**EECE 210 Electric Circuits**

**Final Exam – Dec 14, 2016**

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1. **Using superposition**, determine: (a) **VO** (8 grades) and (b) the power delivered or absorbed by the independent voltage source (4 grades).

**Solution:** The dependent source is replaced by an independent source **VX** = 2**VO**. With the 2 V source applied alone, **VO1** = 0. With the 2 A current source applied alone, the inductor is short circuited, and ; with **VX** applied alone, it follows from voltage division that . Substituting for **VX**, the superposition equation is: **VO** = (1 – *j*) + **VO**(1 + *j*), which gives **VO** = (1 + *j*) V.

The voltage across the dependent source is (2 + *j*2) V; the voltage across the inductor is 2 + *j*2 – 2 = *j*2 V, and the current flowing through the inductor towards the 2 V source is *j*2/*j* = 2 A. The current through the 2 V source is zero, so that this source neither delivers nor absorbs power.



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1. Determine the open-circuit voltage **Vab** and the short-circuit current **Iab** , as phasors in polar coordinates, assuming *vSRC* = 3cos103*t* V.

**Solution:** Replacing the coupled coils by the T-equivalent circuit, the circuit becomes in the frequency domain as shown. It follows from voltage division that: .

 On short circuit, the -*j*3 Ω and *j*3 Ω branches act as an open circuit, so that the current toward these branches is zero and the voltage across them is **VSRC**. It follows that  A.

**Version 1:** **VSRC** = 3∠0°; **Vab** = 4.5∠-90° V,

**Iab** = 1∠-90° A.

**Version 2:** **VSRC** = 6∠0°; **Vab** = 9∠-90° V,

**Iab** = 2∠-90° A.

**Version 3:** **VSRC** = 9∠0°; **Vab** = 13.5∠-90° V, **Iab** = 3∠-90° A.

**Version 4:** **VSRC** = 12∠0°; **Vab** = 18∠-90° V, **Iab** = 4∠-90° A.

**Version 5:** **VSRC** = 15∠0°; **Vab** = 22.5∠-90° V, **Iab** = 5∠-90° A.

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1. (a) Transform the 10∠0° A source and its source impedance to its equivalent voltage source, and (b) determine **VO** **using the mesh-current method**, assuming **ISRC** = 1∠0° A.

**Solution:** Mesh 1: **I1** = **ISRC**;

Mesh 3: -*j*2**I2** + (8 + *j*2)**I3** = 0

For the dependent source, **IX** = **I3**= **I2** – **I1** = **I2** – **ISRC**, so that **I2** = **I3** + **ISRC**. Substituting in the equation for mesh 3:

-*j*2(**I3** + **ISRC**) + (8 + *j*2)**I3** = 0, or, -*j*2**ISRC** + 8**I3** = 0, or,

**I3** = *j*0.25**ISRC**, so that **VO** =

8**I3** = *j*2**ISRC** V.

**Version 1:** **ISRC** = 1∠0° A; **VO** = 2∠90° V.

**Version 2:** **ISRC** = 2∠0° A; **VO** = 4∠90° V.

**Version 3:** **ISRC** = 3∠0° A; **VO** = 6∠90° V.

**Version 4:** **ISRC** = 4∠0° A; **VO** = 8∠90° V.

**Version 5:** **ISRC** = 5∠0° A; **VO** = 10∠90° V.



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1. Determine **VS**, assuming **ISRC** = 1∠0° A.

**Solution:** From symmetry the –*j*20 reactance does not carry current. It is redundant and can be removed. Replacing the coupled coils by the T-equivalent circuit, the circuit becomes as shown. it follows that the impedance seen by the source

Is –*j*17.5 + *j*5 + *j*45/2 = *j*10 Ω, so that **VS** = *j*10**ISRC**.

Alternatively, transforming the delta to a star, and replacing the coupled coils by the T-equivalent circuit, the circuit becomes as shown. It is seen that the impedance seen by the source is -*j*17.5 + *j*5 + *j*22.5 = *j*10 Ω. It follows that **VS** = *j*10**ISRC**.

**Version 1:** **ISRC** = 1∠0°; **VS** = 10∠90° V.

**Version 2:** **ISRC** = 1.5∠0°; **VS** = 15∠90° V.

**Version 3:** **ISRC** = 2∠0°; **VS** = 20∠90° V.

**Version 4:** **ISRC** = 2.5∠0°; **VS** = 25∠90° V.

**Version 5:** **ISRC** = 3∠0°; **VS** = 30∠90° V.

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1. Determine **IL** as a phasor in polar coordinates, assuming *vSRC*(*t*) = cos(*t* + 45°) V.

**Solution:** *ωL* = 22.5 Ω, 1/*ωC* = 10 Ω; the circuit in the frequency domain is as shown.

**V1** = **VSRC** – *j*45**IL**; **V2** = **VSRC** + *j*30**IL**;

2**V1** + 3**V2** = 10**IL**; substituting for **V1** and **V2**, 2**VSRC** – *j*90**IL** + 3**VSRC** + *j*90**IL** = 10**IL**;

**IL** = 0.5**VSRC** A

**Version 1:** **VSRC** = 1∠45°; **IL** = 0.5∠45° A.

**Version 2:** **VSRC** = 2∠45°; **IL** = 1∠45° A.

**Version 3:** **VSRC** = 3∠45°; **IL** = 3∠45° A.

**Version 4:** **VSRC** = 4∠45°; **IL** = 2∠45° A.

**Version 5:** **VSRC** = 5∠45°; **IL** = 2.5∠45° A.

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1. The switch is closed at *t* = 0, with no stored energy in the circuit. Determine *iS*(*t*), *t* ≥ 0+, assuming *VSCR* = 10 V.

**Solution:** The current flowing downwards in the capacitive branch is  A. The current flowing downwards in the inductive branch is  A, where *τC* = 10×0.001= 0.01 s and *τL* = 0.1/10 = 0.01 s. It follows that *iS*(*t*) = *VSRC*/10 A.

**Version 1:** *VSRC* = 10, *iS*(*t*) = 10/10 = 1 A.

**Version 2:** *VSRC* = 15, *iS*(*t*) = 15/10 = 1.5 A.

**Version 3:** *VSRC* = 20, *iS*(*t*) = 20/10 = 2 A.

**Version 4:** *VSRC* = 25, *iS*(*t*) = 25/10 = 2.5 A.

**Version 5:** *VSRC* = 30, *iS*(*t*) = 30/10 = 3 A.

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1. Both switches are moved at *t* = 0 after being in their initial positions for a long time. Determine *vC*(*t*) and *iL*(*t*) for *t* ≥ 0+.

**Solution:** At *t* = 0-, it follows from current division that *iL*(0-) = 10 A and the current through the 4 Ω resistor is 20 A, so that *vC*(0-) = 80 V. These do not change at *t* = 0+. As *t* → ∞, the capacitor acts as an open circuit and the inductor as a short circuit, so that *iL*(∞) = 0. The 5 A current flows through the 8 Ω resistor, making *vC*(∞) = 40 V.

When the 5 A source is set to zero, the circuit is a series circuit; *α* = *R*/2*L* = 8/20 = 0.4 rad/s;  rad/s; the responses are underdamped, and  rad/s.

 V; At *t* = 0+, 80 = *A* + 40, so that *A* = 40 V; at *t* = 0+, *iL* = -*CdvC*/*dt* = -*C*(-*αA* + *ωdB*) = 10; *ωdB* = -25 + 0.4×40 = -9, *B* =

-9/0.3 = -30. Hence, .

*iL*(*t*) = -*CdvC*/*dt* 

 A.

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1. Switch S1 is moved from position ‘a’ to position ‘b’ at *t* = 0 after being in position ‘a’ for a long time. Switch S2 is closed at *t* = 0.5545 ms. Determine *iL*(*t*) and *vC*(*t*) for *t* ≥ 0+.

**Solution:** At *t* = 0, *vX* = 0 and *vC*(0+) = 5×4 = 20 V; 0 ≤ *t* ≤ 0.5545 ms, *τ* = 100×8×10-6 =

8×10-4 ≡ 0.8 ms, and *vC*(*t*) =. At *t* = 0.5545 ms, *vC*(*t*) = 10

V. Let *t*′ = *t* – 0.5545 ms; For *t*′ > 0, the series is a parallel *GCL* circuit having *ω*0 =  rad/s; *αp* = rad/s. The responses are overdamped, with *s*1 = -1250 + -1250 + 750 = -500 rad/s and *s*2 = -1250 – -1250 – 750 = -2000 rad/s. *IL*0 = 0 and *ILF* = -10/100 = -0.1 A. Hence,  A; at *t*′ = 0, *A* + *B* = 0.1; At *t*′ = 0+, *vC*(0+) = 10 = 10 *+* *LdiL*/*dt*. Hence, *LdiL*/*dt* = 0 at *t*′ = 0+, or -500*A* – 2000*B* = 0. Substituting *A* = -4*B* gives *B* = -0.1/3 A and *A* = 0.4/3 A. Hence, mA, where *t*′ is in ms.



=  + 10 V.