}} = 16.96 \text{ kV}$$

$$(c) \quad E = \frac{1}{2} CV^2 \therefore C = \frac{2E}{V^2} = \frac{2(2.5 \times 10^{-6})}{(100^2)} = 500 \text{ pF}$$

$$C = \frac{\epsilon A}{d} \therefore \epsilon = \frac{Cd}{A} = \frac{(500 \times 10^{-12})(100 \times 10^{-6})}{(78.54 \times 10^{-6})} = 636.62 \text{ pF} \cdot \text{m}^{-1}$$

$$\backslash \text{Relative permittivity: } \frac{\epsilon}{\epsilon_0} = \frac{636.62 \times 10^{-12}}{8.854 \times 10^{-12}} = 71.9$$

$$6. \quad (a) \quad \text{For } V_A = -1\text{V}, W = \sqrt{\frac{2K_s \epsilon_0}{qN} (V_{bi} - V_A)} = \sqrt{\frac{2(11.8)(8.854 \times 10^{-12})}{(1.6 \times 10^{-19})(1 \times 10^{24})}} (0.57 + 1)$$

$$= 45.281 \times 10^{-9} \text{ m}$$

$$C_j = \frac{11.8(8.854 \times 10^{-12})(1 \times 10^{-12})}{45.281 \times 10^{-9}} = 2.307 \text{ fF}$$

$$(b) \quad \text{For } V_A = -5\text{V}, W = \sqrt{\frac{2K_s \epsilon_0}{qN} (V_{bi} - V_A)} = \sqrt{\frac{2(11.8)(8.854 \times 10^{-12})}{(1.6 \times 10^{-19})(1 \times 10^{24})}} (0.57 + 5)$$

$$= 85.289 \times 10^{-9} \text{ m}$$

$$C_j = \frac{11.8(8.854 \times 10^{-12})(1 \times 10^{-12})}{85.289 \times 10^{-9}} = 1.225 \text{ fF}$$

$$(c) \quad \text{For } V_A = -10\text{V},$$

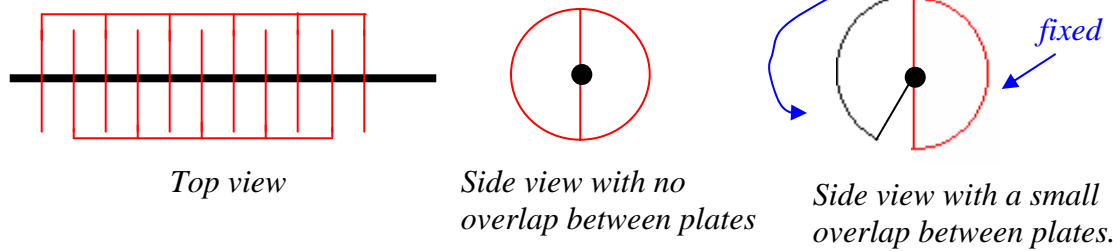
$$W = \sqrt{\frac{2K_s \epsilon_0}{qN} (V_{bi} - V_A)} = \sqrt{\frac{2(11.8)(8.854 \times 10^{-12})}{(1.6 \times 10^{-19})(1 \times 10^{24})}} (0.57 + 10)$$

$$= 117.491 \times 10^{-9} \text{ m}$$

$$C_j = \frac{11.8(8.854 \times 10^{-12})(1 \times 10^{-12})}{117.491 \times 10^{-9}} = 889.239 \text{ aF}$$

7.

We require a capacitor that may be manually varied between 100 and 1000 pF by rotation of a knob. Let's choose an air dielectric for simplicity of construction, and a series of 11 half-plates:



Constructed as shown, the half-plates are in parallel, so that each of the 10 pairs must have a capacitance of $1000/10 = 100$ pF when rotated such that they overlap completely. If we arbitrarily select an area of 1 cm^2 for each half-plate, then the gap spacing between each plate is $d = \epsilon A/C = (8.854 \times 10^{-14} \text{ F/cm})(1 \text{ cm}^2)/(100 \times 10^{-12} \text{ F}) = 0.8854 \text{ mm}$. This is tight, but not impossible to achieve. The final step is to determine the amount of overlap which corresponds to 100 pF for the total capacitor structure. A capacitance of 100 pF is equal to 10% of the capacitance when all of the plate areas are aligned, so we need a pie-shaped wedge having an area of 0.1 cm^2 . If the middle figure above corresponds to an angle of 0° and the case of perfect alignment (maximum capacitance) corresponds to an angle of 180° , we need to set out minimum angle to be 18° .

$$8. \quad (a) \quad \text{Energy stored} = \int_{t_0}^t v \cdot C \frac{dv}{dt} = C \int_0^{2 \times 10^{-3}} 3e^{-\frac{t}{5}} \cdot \left(-\frac{3}{5} e^{-\frac{t}{5}}\right) dt = \boxed{-1.080 \mu J}$$

$$(b) \quad V_{\max} = 3 \text{ V}$$

$$\text{Max. energy at } t=0, = \frac{1}{2} CV^2 = 1.35 \text{ mJ} \therefore 37\% E_{\max} = 499.5 \mu J$$

$$V \text{ at } 37\% E_{\max} = 1.825 \text{ V}$$

$$v(t) = 1.825 = 3e^{-\frac{t}{5}} \therefore t = 2.486 \text{ s} \Rightarrow \boxed{2 \text{ s}}$$

$$(c) \quad i = C \frac{dv}{dt} = 300 \times 10^{-6} \left(-\frac{3}{5} e^{-\frac{1.2}{5}}\right) = \boxed{-141.593 \mu A}$$

$$(d) \quad P = vi = 2.011 \left(-120.658 \times 10^{-6}\right) = \boxed{-242.6 \mu W}$$

9. (a) $v = \frac{1}{C} \cdot \frac{\pi}{2} (1 \times 10^{-3})^2 = \frac{1}{47 \times 10^{-6}} \cdot \frac{(3.14159)}{2} (1 \times 10^{-3})^2 = 33.421mV$
- (b) $v = \frac{1}{C} \cdot \left(\frac{\pi}{2} (1 \times 10^{-3})^2 + 0 \right) = \frac{1}{47 \times 10^{-6}} \cdot \frac{(3.14159)}{2} (1 \times 10^{-3})^2 = 33.421mV$
- (c) $v = \frac{1}{C} \cdot \left(\frac{\pi}{2} (1 \times 10^{-3})^2 + \frac{\pi}{4} (1 \times 10^{-3})^2 \right) = \frac{1}{47 \times 10^{-6}} \cdot \left(\frac{3\pi}{4} (1 \times 10^{-3})^2 \right) = 50.132mV$

$$10. \quad V = \frac{1}{C} \int_0^{200ms} i dt = \frac{1}{C} \left[\left(-\frac{7 \times 10^{-3}}{\pi} \cos \pi t \right) \right]_0^{200ms} = \frac{0.426}{C}$$

$$E = \frac{1}{2} CV^2 = 3 \times 10^{-6} = \frac{181.086 \times 10^{-9}}{2C} \therefore C = \frac{181.086 \times 10^{-9}}{2(3 \times 10^{-6})} = \boxed{30181 \mu F}$$

11.

$$(a) \quad c = 0.2 \mu\text{F}, v_c = 5 + 3 \cos^2 200t \text{V}; \therefore i_c = 0.2 \times 10^{-6} (3) (-2) 200 \sin 200t \cos 200t$$

$$\therefore i_c = -0.12 \sin 400t \text{mA}$$

$$(b) \quad w_c = \frac{1}{2} c v_c^2 = \frac{1}{2} \times 2 \times 10^{-7} (5 + 3 \cos^2 200t)^2 \therefore w_{c \max} = 10^{-7} \times 64 = 6.4 \mu\text{J}$$

$$(c) \quad v_c = \frac{1}{0.2} \times 10^6 \int_0^t 8e^{-100t} \times 10^{-3} dt = 10^3 \times 40(-0.01)(e^{-100t} - 1) = 400(1 - e^{-100t}) \text{V}$$

$$(d) \quad v_c = 500 - 400e^{-100t} \text{V}$$

12. $v_c(0) = 250\text{V}$, $c = 2\text{mF}$ (a) $v_c(0.1) = 250 + 500 \int_0^{0.1} 5 dt$
 $\therefore v_c(0.1) = 500\text{V}; v_c(0.2) = 500 \int_{0.1}^{0.2} 10 dt = 1000\text{V}$
 $\therefore v_c(0.6) = 1750\text{V}, v_c(0.9) = 2000\text{V}$
 $\therefore 0.9 < t < 1: v_c = 2000 + 500 \int_{0.9}^t 10 dt = 2000 + 5000(t - 0.9)$
 $\therefore v_c = 2100 = 2000 + 5000(t_2 - 0.9) \therefore t_2 = 0.92 \therefore 0.9 < t < 0.92\text{s}$

13.

$$(a) \quad w_c = \frac{1}{2} C v^2 = \frac{1}{2} \times 10^{-6} v^2 = 2 \times 10^{-2} e^{-1000t} \therefore v = \pm 200 e^{-500t} \text{ V}$$

$$i = C v' = 10^{-6} (\pm 200) (-500) e^{-500t} = \mp 0.1 e^{-500t}$$

$$\therefore R = \frac{-v}{i} = \frac{200}{0.1} = 2k\Omega$$

$$(b) \quad P_R = i^2 R = 0.01 \times 2000 e^{-1000t} = 20 e^{-1000t} \text{ W}$$

$$\therefore W_R = \int_0^{\infty} 20 e^{-1000t} dt = -0.02 e^{-1000t} \Big|_0^{\infty} = 0.02 \text{ J}$$

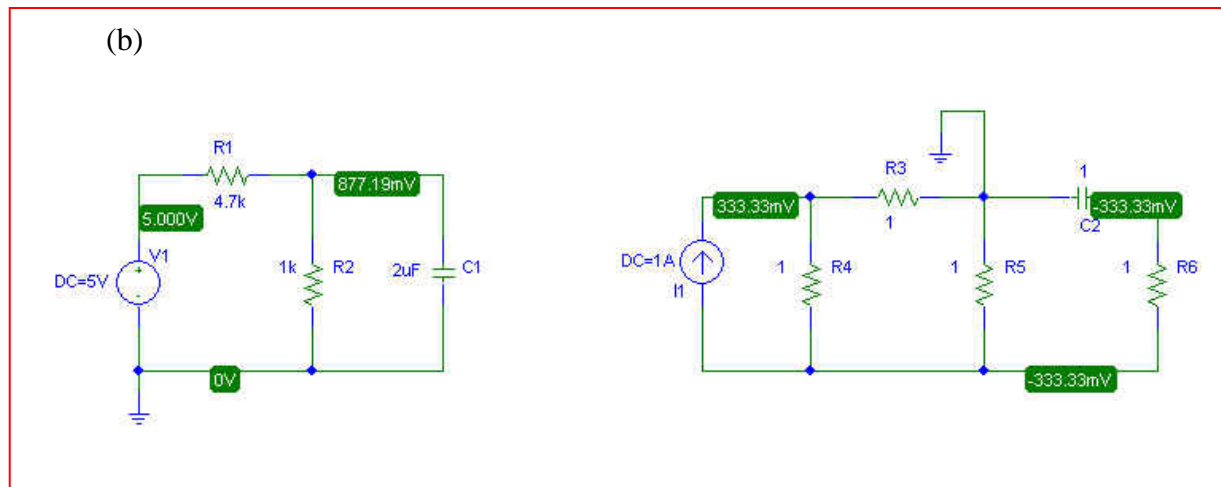
14. (a) Left circuit:

$$\text{By Voltage division, } V_C = \frac{1k}{4.7k + 1k}(5) = 0.877V$$

Right circuit:

$$V_1 = 1(1//2) = \frac{2}{3}V$$

$$\text{By Voltage Division, } V_2 = \frac{1}{3}V \therefore V_C = -\frac{1}{3}V$$



15. $v = L \frac{di}{dt}$

(a) $v = 0$ since $i = \text{constant (DC)}$

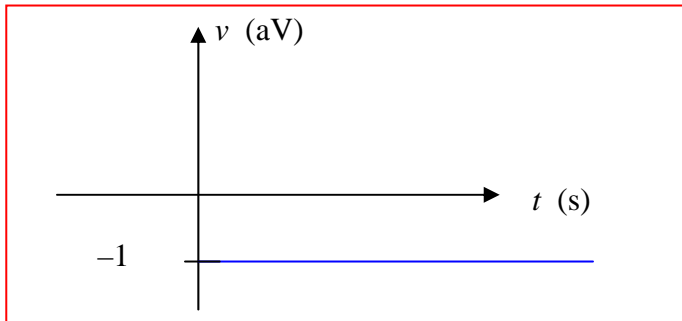
(b) $v = -10^{-8} (115\sqrt{2})(120\pi) \sin 120\pi t = -613 \sin 120\pi t \text{ } \mu\text{V}$

(c) $v = -10^{-8} (115\sqrt{2})(24 \times 10^{-3}) e^{-6t} = -240 e^{-6t} \text{ pV}$

16. $v = L \frac{di}{dt}$

$$i = \left[\frac{(6-0) \times 10^{-9}}{(0-6) \times 10^{-3}} \right] t + 6 \times 10^{-9} = 6 \times 10^{-9} - 10^{-6} t, \text{ therefore}$$

$$v = L \frac{di}{dt} = -(10^{-12})(10^{-6}) = -10^{-18} \text{ V} = -1 \text{ aV}$$



$$17. \quad v = L \frac{di}{dt}$$

$$(a) \quad L \frac{di}{dt} = (5 \times 10^{-6}) 30 \times 10^{-9} [e^{-t} - te^{-t}] = 150(1-t)e^{-t} \text{ fV}$$

(b)

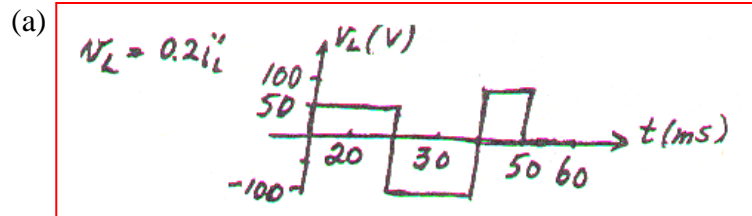
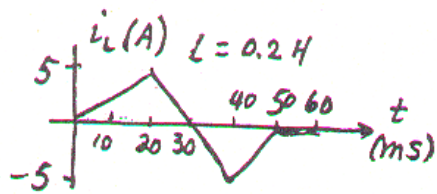
$$L \frac{di}{dt} = (5 \times 10^{-6})(4 \times 10^{-3}) [-5e^{-5t} \sin 100t + 100e^{-5t} \cos 100t]$$

$$\text{therefore } v = 100e^{-5t} (20 \cos 100t - \sin 100t) \text{ pV}$$

18. $W = \frac{1}{2}LI^2$. Maximum energy corresponds to maximum current flow, so

$$W_{\max} = \frac{1}{2}(5 \times 10^{-3})(1.5)^2 = 5.625 \text{ mJ}$$

19.



(b) $P_L = v_{L}i_L \therefore P_{L\max} = (-100)(-5) = 500\text{W}$ at $t = 40^- \text{ms}$

(c) $P_{L\min} = 100(-5) = -500\text{W}$ at $t = 20^+$ and 40^+ ms

(d) $W_L = \frac{1}{2}Li_L^2 \therefore W_L(40\text{ms}) = \frac{1}{2} \times 0.2(-5)^2 = 2.5\text{J}$

20.

$$L = 50 \times 10^{-3}, t < 0: i = 0; t > 0 i = 80te^{-100t} \text{ mA} = 0.08te^{-100t} \text{ A}$$

$$\therefore i' = 0.08e^{-100t} - 8te^{-100t} \therefore 0.08 = 8t, t_m = 0.01\text{s}, |i|_{\max} = 0.08 \times 0.01e^{-1}$$

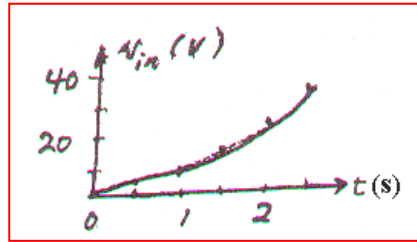
$$\therefore |i|_{\max} = 0.2943\text{mA}; v = 0.05i' = e^{-100t}(0.004 - 0.4t)$$

$$\therefore v' = e^{-100t}(-0.4) - 100e^{-100t}(0.004 - 0.4t) \therefore -0.4 = 0.4 - 40t, t = \frac{0.8}{40} = 0.02\text{s}$$

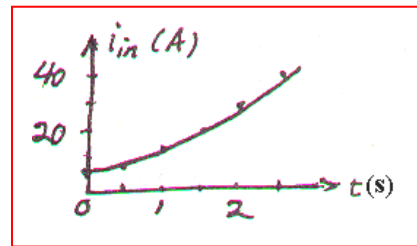
$$v = e^{-2}(0.004 - 0.008) = -0.5413\text{mV} \text{ this is minimum.} \therefore |v|_{\max} = 0.004\text{V at } t=0$$

21.

(a) $t > 0: i_s = 0.4t^2 \text{ A} \therefore v_{in} = 10i_s + 5i_s' = 4t^2 + 4t \text{ V}$



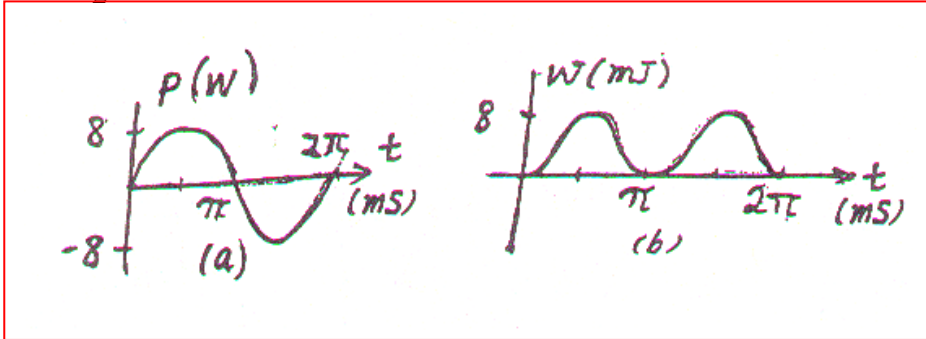
(b) $i_{in'} = 0.1v_s + \frac{1}{5} \int_0^t 40t dt + 5 = 4t + 4t^2 + 5 \text{ A}$



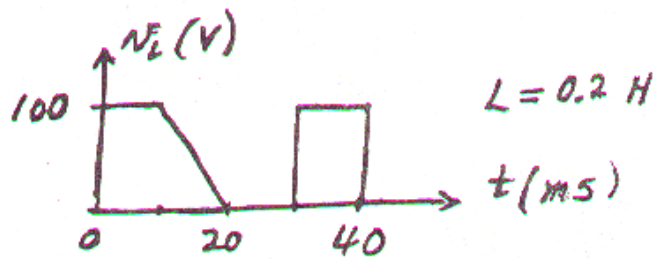
22. $v_L = 20 \cos 1000t \text{ V}$, $L = 25 \text{ mH}$, $i_L(0) = 0$

(a) $i_L = 40 \int_0^t 20 \cos 1000t dt = 0.8 \sin 1000t \text{ A}$. $\therefore p = 8 \sin 2000t \text{ W}$

(b) $w = \frac{1}{2} \times 25 \times 10^{-3} \times 0.64 \sin^2 1000t = 8 \sin^2 1000t \text{ mJ}$



23.



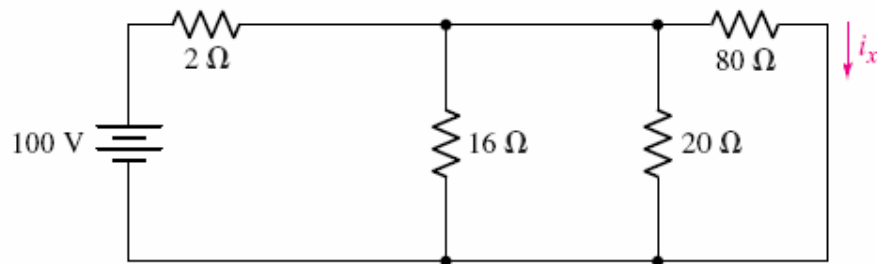
- (a) $0 < t < 10 \text{ ms}: i_L = -2 + 5 \int_0^t 100 dt = -2 + 500t \therefore i_L(10\text{ms}) = 3\text{A}, i_L(8\text{ms}) = 2\text{A}$
- (b) $i_L(0) = 0 \therefore i_L(10\text{ms}) = 500 \times 0.01 = 5\text{A} \therefore i_L(20\text{ms}) = 5 + 5 \int_{0.01}^{0.02} 10^4(0.02 - t) dt$
 $\therefore i_L(20\text{ms}) = 5 + 5 \times 10^4(0.02t - 0.5t^2)_{0.01}^{0.02} = 5 + 5 \times 10^4(0.0002 - 0.00015) = 7.5\text{A}$
 $\therefore w_L = \frac{1}{2} \times 0.2 \times 7.5^2 = 5.625\text{J}$
- (c) If the circuit has been connected for a long time, L appears like short circuit.

$$V_{8\Omega} = \frac{8}{2+8}(100\text{V}) = 80\text{V}$$

$$I_{2\Omega} = \frac{20\text{V}}{2\Omega} = 10\text{A}$$

$$\therefore i_x = \frac{80\text{V}}{80\Omega} = 1\text{A}$$

24. After a very long time connected only to DC sources, the inductors act as short circuits. The circuit may thus be redrawn as



$$\text{And we find that } i_x = \left(\frac{\frac{80}{9}}{80 + \frac{80}{9}} \right) \left(\frac{100}{2+8} \right) = \boxed{1 \text{ A}}$$

25. $L = 5\text{H}, V_L = 10(e^{-t} - e^{-2t})\text{V}, i_L(0) = 0.08\text{A}$

(a) $v_L(1) = 10(e^{-1} - e^{-2}) = 2.325\text{ V}$

(b) $i_L = 0.08 + 0.2 \int_0^t 10(e^{-t} - e^{-2t}) dt = 0.08 + 2(-e^{-t} + 0.5e^{-2t})_0^t$

$$i_L = 0.08 + 2(-e^{-t} + 0.5e^{-2t} + 1 - 0.5) = 1.08 + e^{-2t} - 2e^{-t} \therefore i_L(1) = 0.4796\text{A}$$

(c) $i_L(\infty) = 1.08\text{A}$

26.

$$\begin{aligned} \text{(a)} \quad v_x &= 120 \times \frac{40}{12 + 20 + 40} + 40 \times 5 \times \frac{12}{12 + 20 + 40} \\ &= \frac{200}{3} + \frac{100}{3} = \boxed{100\text{V}} \end{aligned}$$

$$\begin{aligned} \text{(b)} \quad v_x &= \frac{120}{12 + 15 \parallel 60} \times \frac{15}{15 + 60} \times 40 + 40 \times 5 \frac{15 \parallel 12}{15 \parallel 12 + 60} \\ &= \frac{120}{12 + 12} \times \frac{1}{5} \times 40 + 200 \frac{6.667}{66.667} \\ &= 40 + 20 = \boxed{60\text{V}} \end{aligned}$$

27.

(a) $w_L = \frac{1}{2} \times 5 \times 1.6^2 = 6.4\text{J}$

(b) $w_c = \frac{1}{2} \times 20 \times 10^{-6} \times 100^2 = 0.1\text{J}$

(c) Left to right (magnitudes): 100, 0, 100, 116, 16, 16, 0 (V)

(d) Left to right (magnitudes): 0, 0, 2, 2, 0.4, 1.6, 0 (A)

28.

$$(a) \quad v_s = 400t^2 \text{ V}, t > 0; i_L(0) = 0.5 \text{ A}; t = 0.4 \text{ s}$$

$$v_c = 400 \times 0.16 = 64 \text{ V}, w_c = \frac{1}{2} \times 10^{-5} \times 64^2 = \boxed{20.48 \text{ mJ}}$$

$$(b) \quad i_L = 0.5 + 0.1 \int_0^{0.4} 400t^2 dt = 0.5 + 40 \times \frac{1}{3} \times 0.4^3 = 1.3533 \text{ A}$$

$$\therefore w_L = \frac{1}{2} \times 10 \times 1.3533^2 = \boxed{9.1581 \text{ J}}$$

$$(c) \quad i_R = 4t^2, P_R = 100 \times 16t^4 \therefore w_R = \int_0^{0.4} 1600t^4 dt = 320 \times 0.4^5 = \boxed{3.277 \text{ J}}$$

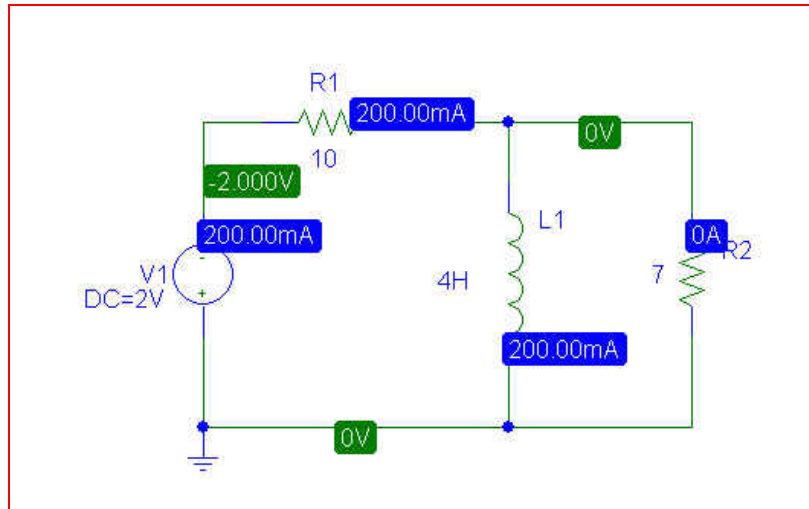
29. (a) $P_{7\Omega} = 0W$; $P_{10\Omega} = \frac{V^2}{R} = \frac{(2)^2}{10} = 0.4W$

(b) PSpice verification

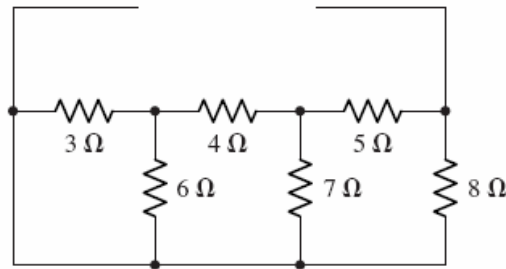
We see from the PSpice simulation that the voltage across the 10- Ω resistor is -2 V, so that it is dissipating $4/10 = 400$ mW.

The 7- Ω resistor has zero volts across its terminals, and hence dissipates zero power.

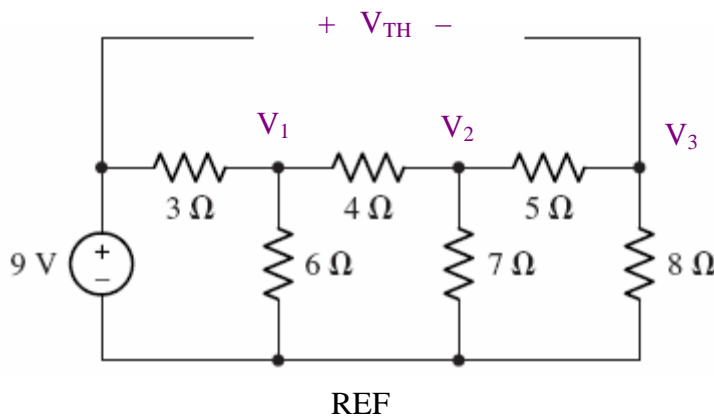
Both results agree with the hand calculations.



30. (a) We find R_{TH} by first short-circuiting the voltage source, removing the inductor, and looking into the open terminals.



Simplifying the network from the right, $3 \parallel 6 + 4 = 6 \Omega$, which is in parallel with 7Ω .
 $6 \parallel 7 + 5 = 8.23 \Omega$. Thus, $R_{TH} = 8.23 \parallel 8 = 4.06 \Omega$. To find V_{TH} , we remove the inductor:

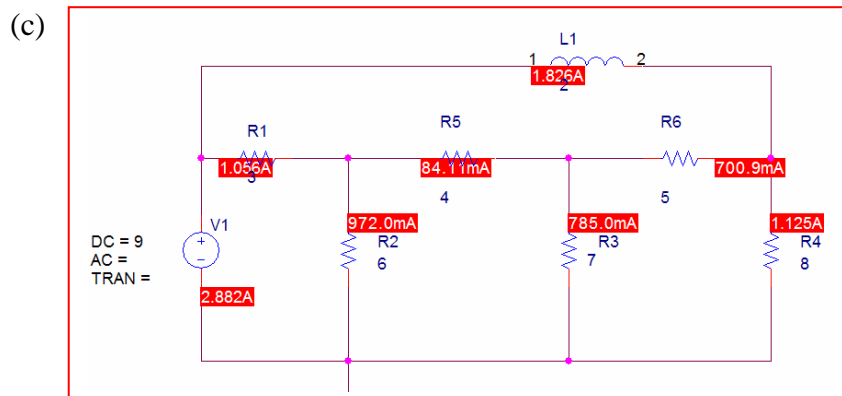


Writing the nodal equations required:

$$\begin{aligned} (V_1 - 9)/3 + V_1/6 + (V_1 - V_2)/4 &= 0 \\ (V_2 - V_1)/4 + V_2/7 + (V_2 - V_3)/5 &= 0 \\ V_3/8 + (V_3 - V_2)/5 &= 0 \end{aligned}$$

Solving, $V_3 = 1.592 \text{ V}$, therefore $V_{TH} = 9 - V_3 = 7.408 \text{ V}$.

(b) $i_L = 7.408/4.06 = 1.825 \text{ A}$ (inductor acts like a short circuit to DC).

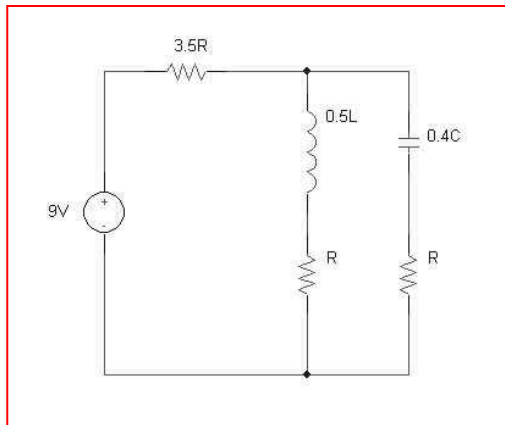


31.

$$C_{equiv} \equiv 10\mu + \left(\frac{1}{\frac{1}{10\mu} + \frac{1}{10\mu}} \right) \text{ in series with } 10\mu \text{ in series with } 10\mu + \left(\frac{1}{\frac{1}{10\mu} + \frac{1}{10\mu}} \right)$$
$$\equiv 4.286\mu F$$

$$32. \quad L_{equiv} \equiv (77 \mu\text{H} // (77 \mu\text{H} + 77 \mu\text{H})) + 77 \mu\text{H} + (77 \mu\text{H} // (77 \mu\text{H} + 77 \mu\text{H})) = 179.6 \mu\text{H}$$

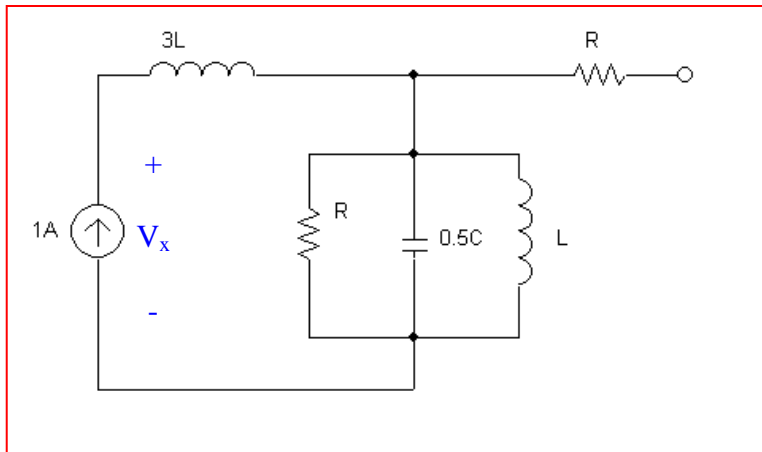
33. (a) Assuming all resistors have value R , all inductors have value L , and all capacitors have value C ,



- (b) At dc, $20\mu\text{F}$ is open circuit; $500\mu\text{H}$ is short circuit.

$$\text{Using voltage division, } V_x = \frac{10k}{10k + 15k}(9) = 3.6V$$

34. (a) As all resistors have value R , all inductors value L , and all capacitors value C ,



- (b) $V_x = 0 \text{ V}$ as L is short circuit at dc.

35. $C_{equiv} = \{ [(100 \text{ n} + 40 \text{ n}) \parallel 12 \text{ n}] + 75 \text{ n} \} \parallel \{ 7 \mu + (2 \mu \parallel 12 \mu) \}$

$$C_{equiv} \equiv 85.211 \text{ nF}$$

$$36. \quad L_{\text{equiv}} = \{[(17 \text{ p} \parallel 4 \text{ n}) + 77 \text{ p}] \parallel 12 \text{ n}\} + \{1 \text{ n} \parallel (72 \text{ p} + 14 \text{ p})\}$$

$$L_{\text{equiv}} \equiv 172.388 \text{ pH}$$

$$37. \quad C_T - C_x = (7 + 47 + 1 + 16 + 100) = 171 \mu F$$

$$E_{C_T - C_x} = \frac{1}{2}(C_T - C_x)V^2 = \frac{1}{2}(171 \mu)(2.5)^2 = 534.375 \mu J$$

$$E_{C_x} = E_{C_T} - E_{C_T - C_x} = (534.8 - 534.375) \mu J = 425 nJ$$

$$\therefore E_{C_x} = 425 n = \frac{1}{2}C_x V^2 \Rightarrow C_x = \frac{425 n(2)}{(2.5)^2} = \boxed{136 nF}$$

38.

(a) For all $L = 1.5H$, $L_{equiv} = 1.5 + \left(\frac{1}{\frac{1}{1.5} + \frac{1}{1.5}} \right) + \left(\frac{1}{\frac{1}{1.5} + \frac{1}{1.5} + \frac{1}{1.5}} \right) = 2.75H$

(b) For a general network of this type, having N stages (and all L values equiv),

$$L_{equiv} = \sum_{N=1}^n \frac{L^N}{NL^{N-1}}$$

39.

$$(a) \quad L_{equiv} = 1 + \left(\frac{1}{\frac{1}{2} + \frac{1}{2}} \right) + \left(\frac{1}{\frac{1}{3} + \frac{1}{3} + \frac{1}{3}} \right) = 3H$$

(b) For a network of this type having 3 stages,

$$L_{equiv} = 1 + \frac{1}{\frac{2+2}{(2)^2}} + \frac{1}{\frac{3+3}{(3)^2} + \frac{1}{3}} = 1 + \frac{(2)^2}{2(2)} + \frac{(3)^3}{3(3)^2}$$

Extending for the general case of N stages,

$$\begin{aligned} L_{equiv} &= 1 + \frac{1}{\frac{1}{2} + \frac{1}{2}} + \frac{1}{\frac{1}{3} + \frac{1}{3} + \frac{1}{3}} + \dots + \frac{1}{\frac{1}{N} + \dots + \frac{1}{N}} \\ &= 1 + \frac{1}{2(1/2)} + \frac{1}{3(1/3)} + \dots + \frac{1}{N(1/N)} = N \end{aligned}$$

$$40. \quad C_{equiv} = \frac{(3p)(0.25p)}{3p + 0.25p} = 0.231pF$$

$$41. \quad L_{equiv} = \frac{(2.3n)(0.3n)}{2.6n} = 0.2916nH$$

42. (a) Use 2 x 1 μ H in series with 4 x 1 μ H in parallel.
- (b) Use 2 x 1 μ H in parallel, in series with 4 x 1 μ H in parallel.
- (c) Use 5 x 1 μ H in parallel, in series with 4 x 1 μ H in parallel.

43.

$$(a) \quad R = 10\Omega : 10\parallel 10\parallel 10 = \frac{10}{3}, \frac{10}{3} + 10 + 10\parallel 10 = \frac{55}{3}$$

$$\therefore R_{eq} = \frac{55}{3}\parallel 30 = \boxed{11.379\Omega}$$

$$(b) \quad L = 10H \therefore L_{eq} = \boxed{11.379H}$$

$$(c) \quad C = 10F : \frac{1}{1/30 + 1/10 + 1/20} = 5.4545$$

$$\therefore C_{eq} = 5.4545 + \frac{10}{3} = \boxed{8.788F}$$

44.

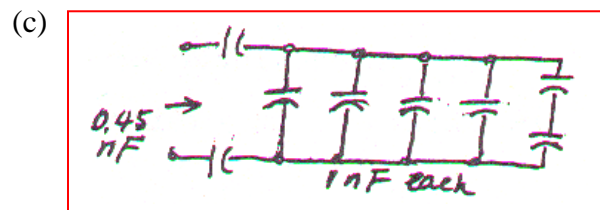
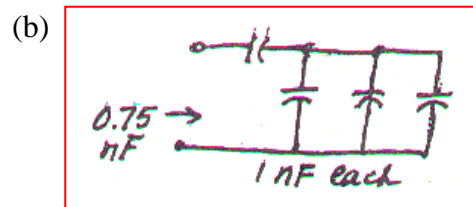
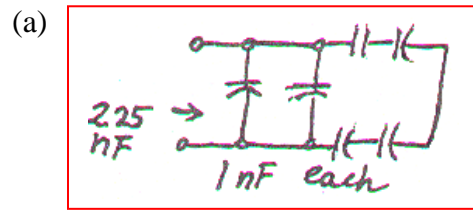
$$(a) \quad oc : L_{eq} = 6 \parallel 1 + 3 = 3.857H$$

$$sc : L_{eq} = (3 \parallel 2 + 1) \parallel 4 = 2.2 \parallel 4 = 1.4194H$$

$$(b) \quad oc : 1 + \frac{1}{1/4 + 1/2} = \frac{7}{3}, C_{eq} = \frac{1}{3/7 + 1/2} = 1.3125F$$

$$sc : \frac{1}{1/5 + 1} = \frac{5}{6}, C_{eq} = 4 + \frac{5}{6} = 4.833F$$

45.



46. $i_s = 60e^{-200t}$ mA, $i_1(0) = 20$ mA

(a) $6 \parallel 4 = 2.4 \text{ H} \therefore v = L_{eq} i_s' = 2.4 \times 0.06(-200)e^{-200t}$
or $v = -28.8e^{-200t}$ V

(b) $i_1 = \frac{1}{6} \int_0^t -28.8e^{-200t} dt + 0.02 = \frac{4.8}{200}(e^{-200t} - 1) + 0.02$
 $= 24e^{-200t} - 4 \text{ mA} (t > 0)$

(c) $i_2 = i_s - i_1 = 60e^{-200t} - 24e^{-200t} + 4 = 36e^{-200t} + 4 \text{ mA} (t > 0)$

$$47. \quad v_s = 100e^{-80t} \text{V}, v_1(0) = 20 \text{V}$$

$$(a) \quad i = C_{eq} v_s' = 0.8 \times 10^{-6} (-80) 100e^{-80t} = -6.4 \times 10^{-3} e^{-80t} \text{A}$$

$$(b) \quad v_1 = 10^6 (-6.4 \times 10^{-3}) \int_0^t e^{-80t} dt + 20 = \frac{6400}{80} (e^{-80t} - 1) + 20$$
$$\therefore v_1 = 80e^{-80t} - 60 \text{V}$$

$$(c) \quad v_2 \frac{10^6}{4} (-6.4 \times 10^{-3}) \int_0^t e^{-80t} dt + 80 = \frac{1600}{80} (e^{-80t} - 1) + 80$$
$$= 20e^{-80t} + 60 \text{V}$$

48.

(a)

$$\frac{v_c - v_s}{20} + 5 \times 10^{-6} v_c' + \frac{v_c - v_L}{10} = 0$$
$$\frac{v_L - v_c}{10} + \frac{1}{8 \times 10^{-3}} \int_0^t v_L dt + 2 = 0$$

(b)

$$20i_{20} + \frac{1}{5 \times 10^{-6}} \int_0^t (i_{20} - i_L) dt + 12 = v_s$$
$$\frac{1}{5 \times 10^{-6}} \int_0^t (i_L - i_{20}) dt - 12 + 10i_L + 8 \times 10^{-3} i_L' = 0$$

49.

$$v_c(t): 30\text{mA}: 0.03 \times 20 = 0.6\text{V}, v_c = 0.6\text{V}$$

$$9\text{V}: v_c = 9\text{V}, 20\text{mA}: v_c = -0.02 \times 20 = 0.4\text{V}$$

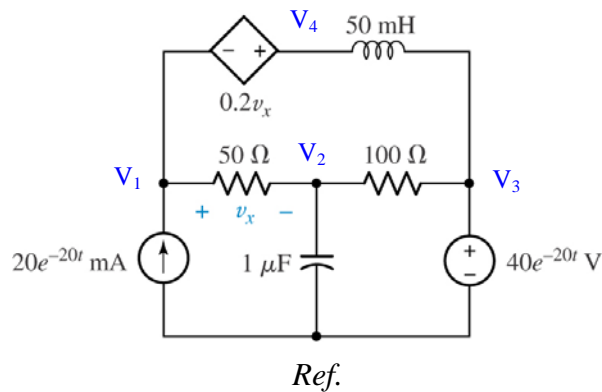
$$0.04 \cos 10^3 t: v_c = 0$$

$$\therefore v_c(t) = 9.2\text{V}$$

$$v_L(t): 30\text{mA}, 20\text{mA},$$

$$9\text{V}: v_L = 0; 0.04 \cos 10^3 t: v_L = -0.06 \times 0.04(-1000) \sin 10^3 t = 2.4 \sin 10^3 t \text{V}$$

50. We begin by selecting the bottom node as the reference and assigning four nodal voltages:



1, 4 Supernode:

$$20 \times 10^{-3} e^{-20t} = \frac{V_1 - V_2}{50} + 0.02 \times 10^3 \int_0^t (V_4 - 40e^{-20t'}) dt' \quad [1]$$

and:

$$V_1 - V_4 = 0.2 V_x \quad \text{or} \quad 0.8V_1 + 0.2 V_2 - V_4 = 0 \quad [2]$$

Node 2:

$$0 = \frac{V_2 - V_1}{50} + \frac{V_2 - 40e^{-20t}}{100} + 10^{-6} \frac{dV_2}{dt} \quad [3]$$

51. (a) $R_i = \infty, R_o = 0, A = \infty \therefore v_i = 0 \therefore i = Cv_s'$
 also $0 + Ri + v_o = 0 \therefore v_o = -RCv_s'$
 $-v_i + Ri - Av_i = 0, v_s = \frac{1}{c} \int idt + v_i$

(b) $v_o = -Av_i \therefore v_i = \frac{-1}{A} v_o \therefore i = \frac{1+A}{R} v_i$
 $\therefore v_s = \frac{1}{c} \int idt - \frac{1}{A} v_o = -\frac{1}{A} v_o + \frac{1+A}{RC} \int -\frac{v_o}{A} dt$
 $\therefore Av_s' = -v_o' - \frac{1+A}{RC} v_o$ or $v_o' + \frac{1+A}{RC} v_o + Av_s' = 0$

52. Place a current source in parallel with a 1-M Ω resistor on the positive input of a buffer with output voltage, v . This feeds into an integrator stage with input resistor, R_2 , of 1-M Ω and feedback capacitor, C_f , of 1 μ F.

$$i = C_f \frac{dv_{c_f}}{dt} = 1.602 \times 10^{-19} \times \frac{\text{ions}}{\text{sec}}$$

$$0 = \frac{V_a - V}{1 \times 10^6} + C_f \frac{dv_{c_f}}{dt} = \frac{V_a - V}{1 \times 10^6} + 1.602 \times 10^{-19} \frac{\text{ions}}{\text{sec}}$$

$$0 = \frac{-V}{R_2} + C_f \frac{dv_{c_f}}{dt} = \frac{-V}{1 \times 10^6} + 1.602 \times 10^{-19} \frac{\text{ions}}{\text{sec}}$$

Integrating current with respect to t , $\frac{1}{R_2} \int_0^t v dt' = C_f (V_{c_f} - V_{c_f}(0))$

$$\frac{1.602 \times 10^{-19} \times \text{ions}}{R_2} = C_f V_{c_f}$$

$$V_{c_f} = V_a - V_{out} \Rightarrow V_{out} = \frac{-R_1}{R_2 C_f} \times 1.602 \times 10^{-19} \times \text{ions} \Rightarrow V_{out} = \frac{-1}{C_f} \times 1.602 \times 10^{-19} \times \text{ions}$$

$$R_1 = 1 \text{ M}\Omega, C_f = 1 \mu\text{F}$$

53. $R = 0.5\text{M}\Omega$, $C = 2\mu\text{F}$, $R_i = \infty$, $R_o = 0$, $v_o = \cos 10t - 1\text{V}$

(a) Eq. (16) is: $\left(1 + \frac{1}{A}\right)v_o = -\frac{1}{RC} \int_0^t \left(v_s + \frac{v_o}{A}\right) dt - v_c(0)$

$$\therefore \left(1 + \frac{1}{A}\right)v_o' = -\frac{1}{RC} \left(v_s + \frac{v_o}{A}\right) \therefore \left(1 + \frac{1}{A}\right)(-10 \sin 10t) = -1 \left(v_s + \frac{1}{A} \cos 10t - \frac{1}{A}\right)$$

$$\therefore v_s = \left(1 + \frac{1}{A}\right)10 \sin 10t + \frac{1}{A} - \frac{1}{A} \cos 10t \quad \text{Let } A = 2000$$

$$\therefore v_s = 10.005 \sin 10t + 0.0005 - 0.0005 \cos 10t$$

(b) Let $A = \infty \therefore v_s = 10 \sin 10t\text{V}$

54. Create a op-amp based differentiator using an ideal op amp with input capacitor C_1 and feedback resistor R_f followed by inverter stage with unity gain.

$$V_{out} = + \frac{R}{R} R_f C_1 \frac{dvs}{dt} = 60 \times \frac{1mV}{rpm} / \text{min}$$

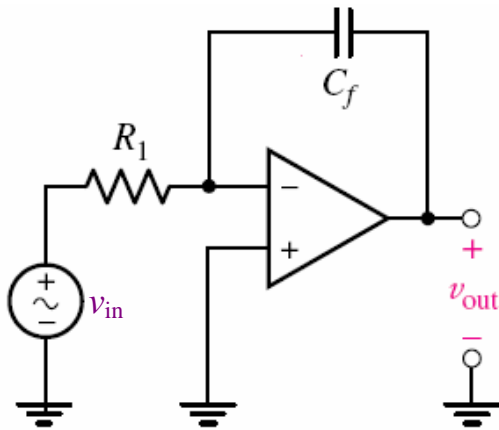
$R_f C_1 = 60$ so choose $R_f = 6 \text{ M}\Omega$ and $C_1 = 10 \mu\text{F}$.

$$55. \quad (a) \quad 0 = \frac{1}{L} \int v dt + \frac{V_a - V_{out}}{R_f}$$

$$V_a = V = 0, \therefore \frac{1}{L} \int v_L dt = \frac{V_{out}}{R_f} \Rightarrow V_{out} = \frac{-R_f}{L} \int_0^t v_s dt'$$

(b) In practice, capacitors are usually used as capacitor values are more readily available than inductor values.

56. One possible solution:



$$v_{out} = -\frac{1}{R_1 C_f} \int v_{in} dt$$

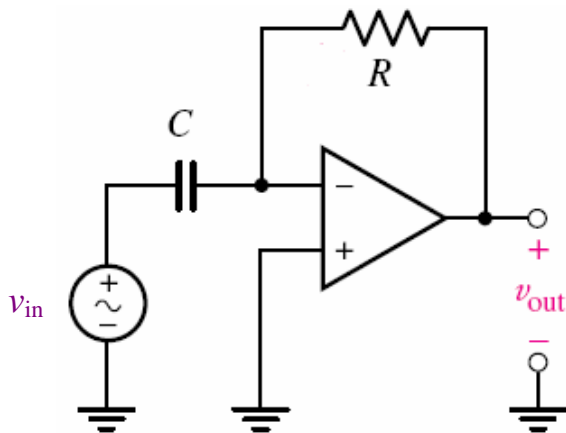
we want $v_{out} = 1$ V for $v_{in} = 1$ mV over 1 s.

$$\text{In other words, } 1 = -\frac{1}{R_1 C_f} \int_0^1 10^{-3} dt = -\frac{10^{-3}}{R_1 C_f}$$

Neglecting the sign (we can reverse terminals of output connection if needed), we therefore need $R_1 C_f = 10^{-3}$.

Arbitrarily selecting $C_f = 1 \mu\text{F}$, we find $R_1 = 1 \text{ k}\Omega$.

57. One possible solution of many:



$$v_{out} = -RC \frac{dv_{in}}{dt}$$

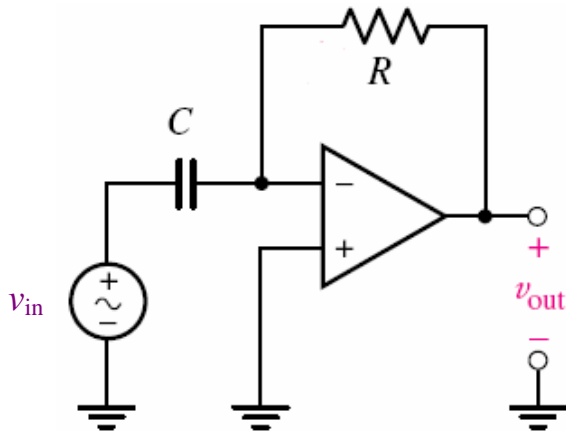
$$\text{maximum} \left(\frac{dv_{in}}{dt} \right) = \frac{100 \text{ mV}}{60 \text{ s}}$$

$$\text{In other words, } |v_{out}| = 1 \text{ V} = RC \left(\frac{100 \text{ mV}}{60 \text{ s}} \right)$$

$$\text{or } RC = 600$$

Arbitrarily selecting $C = 1000 \mu\text{F}$, we find that $R = 600 \text{ k}\Omega$.

58. One possible solution of many:



$$v_{out} = -RC \frac{dv_{in}}{dt}$$

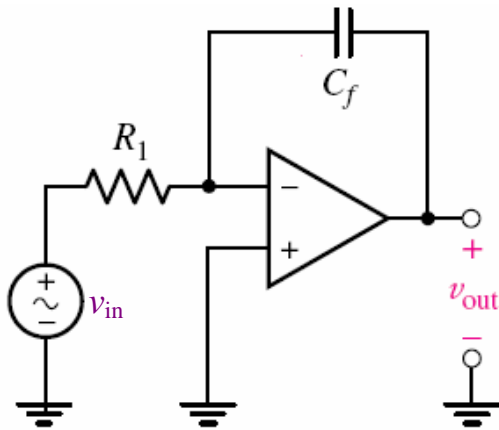
$$\text{At 1 litre/s, } \left(\frac{dv_{in}}{dt} \right) = \frac{100 \text{ mV}}{\text{s}}$$

$$\text{In other words, } |v_{out}| = 1 \text{ V} = RC \left(\frac{100 \text{ mV}}{1 \text{ s}} \right)$$

$$\text{or } RC = 10$$

Arbitrarily selecting $C = 10 \mu\text{F}$, we find that $R = 1 \text{ M}\Omega$.

59. One possible solution:



The power into a $1\ \Omega$ load is I^2 , therefore energy = $W = I^2 \Delta t$.

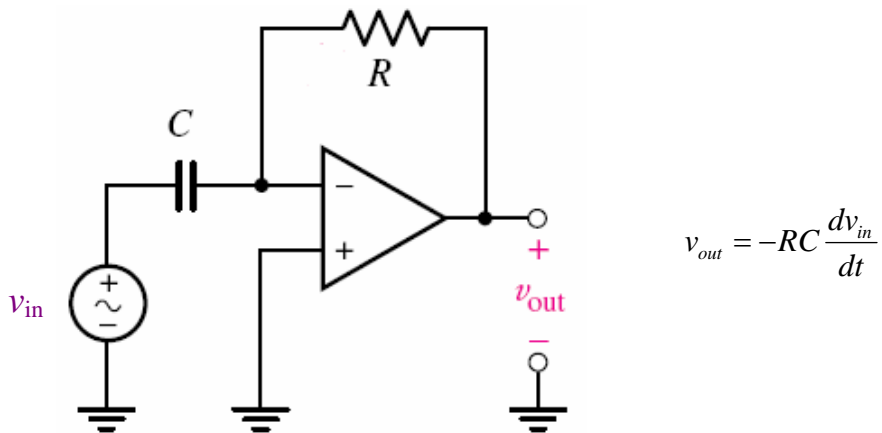
$$|v_{out}| = \frac{1}{R_1 C_f} \int I^2 dt$$

we want $v_{out} = 1\ \text{mV}$ for $v_{in} = 1\ \text{mV}$ (corresponding to $1\ \text{A}^2$).

Thus, $10^{-3} = RC(10^{-3})$, so $RC = 1$

Arbitrarily selecting $C = 1\ \mu\text{F}$, we find that we need $R = 1\ \text{M}\Omega$.

60. One possible solution of many:



Input: 1 mV = 1 mph, 1 mile = 1609 metres.

Thus, on the input side, we see 1 mV corresponding to 1609/3600 m/s.

Output: 1 mV per m/s^2 . Therefore,

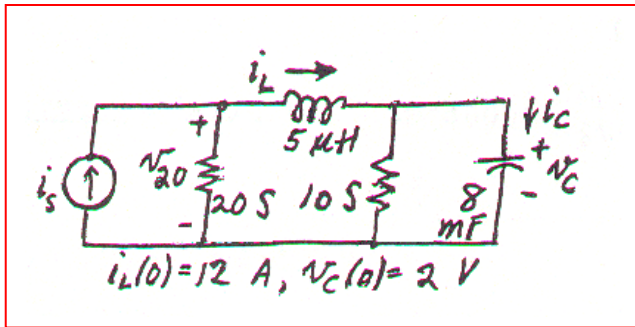
$$|v_{out}| = 2.237RC = 1$$

$$\text{so } RC = 0.447$$

Arbitrarily selecting $C = 1 \mu\text{F}$, we find that $R = 447 \text{ k}\Omega$.

61.

(a)



(b)

$$20v_{20} + \frac{1}{5 \times 10^{-6}} \int_0^t (v_{20} - v_c) dt + 12 = i_s$$

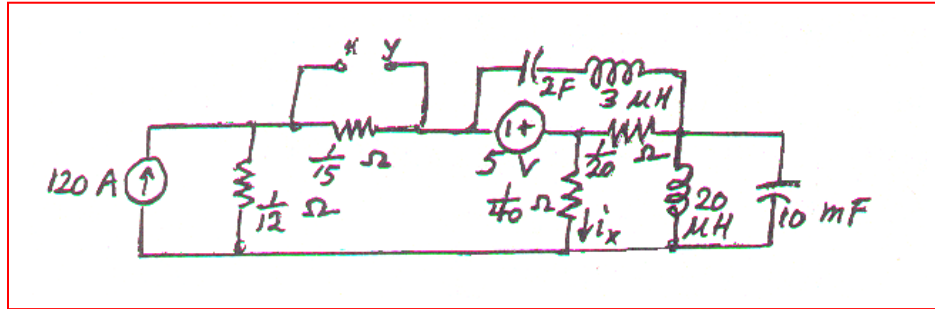
$$\frac{1}{5 \times 10^{-6}} \int_0^t (v_c - v_{20}) dt - 12 + 10v_c + 8 \times 10^{-3} v_c' = 0$$

(c)

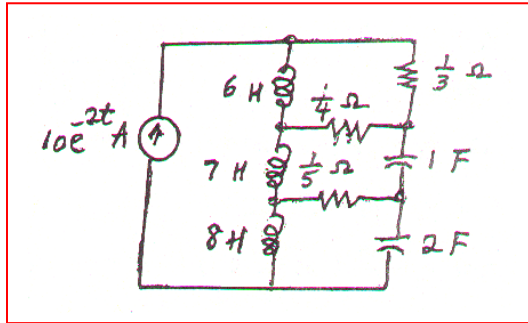
$$\frac{i_L - i_s}{20} + 5 \times 10^{-6} i_L' + \frac{i_L - i_c}{10} = 0$$

$$\frac{i_c - i_L}{10} + \frac{1}{8 \times 10^{-3}} \int_0^t i_c dt + 2 = 0$$

62.

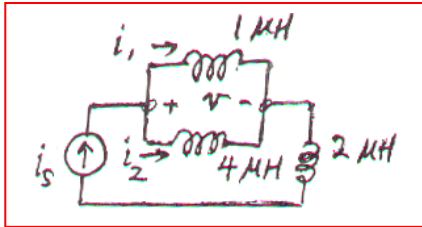


63.



64.

(a)

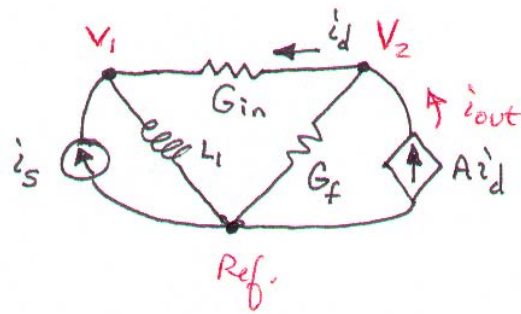
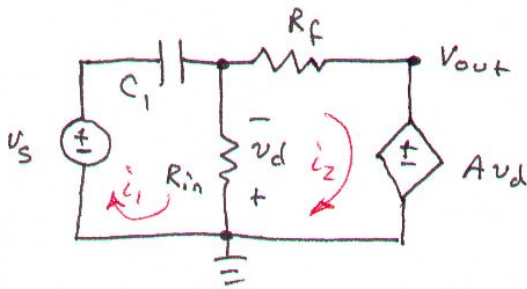
(b) “Let $i_s = 100e^{-80t}$ A and $i_1(0) = 20$ A in the circuit of (new) Fig. 7.62.(a) Determine $v(t)$ for all t .(b) Find $i_1(t)$ for $t \geq 0$.(c) Find $v_2(t)$ for $t \geq 0$.”

(c) (a) $L_{eq} = 1 \parallel 4 = 0.8 \mu\text{H} \therefore v(t) = L_{eq} i_s' = 0.8 \times 10^{-6} \times 100(-80)e^{-80t} \text{ V}$
 $\therefore v(t) = -6.43e^{-80t} \text{ mV}$

(b) $i_1(t) = 10^6 \int_0^t -6.4 \times 10^{-3} e^{-80t} dt + 20 \therefore i_1(t) = \frac{6400}{80}(e^{-80t} - 1) = 80e^{-80t} - 60 \text{ A}$

(c) $i_2(t) = i_s - i_1(t) \therefore i_2(t) = 20e^{-80t} + 60 \text{ A}$

65.



In creating the dual of the original circuit, we have lost both v_s and v_{out} . However, we may write the dual of the original transfer function: i_{out}/i_s . Performing nodal analysis,

$$i_s = \frac{1}{L_1} \int_0^t V_1 dt' + G_{in} (V_1 - V_2) \quad [1]$$

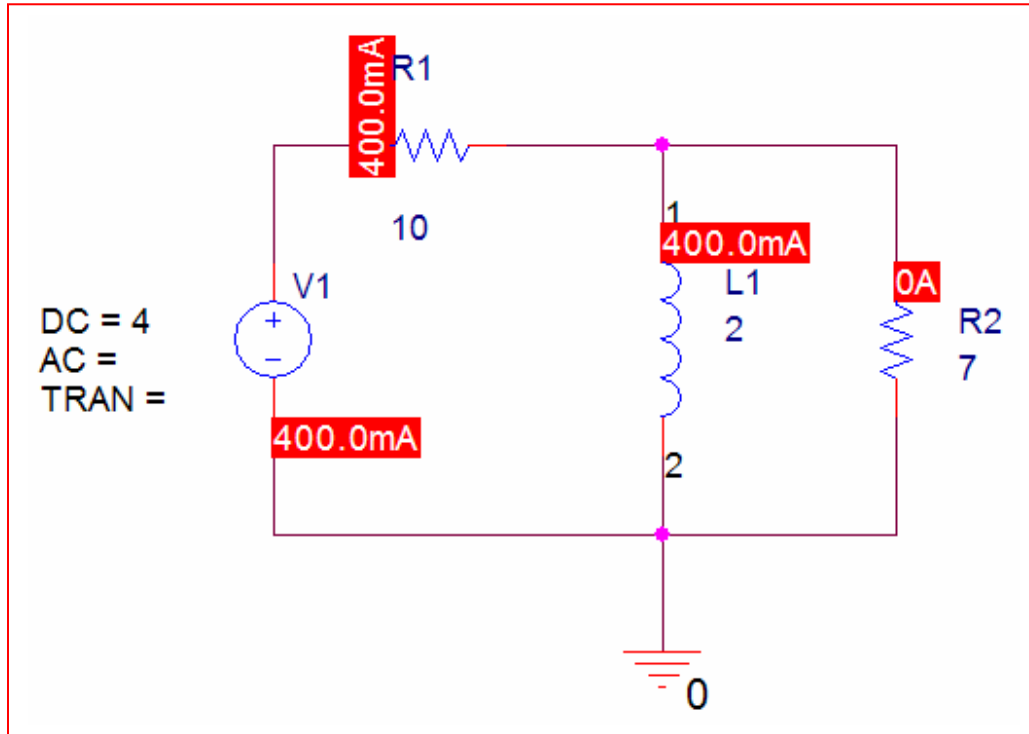
$$i_{out} = A i_d = G_f V_2 + G_{in} (V_2 - V_1) \quad [2]$$

Dividing, we find that

$$\frac{i_{out}}{i_s} = \frac{G_{in} (V_2 - V_1) + G_f V_2}{\frac{1}{L_1} \int_0^t V_1 dt' + G_{in} (V_1 - V_2)}$$

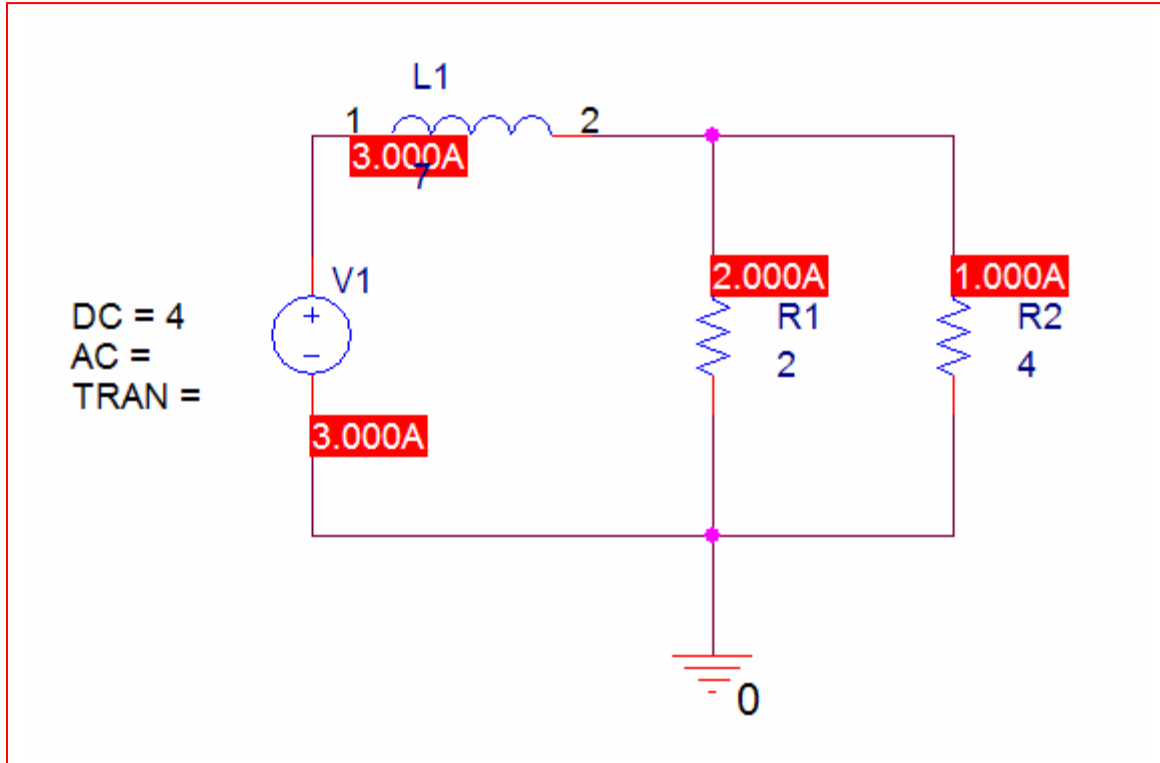
66. $I_L = 4/10 = 400 \text{ mA}$. $W = \frac{1}{2}LI_L^2 = 160 \text{ mJ}$

PSpice verification:



67. $I_L = 4/(4/3) = 3 \text{ A}$. $W = \frac{1}{2} LI_L^2 = 31.5 \text{ J}$

PSpice verification:



68. We choose the bottom node as the reference node, and label the nodal voltage at the top of the dependent source V_A .

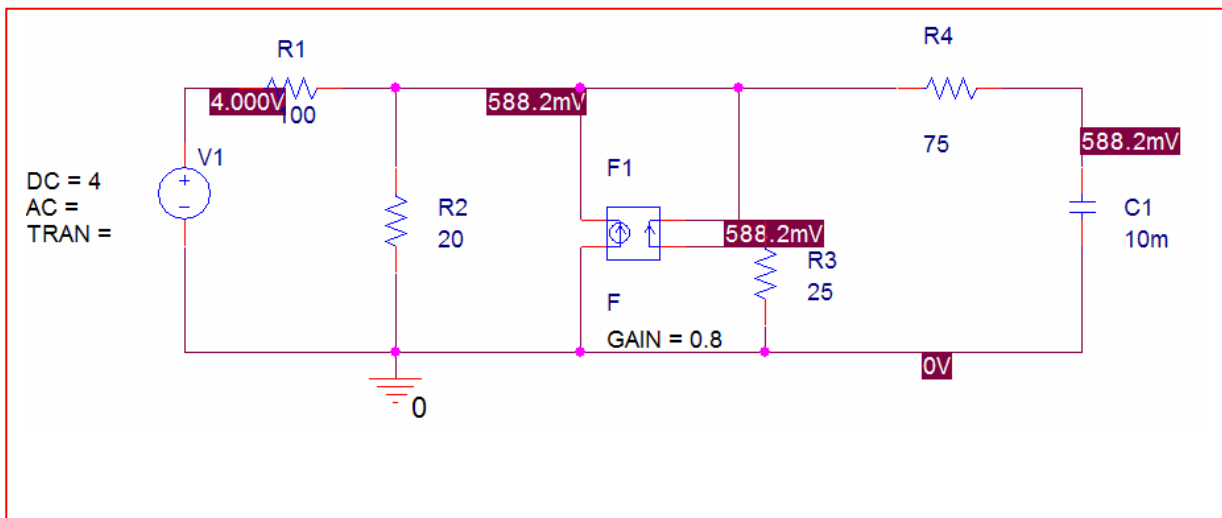
Then, by KCL,

$$\frac{V_A - 4}{100} + \frac{V_A}{20} + \frac{V_A}{25} = 0.8 \frac{V_A}{25}$$

Solving, we find that $V_A = 588 \text{ mV}$.

Therefore, V_C , the voltage on the capacitor, is 588 mV (no DC current can flow through the 75Ω resistor due to the presence of the capacitor.)

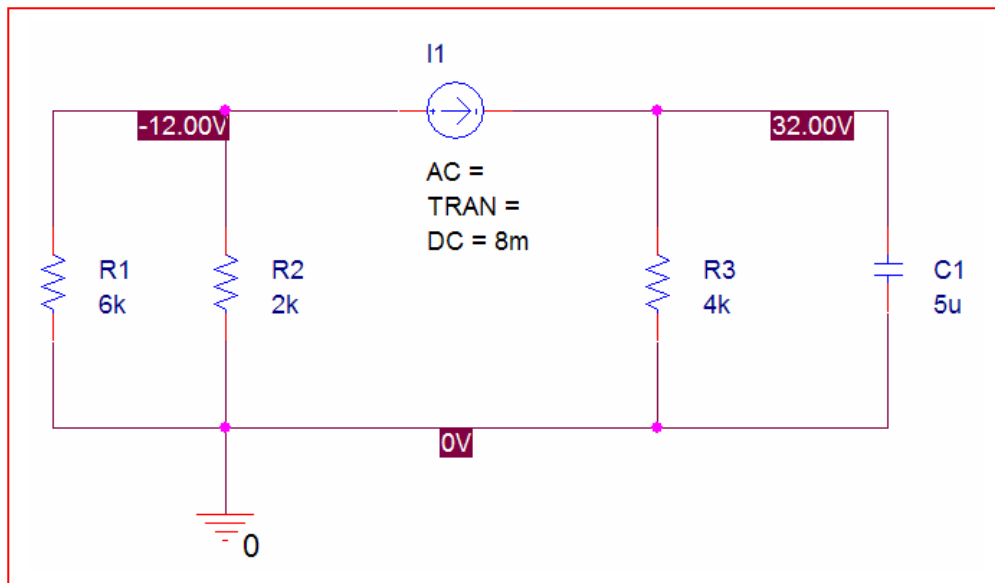
Hence, the energy stored in the capacitor is $\frac{1}{2}CV^2 = \frac{1}{2}(10^{-3})(0.588)^2 = 173 \mu\text{J}$



69. By inspection, noting that the capacitor is acting as an open circuit, the current through the 4 k Ω resistor is 8 mA. Thus, $V_c = (8)(4) = 32$ V.

$$\text{Hence, the energy stored in the capacitor} = \frac{1}{2}CV^2 = \frac{1}{2}(5 \times 10^{-6})(32)^2 = \boxed{2.56 \text{ mJ}}$$

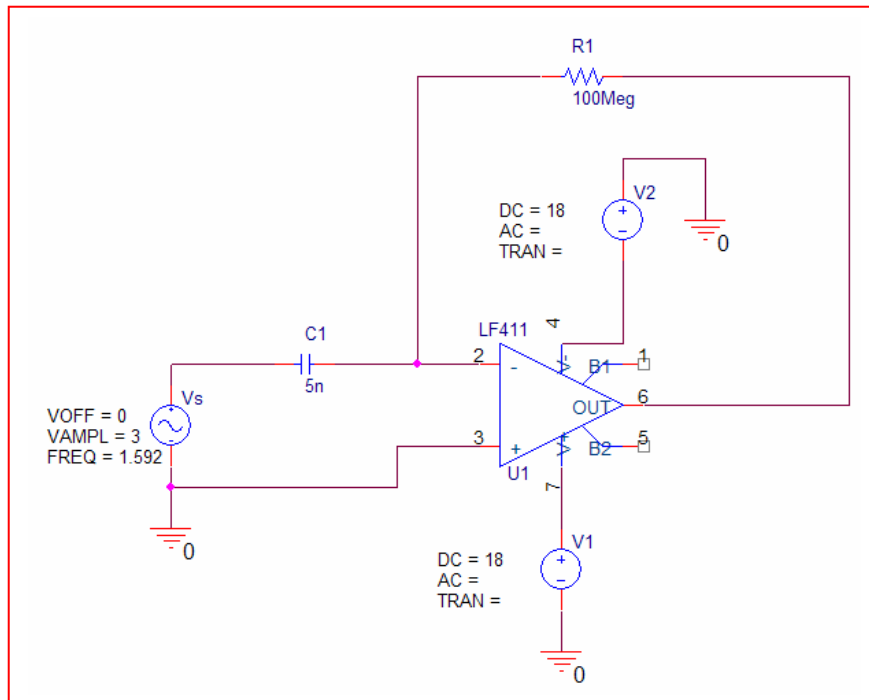
PSpice verification:



70. $C_1 = 5 \text{ nF}$, $R_f = 100 \text{ M}\Omega$.

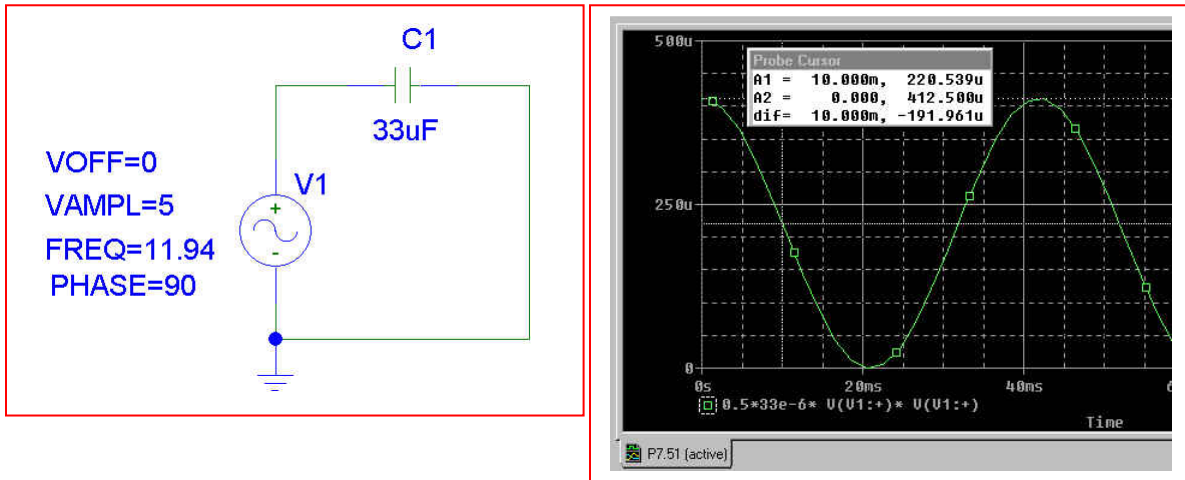
$$v_{out} = -R_f C_1 \frac{dv_s}{dt} = -(5 \times 10^{-9})(10^8)(30 \cos 100t) = -15 \cos 10t \text{ V}$$

Verifying with PSpice, choosing the LF411 and $\pm 18 \text{ V}$ supplies:



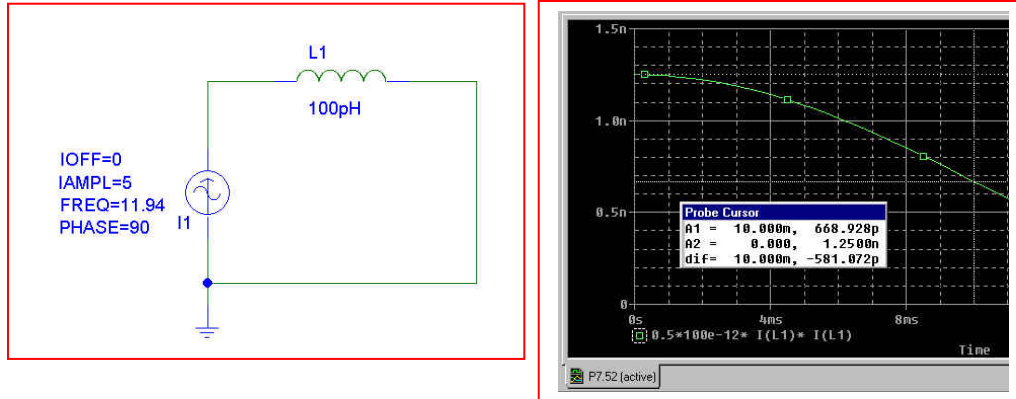
71. PSpice verification

$w = \frac{1}{2} C v^2 = 0.5 (33 \times 10^{-6}) [5 \cos (75 \times 10^{-2})]^2 = 220.8 \mu\text{J}$. This is in agreement with the PSpice simulation results shown below.



72. PSpice verification

$w = \frac{1}{2} Li^2 = 0.5 (100 \times 10^{-12}) [5 \cos(75 \times 10^{-2})]^2 = 669.2 \text{ pJ}$. This is in agreement with the PSpice simulation results shown below.



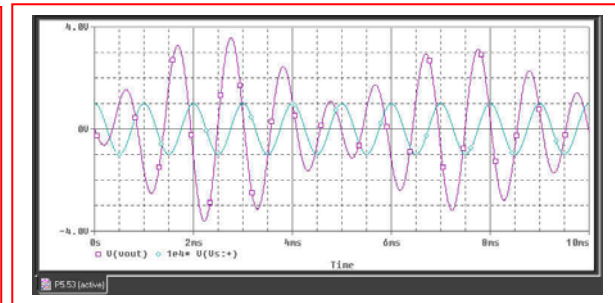
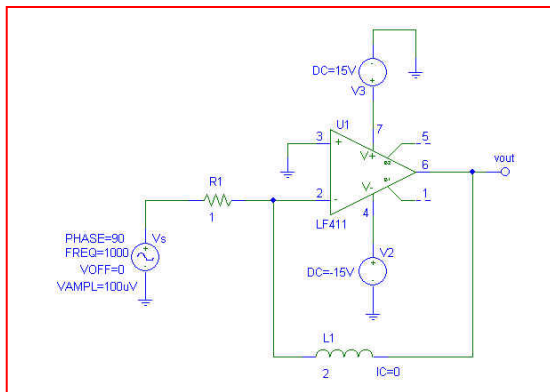
$$73. \quad 0 = \frac{V_a - V_s}{R_1} + \frac{1}{L} \int v_{L_f} dt$$

$$V_a = V_b = 0, \quad 0 = \frac{-V_s}{R_1} + \frac{1}{L} \int v_{L_f} dt$$

$$V_{L_f} = V_a - V_{out} = 0 - V_{out} = \frac{L}{R_1} \frac{dV_s}{dt}$$

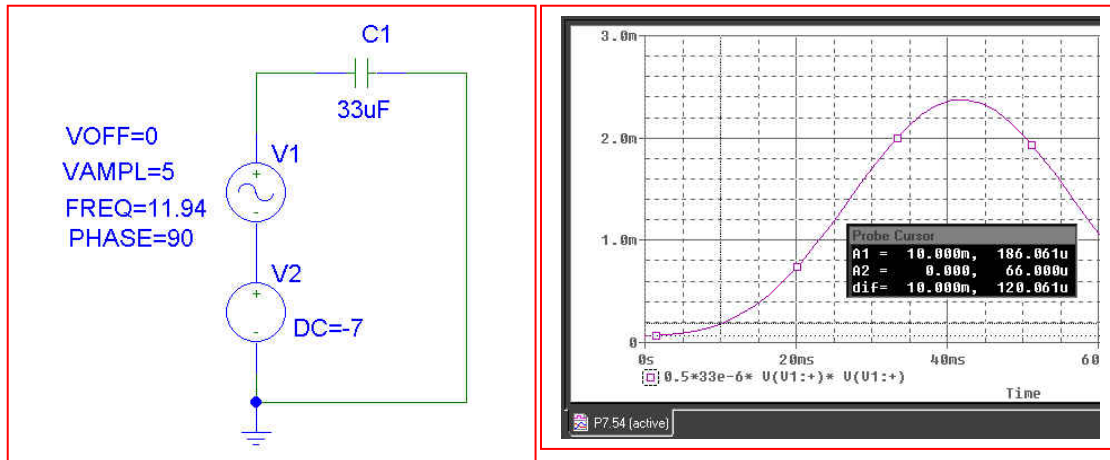
$$V_{out} = -\frac{L_f}{R_1} \frac{dV_s}{dt} = -\frac{L_f}{R_1} \frac{d}{dt} (A \cos 2\pi 10^3 t) \Rightarrow L_f = 2R_1; \text{ Let } R = 1 \Omega \text{ and } L = 1 \text{ H.}$$

PSpice Verification: clearly, something rather odd is occurring in the simulation of this particular circuit, since the output is not a pure sinusoid, but a combination of several sinusoids.



74. PSpice verification

$w = \frac{1}{2} C v^2 = 0.5 (33 \times 10^{-6}) [5 \cos (75 \times 10^{-2}) - 7]^2 = 184.2 \mu\text{J}$. This is in reasonable agreement with the PSpice simulation results shown below.



75. PSpice verification

$w = \frac{1}{2} Li^2 = 0.5 (100 \times 10^{-12}) [5 \cos(75 \times 10^{-2}) - 7]^2 = 558.3 \text{ pJ}$. This is in agreement with the PSpice simulation results shown below.

