**Homework 13 – F2017**



**P11.32** The switch in Figure P11.32 is opened at *t* = 0 after having been closed for a long time. Determine *iX*(*t*) and *vX*(*t*), *t* ≥ 0+.

**Solution:** After the switch has been closed for a long time in Figure P11.32, the inductor behaves as a short circuit, so that *VX* = *IX*. Since the circuit is a two-essential- node circuit, it follows from KCL that: . This gives *iX*(0-) = 10/2.5 = 4 mA, and *vX*(0-) = 4 V. At *t* = 0+, *iX* stays the same, and a current 0.5*iX* flows upwards through the 1 kΩ resistor on the LHS, so that *vX*(0+) = -2 V. As *t* → ∞, both *iX* and *vX* go to zero.

To determine the resistance seen by the inductor, the inductor is replaced by a test source, as shown in Figure P11.32A. It is seen that *VT* = *IT* + 0.5*IT*, so that *VT*/*IT* = 1.5 kΩ and *τ* = 2/3 ns. It follows that *iX*(*t*) = 4*e*-1.5*t* mA, *vO*(*t*) = -2*e*-1.5*t* V. As a check, *vX* = *iX*×1 + 109*LdiX*/*dt* = 4*e*-1.5*t –* 6*e*-1.5*t* = -2*e*-1.5*t* V.

**P11.40** The switch In Figure P11.40 is initially in position ‘a’, with the capacitors uncharged. At *t* = 0, the switch is moved to position ‘b’. When  the switch is moved to position ‘c’. Determine (*t*) for the time when the switch (a) is in position ‘b’ and (b) after it was moved to position ‘c’.

**Solution:** When the switch is in position ‘b’, the circuit is as shown in Figure P11.40A. *vC*(0) = 0. As , the voltage across the capacitors becomes ; *Ceqs* = 3/4 μF. The charge on *Ceqs* and each of the two capacitors is  μC. It follows that, *vC*(∞) =  V. With the voltage source set to zero, the resistance that is effectively in series with the two capacitors is (1||105) = 0.99 kΩ. *τ* =  ms. Hence,  V, where *t* is in ms. When *vC*(*t*) = 10 V, *t* = 0.83 ms.

When the switch is moved to position ‘c’, the circuit becomes as shown in Figure P11.40B. *vO*(0) = 10 V. *vO*(∞) = V.  ms. Hence, for *t* ≥ 0.83 ms,  V, *t* is in ms.

**P11.44** The switch in Figure P11.44 is moved at *t* = 0 from position ‘a’ to position ‘b’ after being in position ‘a’ for a long time. Determine, for *t* ≥ 0+: (a) *v*(*t*); (b) energy dissipated in the resistor.

**Solution:** (a) When the linear transformer is replaced by its T-equivalent circuit, the circuit becomes as shown in Figure P11.44A. After the switch has been in position ‘a’ for a long time, the inductors act as short circuits and the 0.5 A flows through the inductors. At *t* = 0+, the 0.5 A current in the 0.1 H inductor flows upwards through the 20 Ω resistor so that *v*(0+) = -10 V; *VF* = 0; *τ* = 0.1/20 = 1/200 s ≡ 5 ms. It follows that  V, *t* is in ms;

(b) The energy dissipated in the resistor is  = 12.5 mJ.

**P11.49** Switch S1 in Figure P11.49 is opened at *t* = 0 after being closed for a long time. Switch S2 is closed at *t* = 5 ms. Determine *iL*(*t*) at *t* = 20 ms.

**Solution:** At *t* = 0-, the inductors act as a short circuit in Figure P11.49. *IL*0 = 5/2 + 3*IL*0/6, which gives *IL*0 = 5 A. If the switch remains open, *iL*(*t*) tends to zero. *Leq* = 15 + 12 + 2×2.5 = 30 mH. If a test source is applied in place of the inductors, as shown in Figure P11.49A, the polarity of the dependent source is reversed, so that *IT* = (*VT* + 3*IT*)/6, or *VT*/*IT* = 3 Ω. Hence, *τ* = *Leq*/*R* = 30/3 = 10 ms. It follows that  A, 0 ≤ *t* ≤ 5 ms. At *t* = 5 ms, *iL*(5) = 5*e*-0.5 ≅ 3 A.

For *t* ≥ 5 ms: As *t* → ∞, *ILF* = 30/6 + 3*ILF*/6, which gives *ILF* = 10 A. If a test source is applied in place of the inductor, Figure P11.48A applies but with a 6 Ω resistor across *VT*. Hence, *IT* = (*VT* + 3*IT*)/6 + *VT*/6, which gives *VT*/*IT* = 1.5 Ω, so

that *τ* = *Leq*/*R* = 30/1.5 = 20 ms. Hence, , *t* is in ms. At *t* = 20 ms, *iL*(20) = A.

**P11.50** The switch in Figure P11.50 is opened at *t* = 0 with no energy initially stored in the circuit. Determine *vS*(*t*), *t* ≥ 0+.

**Solution:** After the switch is opened in Figure P11.50A, the current source partitions the circuit into two; *vC*(*t*) is that of an *RC* parallel circuit charged by a 1 A source. *vC*(0+) = 0, *VCF* = 5 V, and *τ* = 0.5 s. It follows that  V; *vL*(*t*) is that of an *RL* parallel circuit charged by a 1 A source. *vL*(0+) = 5 V, *VLF* = 0, and *τ* = 2.5/5 = 0.5 s. It follows that  V; hence, *vS*(*t*) = *vC*(*t*) + *vL*(*t*) = 5 V.

**P12.10** The switch in Figure P12.10 is opened at *t* = 0 after being closed for a long time. (a) Determine *iL*, *vC*, *dvC*/*dt*, and *diL*/*dt* just after the switch is opened. (b) Is the circuit reducible to a prototypical series *LCR* circuit or a parallel *GCL* circuit?

**Solution:** (a) Just before *t* = 0, *iC* = 0 in Figure P12.10 and the 3 mA divides between the 3 kΩ and 6 kΩ resistors, so that *IL*0 = 3×3/9 = 1 mA; *VC*0 = 6×1 = 6 V. These do not change on switching. Just after *t* = 0, 2*iC* + *iL* = 0, so that *iC* = -*iL*/2 = -0.5 mA = *C*, and **-1000 V/s. From KVL, *VC*0 + 1×*iC* = 6*IL*0 + *vL*. Hence, *vL* = 6 – 0.5 – 6 = -0.5 V = *L*, and **=** = -5 A/s.

(b) The circuit is not reducible to a prototypical second-order circuit.

**P12.13** The switch in Figure P12.13 is opened at *t* = 0, after being closed for a long time. Determine *dvR*/*dt* at *t* = 0+.

**Solution:** Before the switch opens in Figure P12.13, *vR* = 0 and *iL* = 0. Both remain zero just after the switch is opened. *ISRC* will therefore initially flow through the capacitor, which makes 1 mA = -*CdvR*/*dt*. It follows that *dvR*/*dt* = -1×10-3/1×10-6 = -103 V/s = -1 V/ms.

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**P12.16** Given  mA in Figure P12.16, *t* is in s. Determine , , *vL*(*t*), and *vC*(*t*), assuming zero initial charge on the capacitor. Verify that *vR* + *vL* + *vC* = 0.

**Solution:** It is seen from the expression for current that the response in Figure P12.16 is critically damped; ; hence   H; *R* = 2×6.25×400 = 5 KΩ; =  + =  V.

=

 V.

As a check, .

**P12.18** The switch in Figure P12.18 is moved from position ‘a’ to position ‘b’ at *t* = 0 after being in position ‘a’ for a long time. Determine *vC*(*t*) and *iL*(*t*) for *t* ≥ 0+.

**Solution:** After the switch is moved to position ‘b’ in Figure P12.18, the circuit becomes a series circuit;  rad/s,  rad/s; the response is overdamped.  rad/s; . At *t* = 0, *iL* = 2 A, *vC* = 0. . At *t* = 0, *A* + *B* = 2.  . At *t* = 0, . Solving for *A* and *B* gives: , and . It

follows that  A, where *t* is in ms and  kV.