Answer 1

A -4 volts

B -2 volts

C -10 volts

D 4 volts (voltage follower circuit)

E 5 volts (Zener action: 100 mA available
50 mA needed)

F 1 mA (2 mA from 4 volt supply, -1 from -8 v)

G 3 volts (no Zener action: "100 mA available,
200 mA needed")
Circuit acts as a voltage divider

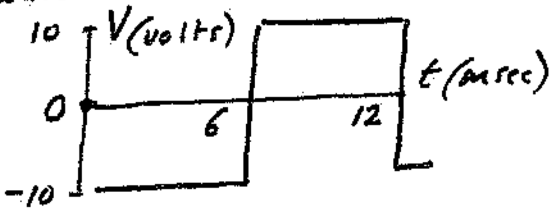
H 7 volts Linear op amp operation ($v_I = 0$)
places 5 volts across 10 kΩ.
The resulting 0.5 mA flows in
both 2 kΩ resistors.
Application of KVL gives result

Answer 2

a) We have an integrator feeding into a trigger. Feedback from the latter to the former results in oscillation, with the output of the trigger switching between −10 volts and + 10 volts.

<u>Trigger</u> With V at 10 volts, threshold at + input is 3 volts. So as output of integrator rises from <u>below</u> 3 volts, V changes to -10^V when integrator output reaches 3 volts. Threshold is −3 volts when integrator output is falling.

<u>Integrator</u> When $V = 10$ volts, current into capacitor is 1 mA so capacitor voltage rises (and integrator output falls) at $dv/dt = i/C = 10^{-3}/1.10^{-6} = 1000$ volts/sec. The integrator output will vary from -3^V to $+3^V$ ($dv = 6$ volts) so time taken is $6/1000 = 6$ msec. Thus, the waveform of V is as shown below:



<u>Modification</u>

With the modification shown in Fig. 2(b):
With the modification capacitor current = 1.5 mA

<u>with $V=10$</u>, capacitor current $= 1.5$ mA

so $dv/dt = 1.5.10^{-3}/1.10^{-6} = 1.5.10^3$ v/sec

with $dv = 6$ volts, $dt = 4$ msec.

<u>with $V = -10$</u> capacitor current $= 0.5$ mA

so $dv/dt = 0.5.10^{-3}/1.10^{-6} = 0.5 \times 10^3$ v/sec

and with $dv = 6$ volts, $dt = 12$ msec.

So the periodic time of the square-wave voltage V is 16 msecs, and the frequency is $1000/16 = 62.5$ cycles per second.

(b) Upper Opamp: output $= 10^V$ when $V > -2^V$ otherwise output $= -10^V$

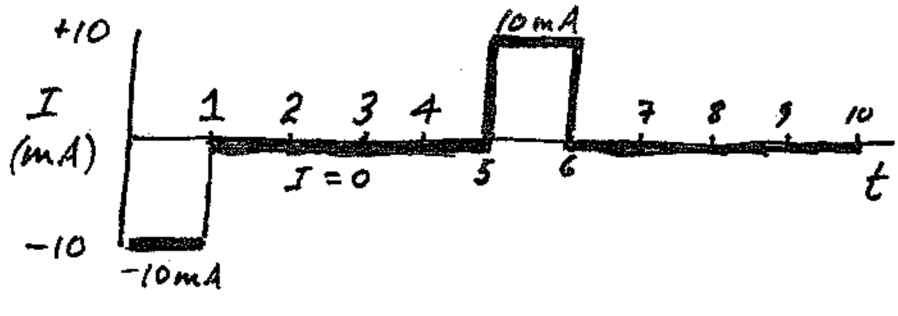
Lower Opamp: output $= 10^V$ when $V < 3^V$ otherwise output $= -10^V$

Thus:

$V > 3$ volts $\left.\begin{array}{l}\text{upper opamp ON}\\ \text{lower opamp OFF}\end{array}\right\}$ 20 volts across $2k\Omega$, $I = 10$ mA

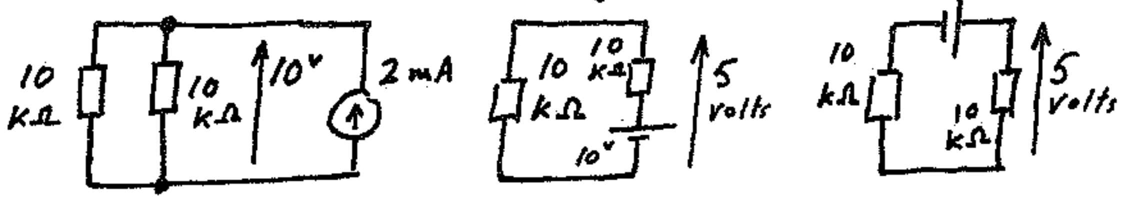
$-2 < V < 3$ volts $\left.\begin{array}{l}\text{upper opamp ON}\\ \text{lower opamp ON}\end{array}\right\}$ 0 volts across $2k\Omega$, $I = 0$ mA

$V < -2$ volts $\left.\begin{array}{l}\text{upper opamp OFF}\\ \text{lower opamp ON}\end{array}\right\}$ 20 volts across $2k\Omega$, $I = -10$ mA

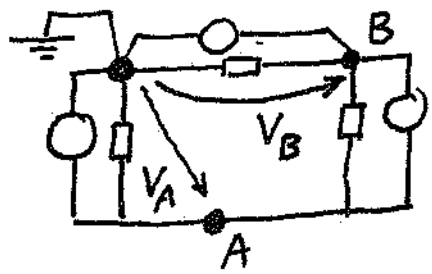


Answer 3

(a) The three relevant circuits and corresponding values of V are shown below, showing that $V = 10 + 5 + 5 = 20$ volts



(b) See node assignment at right
Note that V is identical to V_B



KCL at A (IN):

$$+V_B - \frac{V_A}{10} + \frac{V_B - V_A}{10} + 2 = 0$$

simplified gives

$$-0.2\,V_A + 1.1\,V_B = -2 \qquad (1)$$

KCL at B (IN):

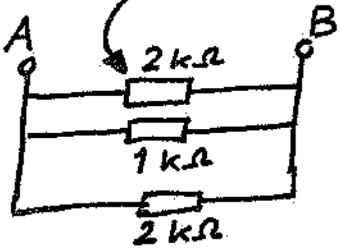
$$3 - \frac{V_B}{10} + \frac{V_A - V_B}{10} - 2 = 0$$

simplified gives

$$0.1\,V_A - 0.2\,V_B = -1 \qquad (2)$$

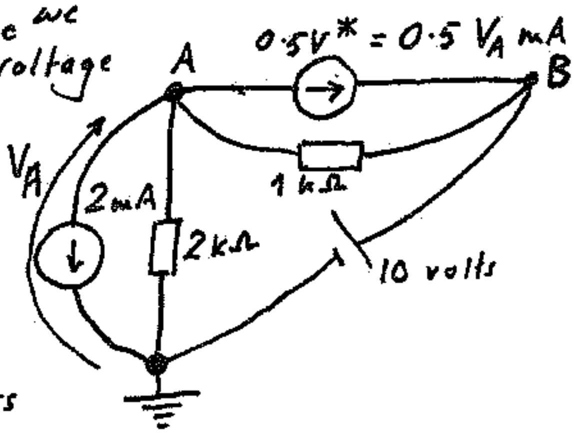
Nodal voltage equations.

VCCS equivalent



(c) The Thevenin resistance R_o is the resistance between A and B with independent sources set to zero. The VCCS is equivalent to a $2\,k\Omega$ resistor (see circuit at right). $R_o = 0.5\,k\Omega$

To find the Thevenin parameter V_{oc} we analyse circuit at right, choosing the voltage reference node shown

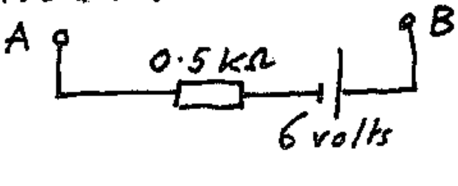


KCL at A (OUT) gives

$$2 + \frac{V_A}{2} + \frac{V_A - 10}{1} + 0.5V_A = 0$$

or, rearranging, $V_A = 4$ volts so $V_{oc} = 10 - 4$
$= 6$ volts

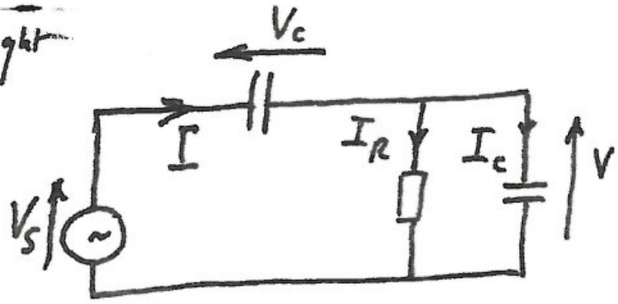
Thevenin Equivalent Circuit is:

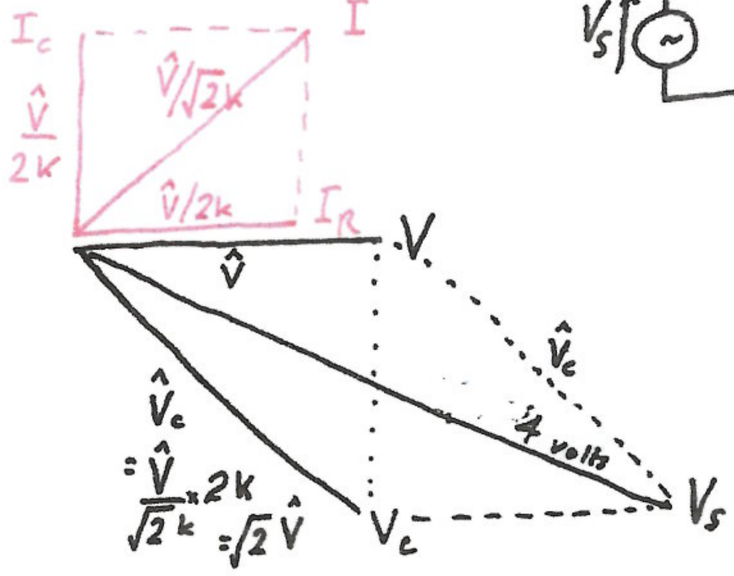


Answer 4

(a) Reactance of each capacitor is $\frac{1}{\omega C} = 2\ k\Omega$

Using the phasor notation shown at right the following phasor diagram can be constructed:





Length of V_s phasor $= \sqrt{5}\,\hat{V}$ which we know is 4 volts. So $\hat{V} = \frac{4}{\sqrt{5}}$ volts.

Therefore $\hat{V}_c = \sqrt{2}\,\hat{V} = \sqrt{2} \times 4/\sqrt{5} = \frac{8}{\sqrt{10}}$ volts

So $v_c(t)$ has an amplitude of $8/\sqrt{10}$ volts and lags $v_S(t)$ by $45° - \tan^{-1} 0{\cdot}5$

With the inductor ($\omega L = 2\ k\Omega$) connected its phasor current I_L (see diagram at right) has the same length as I_c and cancels it out. So I ($= I_R + I_c + I_L$) has a magnitude $\hat{V}/2k$ in phase with $\hat{V}$. The voltage V_c lags $90°$ behind I and V. The magnitude of V_c is $2k \times \hat{V}/2k = \hat{V}$

From the new phasor diagram (right) we see that $\sqrt{2}\,\hat{V} = 4$ volts so $\hat{V} = 2\sqrt{2}$ volts.

Therefore the amplitude of V_C is $2\sqrt{2}$ volts and and $i_S(t)$ has a magnitude of $2\sqrt{2}/2k$ mA ($= \sqrt{2}$ mA) and leads $v_S(t)$ by $45°$.

(b)