**Homework 1**



**P13.1.10** Determine *iO* in Figure P13.1.10.

**Solution:** *Ir* = 25/5 = 5 mA = *If*;

*Va* = 0 – 50×5 = -250 V;

currentin 10 kΩ resistor = 250/10 = 25 mA; currentin 40 kΩ resistor = 25 + 5 = 30 mA; *VO* = -250 – 40×30 = -1450 V; current in 30 kΩ resistor = 1450/30 = 145/3 mA; *iO* = 30 + 145/3 = 235/3 mA.

**P13.1.11** Determine, in Figure P13.1.11: (a) *VO*; (b) power delivered or absorbed by each source.



**Solution:** (a) Because of the virtual short circuit, current in 2 kΩ resistor = 0; current in upper 1 kΩ resistor = 0.5 mA; *VO* – *VN* = *VO* – *VP* = 0.5 V = 2 + *IX*×1, from KVL. This gives *IX* = -1.5 mA; from KCL at node P, current in lower 2 kΩ resistor = 1 mA; *VP* = -2×1 = - 2 V; *VO* – (-2) = 0.5, which gives *VO* = -1.5 V.

(b) Voltage across current source is 0, so no power is delivered or absorbed by this source; 2 V source delivers 2×1.5 = 3 mW.

**P13.1.15** Show that *iL =* (*v*2 *– v*1)/*R2* in Figure P13.1.15. Note that the load sees a current source whose value is determined by the differential input (*v*2 *– v*1).



**Solution:** From KCL at the op amp terminals,  and *iL* = . This gives: *R*2*iL* = *v*2 – *vP* +  and *v*1 – *vN* –  = 0; Subtracting the second equation from the first, with *vP* = *vN*: *R*2*iL* = *v*2 – *v*1, or *iL* = .



**P13.1.20** The switch is closed at *t* = 0, with *VC*0 = 20 V. Determine *t* at which the op amp just reaches negative saturation.

**Solution:** *ir* = 10/1 = 10 mA. . Let *vO* = -20 V at *t* = *T*. This gives,  = , so that *T* = 4×10-3 ≡ 4 ms.



Physically, the change in capacitor voltage is 40 V, which requires a change of capacitor charge of 40 μC. When the capacitor current is 10 mA, the time taken to change the charge by 40 μC is given by: 10-2×*T* = 40×10-6, or *T* =

40×10-4 ≡ 4 ms.

**P13.1.22** The switch in Figure P13.1.22 is closed at *t* = 0, with the inductor initially uncharged. Determine *vO*, given *vSRC* = 5sin100*t* V.



**Solution:** *i*1 = *vSRC*/200 = 5sin100*t*/200 = sin100*t*/40 A.

*i*2 = 10/104 = 10-3 A. *iL* = *i*1 + *i*2 =

sin100*t*/40 + 10-3 A. *vO* = -*LdiL*/*dt* = -(100/40)cos100*t* =

-2.5cos100*t* V.



**P13.2.3** Determine *VO*1 and *VO*2 in Figure P13.2.3.

**Solution:** From the virtual short circuit, the voltages of 15 V and 10 V appear at the nodes shown. It follows that the current in the 1 kΩ resistor is 10 mA, and that in the 5 kΩ resistor is 1 mA. From KCL at the lower node, the current in the 0.4 kΩ resistor is 9 mA. Hence, *VO*2 = 10 + 0.4×9 = 13.6 V.



*i*2 = (15 – 13.6)/2 = 0.7 mA.

*I*1 = 1.7 mA, and *VO*1 = 15 + 0.5×1.7 = 15.85 V.



**P13.2.5** Determine *vO*/*vSRC* in Figure P13.2.5.

**Solution:** The lower amplifier is an inverting amplifier of gain -25/5 = -5, so that *vO*2 = -5*vSRC*.



In the upper amplifier, the voltage of the op amp terminals is *vSRC*, so that the current in the 10 kΩ resistor is *vSRC*/10. This same current flows through the 20 kΩ resistor, producing a voltage drop of 2*vSRC* across this resistor and resulting in *vO*1 = 3*vSRC*. It follows that *vO* = *vO*1 – *vO*2 = 8*vSRC*, and *vO*/*vSRC* = 8.

**P13.2.8** Show that *Cin* = *C*/*α* in Figure P13.2.8, where *α* is the fraction of *Rp* that appears between nodes ‘a’ and ‘b’.



**Solution:** The first amplifier is a unity-gain follower of output = **VT**. The second amplifier is an inverting amplifier of gain -(1 – *α*)/*α* and whose input is **VT**. this gives **VO** = **VT**. Hence, **IT** = (**VT** – **VO**)*jωC* = *jωC***VT** = **VT.** It follows *Cin* = *C*/*α.*

