**Homework 12 – F2018**



**P11.6** The switch in Figure P11.6 is moved to position ‘b’ at *t* = 0 after being in position ‘a’ for a long time. Determine, for *t* ≥ 0+: (a) *vC*(*t*); (b) *vO*(*t*); (c) *iO*(*t*); (d) the total energy dissipated in the 60 kΩ resistor as *t* → ∞.

**Solution:** (a) In Figure P11.6, *vC*(0+) = 100 V; *VF* = 0; the resistance seen by *C* is: 32 + 240||60 = 32 + 48 = 80 kΩ; *τ* = 0.5×10-6×80×103 = 0.04 s; it follows that  V, *t* is in s.

(b) From voltage division, *vO*(*t*) = (48/80)*vC*(*t*) =  V.

(c) *iO*(*t*) = *vO*(*t*)/60 =  mA.

(d) The total energy dissipated in the 60 kΩ resistor is 60×103=

60×10-3 mJ. Alternatively, The initial energy stored in the capacitor is 0.5×0.5×10-6×104 ≡ 2.5 mJ; the energy dissipated in the 48 kΩ resistor in series with the 32 kΩ resistor is 2.5×48/80 = 1.5 mJ; this energy is dissipated in 60 kΩ in parallel with 240 kΩ, and divides in proportion to the conductances. The energy dissipated in the 60 kΩ resistor is therefore

 mJ.

**P11.8** The switch in Figure

P11.8 is closed at *t* =

0, the capacitor being

initially uncharged.

Determine for *t* ≥ 0+:

(a) *vC*(*t*); (b) *iX*(*t*).

**Solution:** (a) *VC*0 = 0 in Figure P11.8. *VCF* = 45×10/15 = 30 V. The time constant after the switch is closed and with

the source set to zero, is: 10-6(5||10)×103 = 10/3 ms. It follows that *vC* = 30V, where *t* is in ms.

(b) Just after the switch is closed, *VC0* = 0 and *IX*0 = 45/5 = 9 mA. *IXF* = 45/15 = 3 mA. It follows that *iX* = 3 + mA.



###### P11.14 The switch in Figure P11.14 is moved to position ‘b’ at t = 0, after being in position ‘a’ for a long time. Determine *vC*(*t*) for *t* ≥ 0+.

**Solution:** Just before the switch is moved in Figure P11.14, *VC*0 = -30 V; *VCF* = -20 V; *τ* = 50×103×2×10-6 = 0.1 s. Hence,  V.

**P11.15** The switch in Figure P11.15 is moved to position ‘b’ at *t* = 0 after being in position ‘a’ for a long time. Determine, for *t* ≥ 0+: (a) *vC*(*t*); (b) *iC*(*t*) from initial and final values as well as from the *v*-*i* relation for the capacitor.

**Solution:** (a) *VC*0 = -40×60/80 = -30 V in Figure P11.15; *VCF* = 90 V.

*τ* = 400×103×0.5×10-6 = 0.2 s. It follows that *vC* = 90 + (-30 – 90) =  V.

(b) Just before the switch is moved, *iC* = 0 and *vC* = -30 V. Just after the switch is moved is moved, *vC* = -30 V and *iC* = (90 – (-30)) /400 = 120/400 = 0.3 mA. The final value of *iC* is zero. Hence,  mA. Alternatively, *iC* = *CdvC*/*dt* = 0.5×10-6(5×120) = 300×10-6 A ≡ 0.3 mA.

**P11.20** The capacitor in Figure P11.20, was initially uncharged and the switch was in position ‘a’. At  the switch is moved to position ‘b’. Determine for *t* ≥ 0+: (a) *vC*(*t*); (b) *iC*(*t*); (c) the energy delivered by the 12 V battery as *t* → ∞ (d) the energy absorbed by the 6 V battery as *t* → ∞; (e) the energy dissipated in the resistor as *t* → ∞; verify this by integrating the power dissipated by *iC* from *t* = 0+ to *t* → ∞; (f) If after a long time, *t′* = 0, the switch is moved to position ‘c’, determine *vC*(*t*) and *iC*(*t*) for *t′* ≥ 0+, the energy delivered by the 6 V battery, the energy gained or lost

by the capacitor, and the energy dissipated in the resistor.

**Solution:** (a) *vC*(0-) = 0 in Figure P11.20; *VCF* = 6 V. *τ* = 1×1 = 1 ms. Hence, *vC* =  V, *t* is in ms;

(b) *iC*(0+) = (12 – 6)/1 = 6 mA; *ICF* = 0;  mA.

(c) Energy delivered by the 12 V battery is = =  ≡ 72 μJ as *t* →∞.

(d) Energy absorbed by the 6V battery is = ≡ 36 μJ as *t* →∞.

(e) As *t* →∞, net energy delivered by the two batteries is 36 μJ. Energy stored in capacitor is (1/2)×10-6×36 = 18 μJ. Energy dissipated in the resistor = 36 – 18 = 18 μJ = 18 μJ, or *W* =  J ≡ 18 μJ.

(f) For *t*′ ≥ 0, initial value of *vC* is 6 V, final value is –6 V, *τ* being the same. Hence, V; initial value of *iC* is -12/1 mA, final value is zero; . As , energy delivered by the battery is = 72

μJ; net energy lost by the capacitor is 18 – 18 = 0, energy dissipated in the resistor is μJ.



**P11.26** The switch In Figure P11.26 is moved to position ‘b’ at *t* = 0 after being in position ‘a’ for a long time. Determine *vC*(*t*) for *t* ≥ 0+.

**Solution:** When the switch has been in position ‘a’ for a long time in Figure P11.26, the two current sources may be combined into a single 2 mA source directed downwards. From current division, the upward current in the capacitive branch is 2×40/70 = 8/7 mA, and *v*C(0-) = V. When the switch is moved to position ‘b’, the 4 mA source and 10 kΩ resistor are switched out of the circuit. The current in the capacitive branch as *t* → ∞ is 8/7 mA upwards, and *VCF* = V. With the 2 mA source set to zero, the effective resistance across *C* is 20||(10 + 40) =  kΩ; *τ* = s. It follows that *v*C(*t*)=  V, *t* is in s.

**P11.27** The capacitor in Figure P11.27 is charged to 10 V at *t* = 0. Determine *vC*(*t*) for *t* ≥ 0.

**Solution:** *vC*(0) = 10 V in Figure P11. .27. As *t* →∞, *iC* → 0, so the voltage of the dependent source is zero. The 15 Ω and 10 Ω resistors appear in parallel with *C*, which must be completely discharged; *vC*(∞) = 0. To determine *τ*, a test *vT* is applied as shown in Figure P11.27A.

From KCL, , which gives *vT*/*iT* = 8 kΩ. Hence, *τ* = 8×1.25 = 10 ms. It follows that  V, *t* is in ms.



**P11.31** The switch in Figure P11.31, is closed at  after being open for a long time. Determine *vO*(*t*) for *t* ≥ 0+.

**Solution:** When the switch has been open for a long time in Figure P11.31, the capacitor current is zero, so that *VA* = 4×3 = 12 V, and *vO*(0-) = 3*v*A + 24 = 60 V. As *t* → ∞, *V*A = 0 and *VOF* = 24 V. To find the effective resistance across *C*, a test source *VT* is applied in place of *C*, as shown in Figure P11.31A. It is seen that *VT* = 3*V*A, where *V*A = 2*IT*; hence,  = 6 kΩ, and *τ* = 6×20 = 120 ms. It follows that *vO*(*t*) = 24 + 48*e*-*t*/0.12 V, where *t* is in s.