Chapter 10, Solution 78.

Determine $v_o(t)$ in the op amp circuit in Fig. 10.121 below.

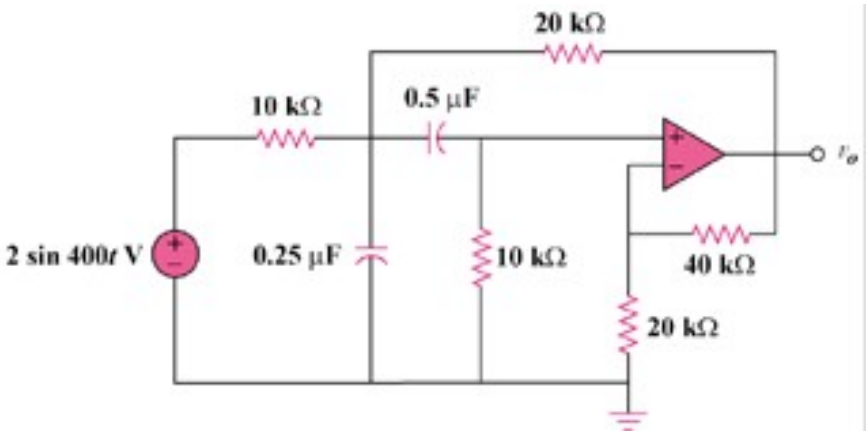


Figure 10.121
For Prob. 10.78.

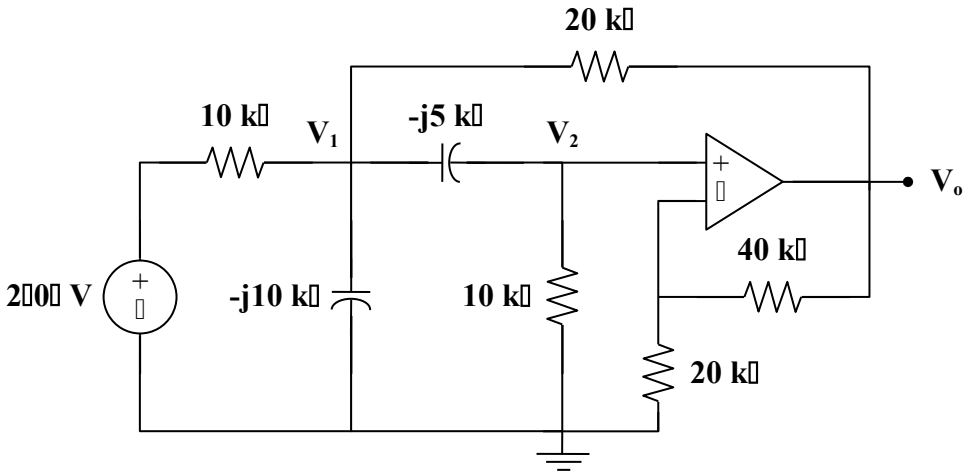
Solution

$$2\sin(400t) \longrightarrow 2\angle 0°, \quad \omega = 400$$

$$0.5\ \mu\text{F} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j(400)(0.5\times10^{-6})} = -j5\ \text{k}\Omega$$

$$0.25\ \mu\text{F} \longrightarrow \frac{1}{j\omega C} = \frac{1}{j(400)(0.25\times10^{-6})} = -j10\ \text{k}\Omega$$

Consider the circuit as shown below.



At node 1,

$$\frac{2-V_1}{10} = \frac{V_1}{-j10} + \frac{V_1-V_2}{-j5} + \frac{V_1-V_o}{20}$$

$$4 = (3 + j6)\mathbf{V}_1 - j4\mathbf{V}_2 - \mathbf{V}_o \tag{1}$$

At node 2,

$$\frac{\mathbf{V}_1 - \mathbf{V}_2}{-j5} = \frac{\mathbf{V}_2}{10}$$

$$\mathbf{V}_1 = (1 - j0.5)\mathbf{V}_2 \tag{2}$$

But

$$\mathbf{V}_2 = \frac{20}{20 + 40}\mathbf{V}_o = \frac{1}{3}\mathbf{V}_o \tag{3}$$

From (2) and (3),

$$\mathbf{V}_1 = \frac{1}{3} \cdot (1 - j0.5)\mathbf{V}_o \tag{4}$$

Substituting (3) and (4) into (1) gives

$$4 = (3 + j6) \cdot \frac{1}{3} \cdot (1 - j0.5)\mathbf{V}_o - j\frac{4}{3}\mathbf{V}_o - \mathbf{V}_o = \left(1 + j\frac{1}{6}\right)\mathbf{V}_o$$

$$\mathbf{V}_o = \frac{24}{6 + j} = 3.945\angle -9.46°$$

Therefore,

$$v_o(t) = \mathbf{3.945\sin(400t - 9.46°)\ V}$$