BME 372

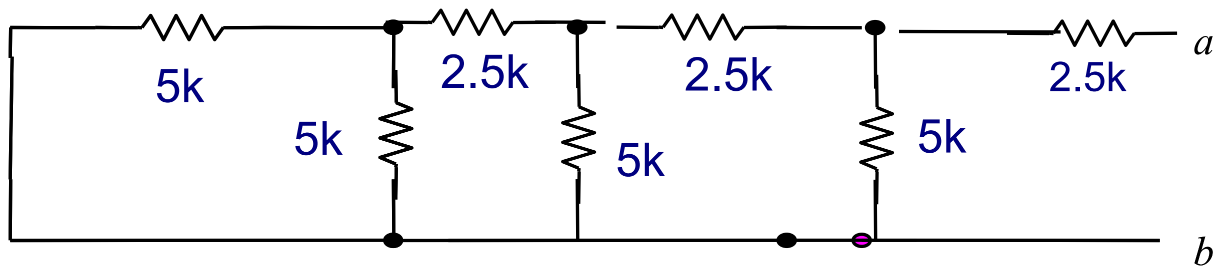
Quiz #1

Electronics I

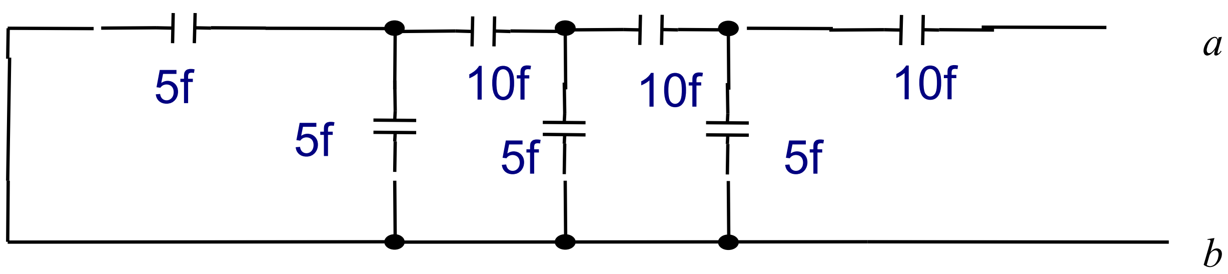
- There are 5 questions, you need to complete 4
- Questions 2, 3, and 4 are **mandatory**
- Choose 1 more from 1 or 5

Quiz #1

1. See the following two circuits. Find the resistance R_{ab} of the following circuit.

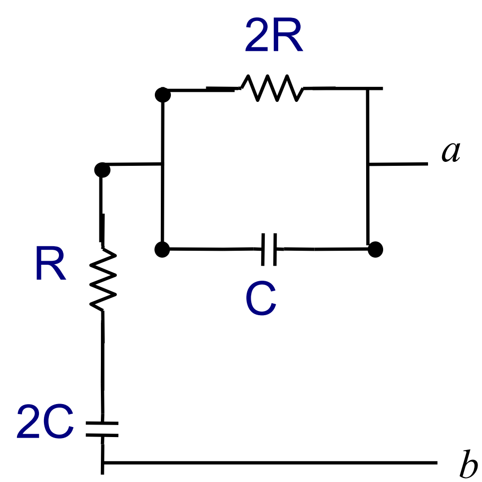


Find the total capacitance C_{ab} of the following circuit.



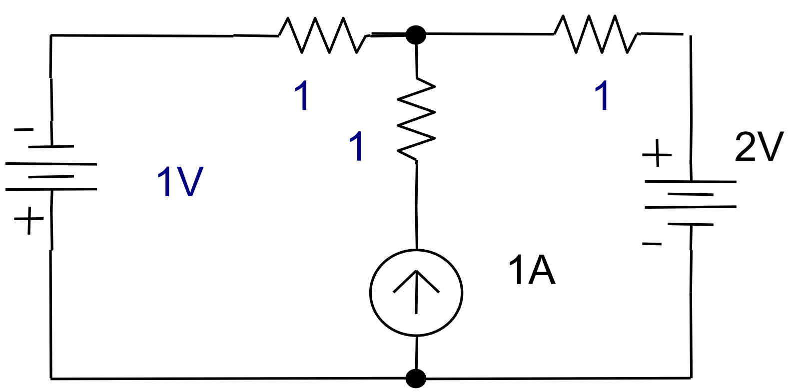
Quiz #1

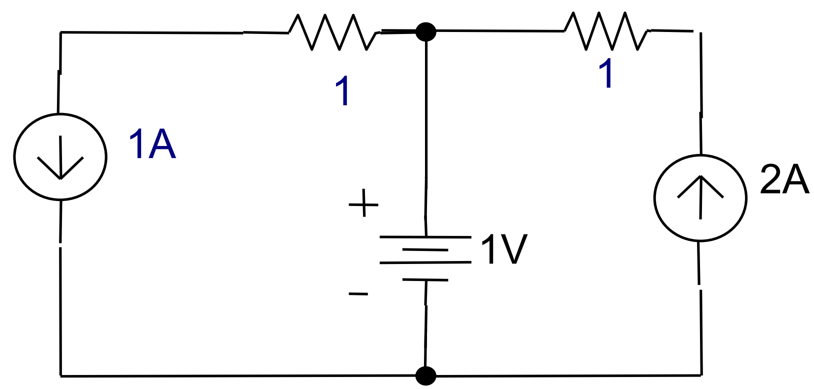
2. Find the impedance $Z_{ab}(j\omega)$. Describe (use **calculations**) what happens to the circuit elements of $Z_{ab}(j\omega)$ for $\omega = 0$ and $\omega \rightarrow \infty$ and show graphically by sketching the Bode plot from the mathematical calculation. Assume R=1 and C=1.



Quiz #1

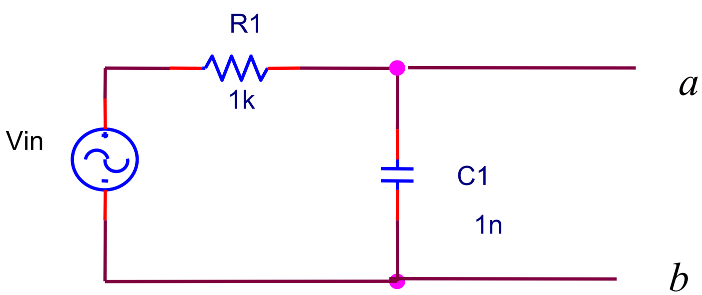
3. Calculate the all of the Currents and all of the Voltages for **<u>ONE</u>** of the following circuits. Name the circuit analysis technique you use. Prove that your solution is correct by re-calculating the currents and voltages by using a different circuit analysis technique. Note the polarities of the sources.

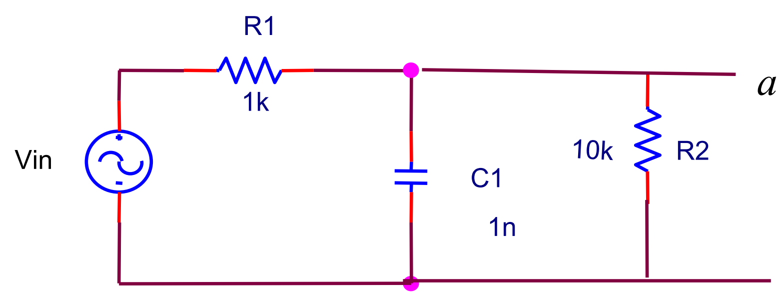




Quiz #1

4. Find the Voltage, V_{ab} for both circuits and sketch the Bode Plots of V_{ab}/V_{in}. Describe (use **calculations**) what happens to the circuit elements for $\omega = 0$ and $\omega \rightarrow \infty$ and show this mathematically. In addition, choose another interesting value of ω. What is the cutoff frequency in Hertz?





Quiz #1

5. For the Arduino Uno describe the following:

a. What are the two type of pins, what type of signal is used at each pin and describe whether they are input or outputs or both.

b. What is PWM mean and how does one implement it.

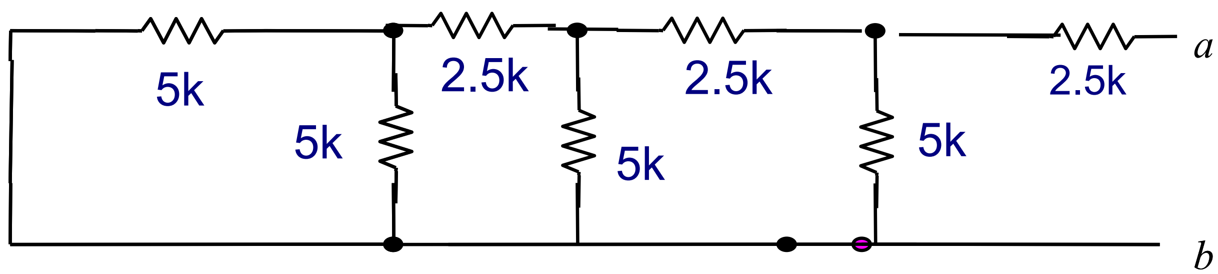
c. What is the IDE?

d. What is the Arduino program called and what computer language used to create an Arduino program.

e. What are the **<u>necessary</u>** sections of an Arduino program and what are they used for.

Quiz #1 Answers

1. Find the resistance



R_{ab}

$$R_{ab} = \{\{\{\{\{\{5k \,||\, 5k\} \Leftrightarrow 2.5k\} \,||\, 5k\} \Leftrightarrow 2.5k\} \,||\, 5k\} \Leftrightarrow 2.5k\}$$

$$R_{ab} = \{\{\{\{\{2.5k \Leftrightarrow 2.5k\} \,||\, 5k\} \Leftrightarrow 2.5k\} \,||\, 5k\} \Leftrightarrow 2.5k\}$$

$$R_{ab} = \{\{\{\{5k \,||||\, 5k\} \Leftrightarrow 2.5k\} \,||\, 5k\} \Leftrightarrow 2.5k\}$$

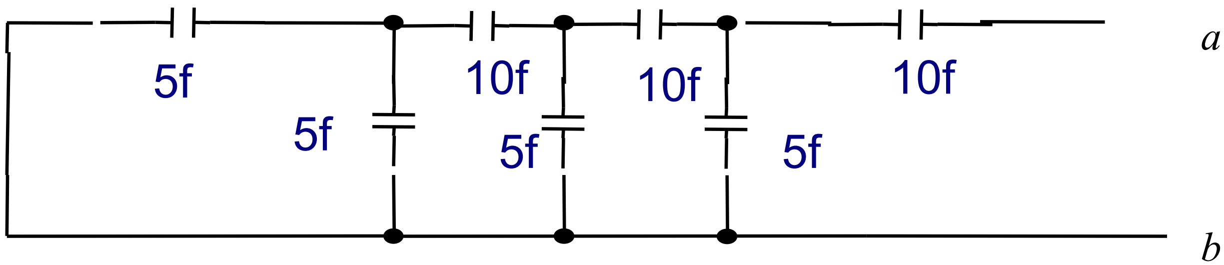
$$R_{ab} = \{\{\{2.5k \Leftrightarrow 2.5k\} \,||\, 5k\} \Leftrightarrow 2.5k\}$$

$$R_{ab} = \{\{5k \,||\, 5k\} \Leftrightarrow 5.5k\}$$

$$R_{ab} = \{2.5k \Leftrightarrow 2.5k\} = 5k$$

Quiz #1 Answers

Find the total capacitance



C_{ab}

$$C_{ab} = \{\{\{\{\{\{5 \| 5\} \Leftrightarrow 10\} \| 5\} \Leftrightarrow 10\} \| 5\} \Leftrightarrow 10\}$$

$$C_{ab} = \{\{\{\{\{10 \Leftrightarrow 10\} \| 5\} \Leftrightarrow 10\} \| 5\} \Leftrightarrow 10\}$$

$$C_{ab} = \{\{\{\{5 \||| 5\} \Leftrightarrow 10\} \| 5\} \Leftrightarrow 10$$

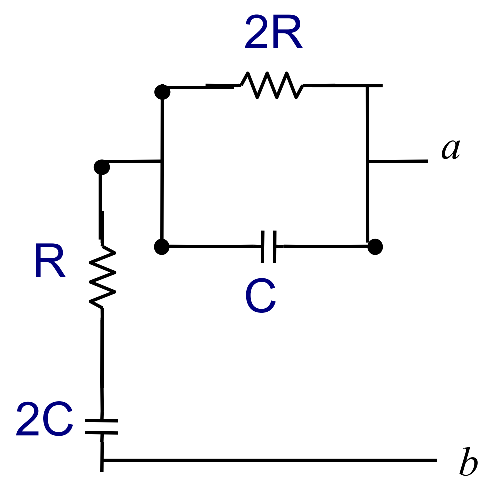
$$C_{ab} = \{\{\{10 \Leftrightarrow 10\} \| 5\} \Leftrightarrow 10\}$$

$$C_{ab} = \{\{5 \| 5\} \Leftrightarrow 10\}$$

$$C_{ab} = \{10 \Leftrightarrow 10\} = 5f$$

Quiz #1 Answers

2. Find the impedance $Z_{ab}(j\omega)$



$$Z_{ab}(j\omega) = \{\frac{1}{j\omega C} \parallel 2R\} \Leftrightarrow \{\frac{1}{j\omega 2C} \Leftrightarrow R\}$$

$$\{\frac{1}{j\omega C} \parallel 2R\} = \frac{\frac{1}{j\omega C} \times 2R}{\frac{1}{j\omega C} + 2R} = \frac{\frac{2R}{j\omega C}}{\frac{1 + j\omega 2RC}{j\omega 2C}} = \frac{2R}{1 + j\omega 2RC}$$

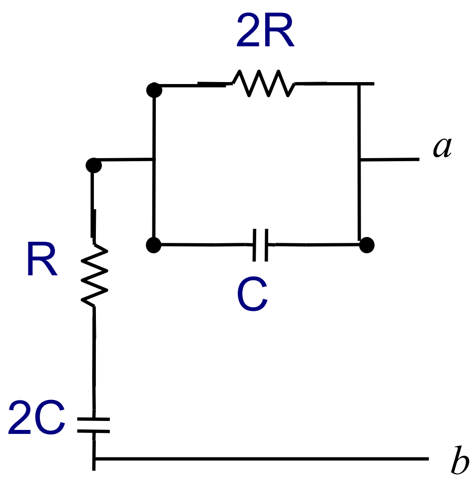
$$\frac{1}{j\omega 2C} \Leftrightarrow R = \frac{1}{j\omega 2C} + R = \frac{1 + j\omega 2RC}{j\omega 2C}$$

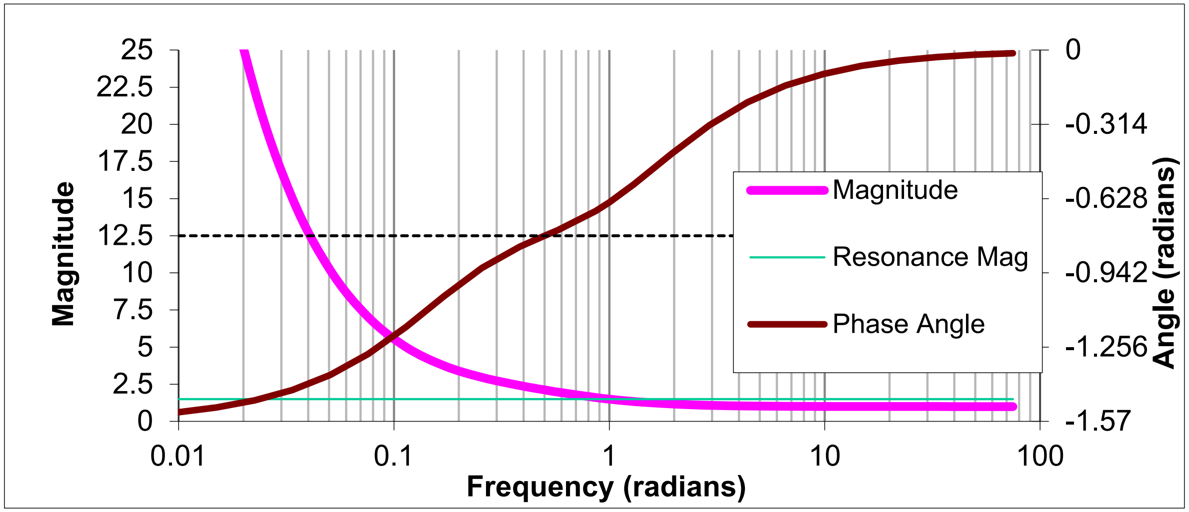
$$Z_{ab}(j\omega) = \frac{2R}{1 + j\omega 2RC} + \frac{1 + j\omega 2RC}{j\omega 2C} = \frac{j\omega C2R + (1 + j\omega 2RC)(1 + j\omega 2RC)}{j\omega 2C(1 + j\omega 2RC)} = \frac{j\omega C2R + 1 + j4\omega RC - (\omega 2RC)^2}{-\omega^2 2RC^2 + j\omega 2C}$$

$$Z_{ab}(j\omega) = \frac{1 - (\omega 2RC)^2 + j6\omega RC}{-\omega^2 4RC^2 + j\omega 2C} = \frac{\sqrt{(1 - (\omega 2RC)^2)^2 + (\omega 6RC)^2}}{\sqrt{(\omega 4RC^2)^2 + (\omega 2C)^2}} \angle \tan^{-1}(\frac{\omega 6RC}{1 - (\omega 2RC)^2}) - \tan^{-1}(\frac{\omega 2C}{-\omega^2 4RC^2})$$

Quiz #1 Answers

2. Find the impedance $Z_{ab}(j\omega)$





$$Z_{ab}(j\omega)=\frac{1-(\omega 2RC)^2+j6\omega RC}{-\omega^2 4RC^2+j\omega 2C}=\frac{\sqrt{(1-(\omega 2RC)^2)^2+(\omega 6RC)^2}}{\sqrt{(\omega 4RC^2)^2+(\omega 2C)^2}}\angle\tan^{-1}\left(\frac{\omega 6RC}{1-(\omega 2RC)^2}\right)-\tan^{-1}\left(\frac{\omega 2C}{-\omega^2 4RC^2}\right)$$

$$Z_{ab}(j\omega)|_{\omega\to 0}=\frac{1-(\omega 2RC)^2+j\omega 6RC}{-\omega^2 4RC^2+j\omega 2C}|_{\omega\to 0}\to\frac{1}{j\omega 2C}\to\infty\angle-\frac{\pi}{2};$$

when ω=0 capacitors become open circuits and circuit looks like $2R$ in series with series C which approaches an open circuit

$$Z_{ab}(j\omega)|_{\omega\to\infty}=\frac{1-(\omega 2RC)^2+j\omega 6RC}{-\omega^2 4RC^2+j\omega 2C}|_{\omega\to\infty}\to\frac{-(\omega 2RC)^2}{-\omega^2 4RC^2}=\frac{-\omega^2 4R^2C^2}{-\omega^2 4RC^2}=R=R\angle 0;$$

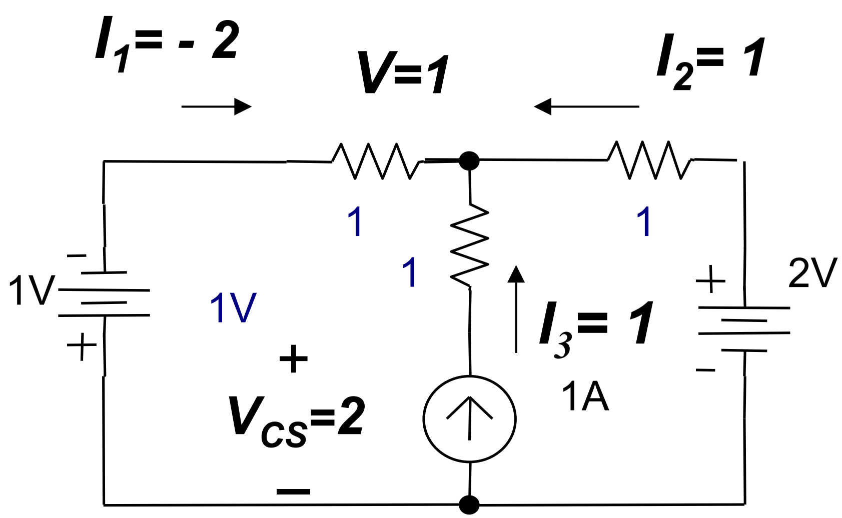
when $\omega\to\infty$ capacitors become short circuits and parallel C shorts out parallel R and circuit looks like series R and a short.

Third point: try $\omega=\frac{1}{2RC}$ to make the real part of the numerator = 0.

$$Z_{ab}(j\omega)|_{\omega=\frac{1}{2RC}}=\frac{1-(\omega 2RC)^2+j\omega 6RC}{-\omega^2 4RC^2+j\omega 2C}|_{\omega=\frac{1}{2RC}}=\frac{0+j\frac{1}{2RC}6RC}{-(\frac{1}{2RC})^2 4RC^2+j\frac{1}{2RC}2C}=\frac{0^2+j3}{-(\frac{1}{R})+j\frac{1}{R}}=\frac{j3R}{-1+j1}=\frac{3R}{\sqrt{2}}\angle\frac{\pi}{2}-\frac{3\pi}{4}=2.12\angle-\frac{\pi}{4}$$

Quiz #1 Answers

3a. Calculate the Currents and Voltages for the following circuits:



Nodal Analysis:

$$I_1 + I_2 + I_3 = 0; I_3 = 1$$

$$\frac{-1-V}{1} + \frac{2-V}{1} + 1 = 0$$

$$-2V + 2 = 0$$

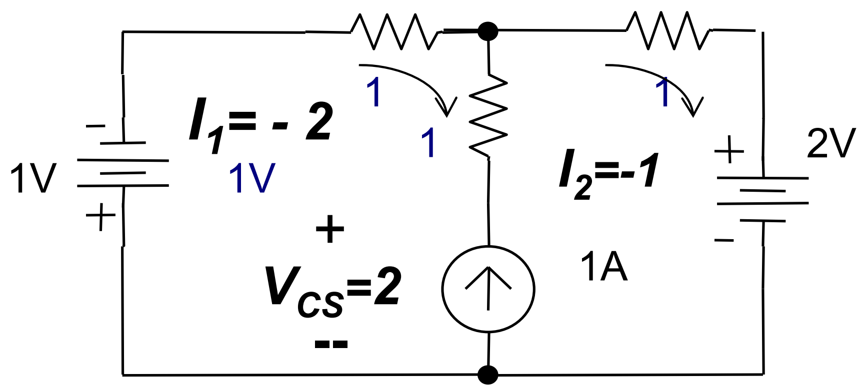
$$V = 1$$

$$I_1 = \frac{-1-1}{1} = -2; I_2 = \frac{2-1}{1} = 1$$

$$V_{cs} = I_3 1 + V = 1 \times 1 + 1 = 2V$$

Quiz #1 Answers

3b. Calculate the Currents and Voltages for the following circuits:



Mesh Analysis:

Mesh #1

$1 + I_1 + (I_1 - I_2)1 + V_{cs} = 0$

Note $I_1 - I_2 = -1$

$1 + I_1 + -1 \times 1 + V_{cs} = 0$

1) $V_{cs} = -I_1$

Mesh #2

$2 + I_2 \times 1 + (I_2 - I_1)1 - V_{cs} = 0$

Note $I_2 - I_1 = 1$

2) $V_{cs} = 2 + I_2 + 1 = 3 + I_2$

Adding 1) and 2) $\Rightarrow 2V_{cs} = 3 + I_2 - I_1 = 3 + 1 = 4;$

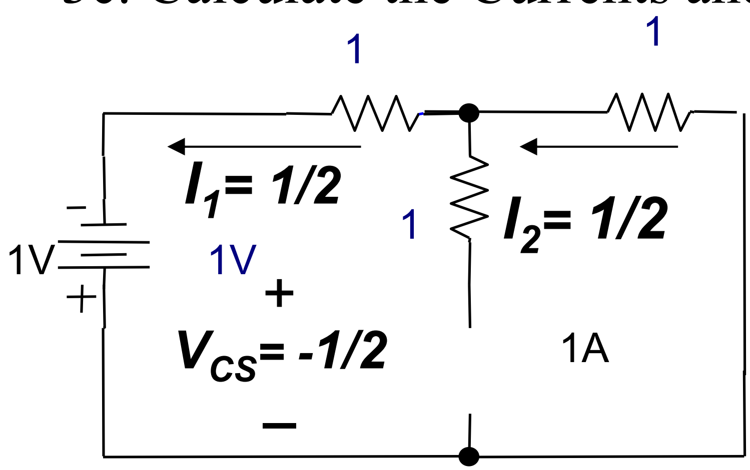
$V_{cs} = 2;$

$V_{node} = V_{cs} - (I_2 - I_1)1 = 2 - 1 = 1$

$I_1 = -2; I_2 = -1$

Quiz #1 Answers

3c. Calculate the Currents and Voltages for the following circuits:

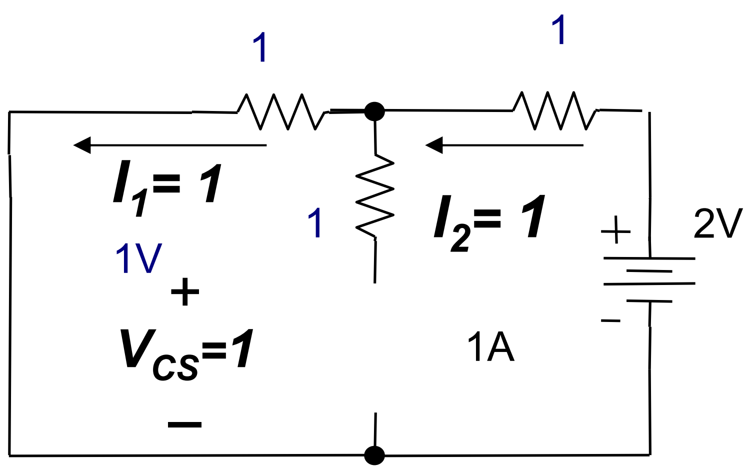


Superposition:

Voltage source #1 only

$$I_1^{V1} = I_2^{V1} = \frac{1}{2}$$

$$V_{cs}^{V1} = -\frac{1}{2}\times 1 = -\frac{1}{2}$$



Voltage source #2 only

$$I_1^{V2} = I_2^{V2} = 1$$

$$V_{cs}^{V2} = 1\times 1 = 1$$

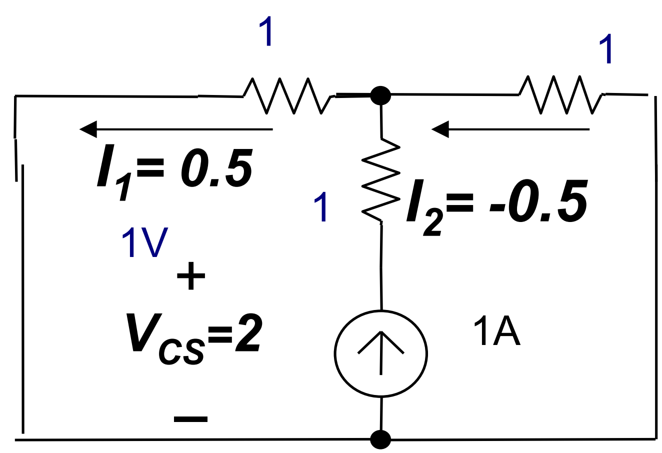
Superposition:

Current source only

$$I_1^{CS} = \frac{1}{2}\times 1 = \frac{1}{2}; \text{ Current division}$$

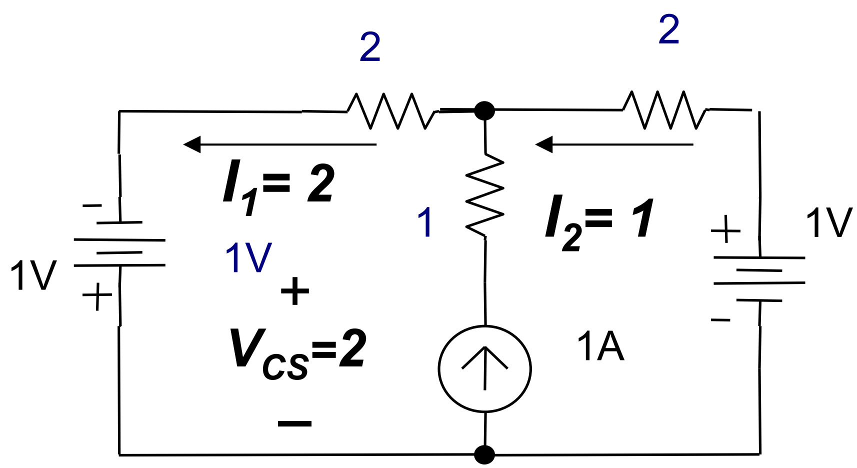
$$I_2^{CS} = -\frac{1}{2}\times 1 = -\frac{1}{2}; \text{ Current division}$$

$$V_{cs}^{CS} = \frac{1}{2}\times 1 + 1\times 1 = 1.5$$



Quiz #1 Answers

3d. Calculate the Currents and Voltages for the following circuits:



Superposition:

Total Solution:

$$I_1 = I_1^{V1} + I_1^{V2} + I_1^{CS} = \frac{1}{2} + 1 + \frac{1}{2} = 2$$

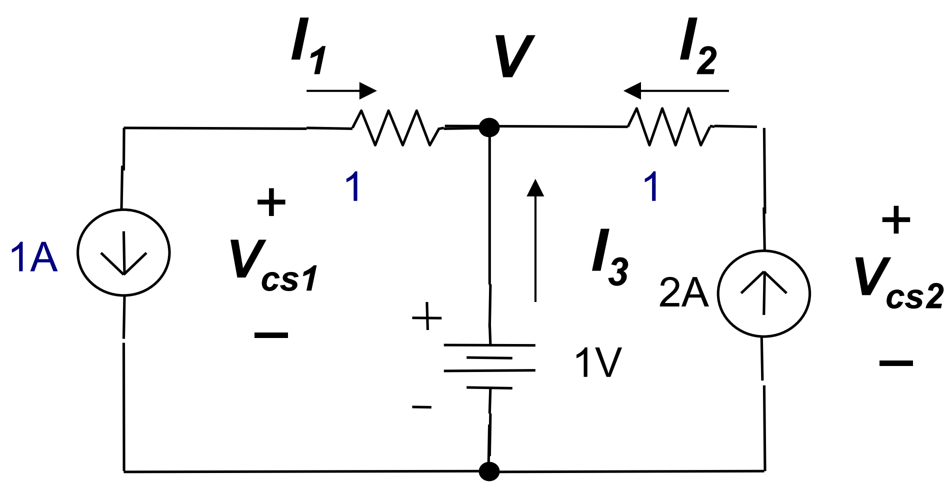
$$I_2 = I_2^{V1} + I_2^{V2} + I_2^{CS} = \frac{1}{2} + 1 - \frac{1}{2} = 1$$

$$V_{cs} = V_{cs}^{V1} + V_{cs}^{V2} + V_{cs}^{CS} = -\frac{1}{2} + 1 + 1.5 = 2$$

Quiz #1 Answers

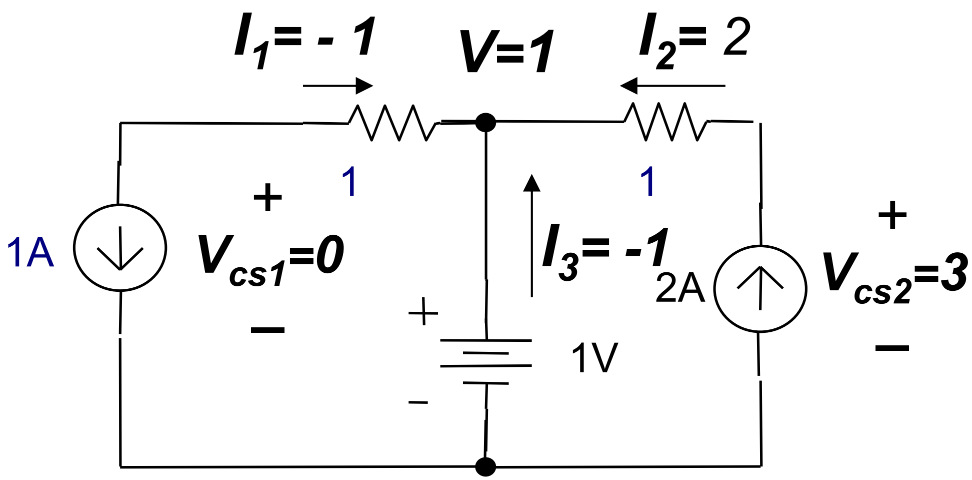
3e. Calculate the Currents and Voltages for the following circuits:

For Nodal Analysis



Quiz #1 Answers

3e. Calculate the Currents and Voltages for the following circuits:



Nodal Analysis:

Note:

$I_1 = -1; I_2 = 2$

Then:

$I_1 + I_2 + I_3 = 0$

$-1 + 2 + I_3 = 0; I_3 = -1$

$V = 1$

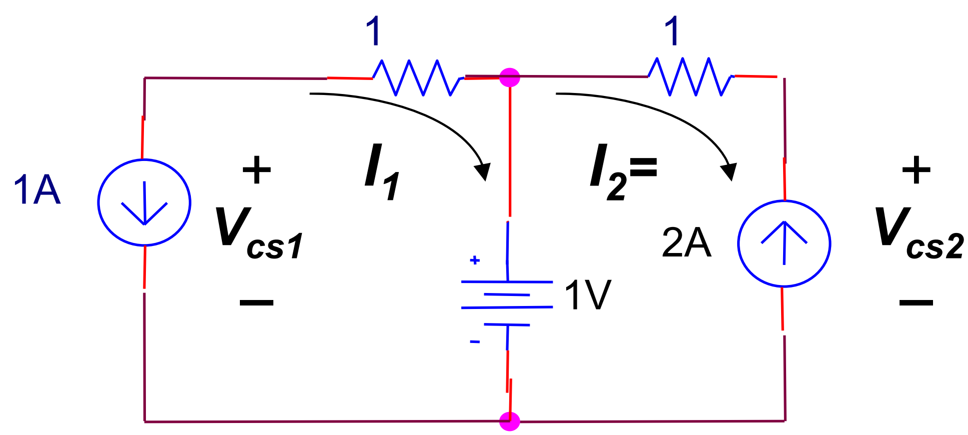
$V_{cs1} = I_1 1 + V = -1 + 1 = 0$

$V_{cs2} = I_2 + V = 1 \times 2 + 1 = 3$

Quiz #1 Answers

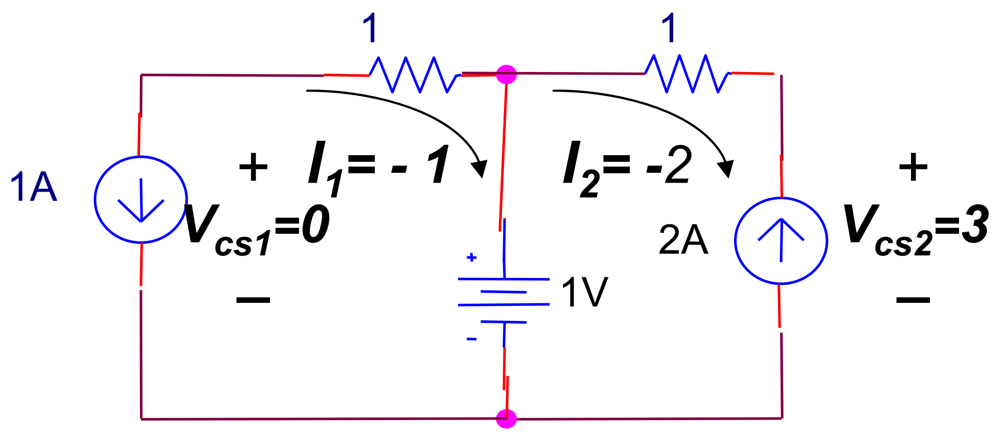
3f. Calculate the Currents and Voltages for the following circuits:

For Mesh Analysis



Quiz #1 Answers

3f. Calculate the Currents and Voltages for the following circuits:



Mesh Analysis:

Note:

$I_1 = -1; I_2 = -2$

Mesh #1:

$V_{cs1} = I_1 \times 1 + 1 = -1 + 1 = 0$

Mesh #2:

$+V_{cs2} = -(I_2 \times 1) + 1 = -(-2 \times 1) + 1 = 3$

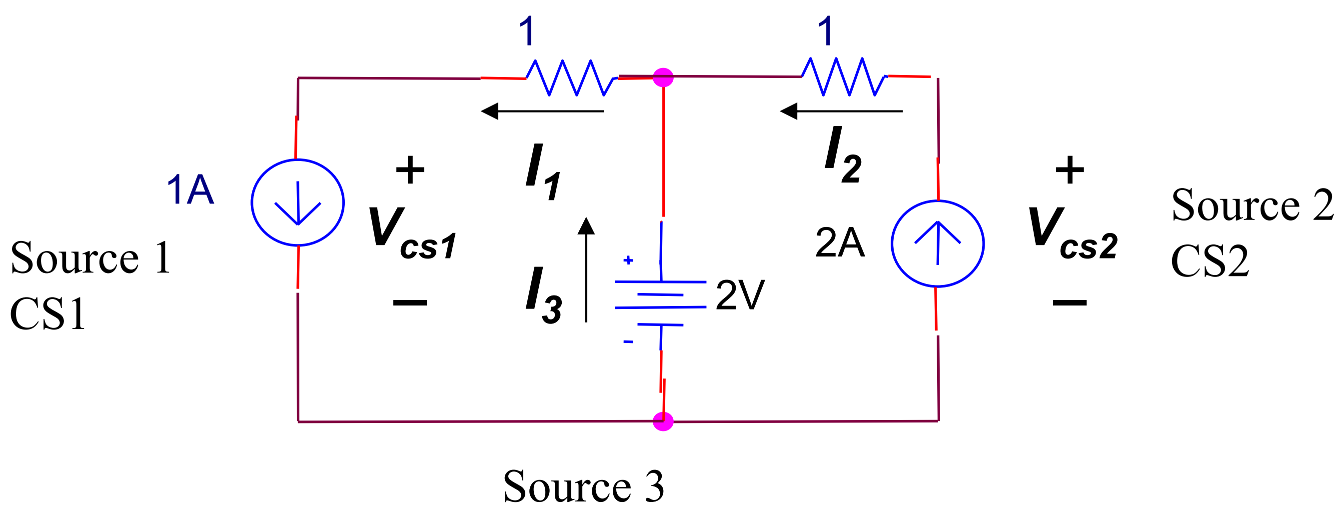
Note that the current in the branch with the voltage source:

$I_1 - I_2 = -1 - (-2) = 1$

Quiz #1 Answers

3f. Calculate the Currents and Voltages for the following circuits:

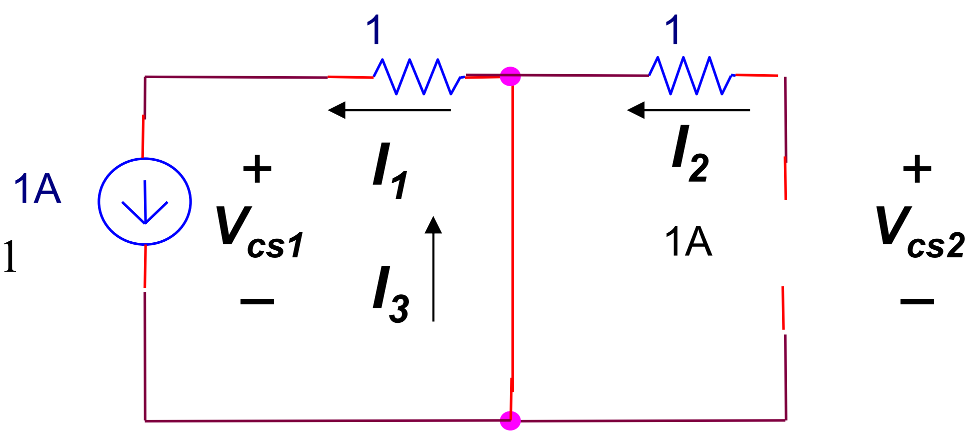
For Superposition



Quiz #1 Answers

3f. Calculate the Currents and Voltages for the following circuits:

For Superposition Source 1



Source 1
CS1

Source 2
CS2
Open
Circuit

Source 3
Short
Circuit

$$I_1^1 = 1; I_2^1 = 0; I_3^1 = 1;$$

$$V_{CS1}^1 = -I_1^1 \times 1 = -1$$

$$V_{CS2}^1 = I_2^1 \times 1 = 0$$

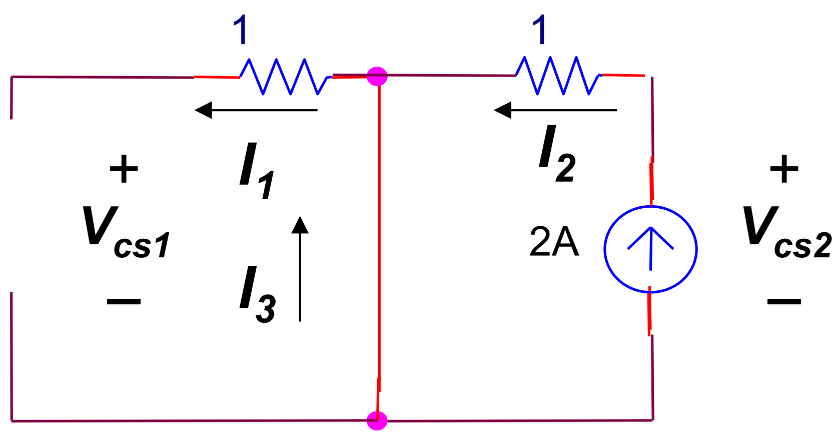
Quiz #1 Answers

3f. Calculate the Currents and Voltages for the following circuits:

For Superposition Source 2

Source 1
CS1

Open
Circuit



Source 2
CS2

Source 3
Short
Circuit

$$I_1^2 = 0; I_2^2 = 2; I_3^2 = -2;$$

$$V_{CS1}^2 = -I_1^2 \times 1 = 0$$

$$V_{CS2}^2 = I_2^2 \times 1 = 2$$

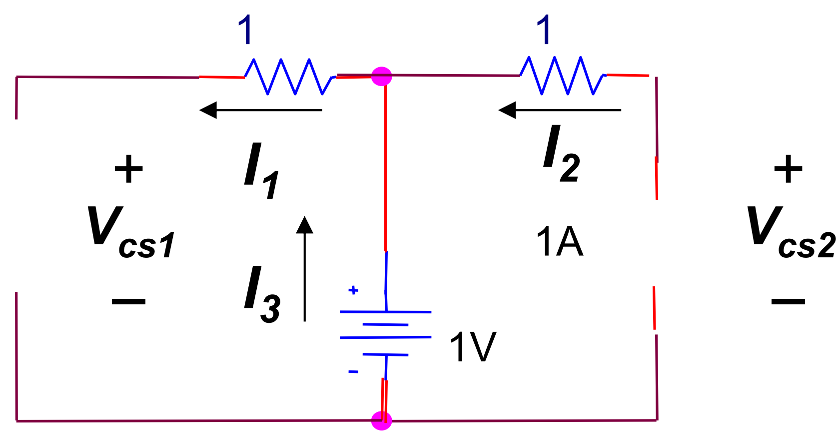
Quiz #1 Answers

3f. Calculate the Currents and Voltages for the following circuits:

For Superposition Source 3

Source 1
CS1

Open
Circuit



Source 3

Source 2
CS2

Open
Circuit

$$I_1^3 = 0; I_2^3 = 0; I_3^3 = 0;$$

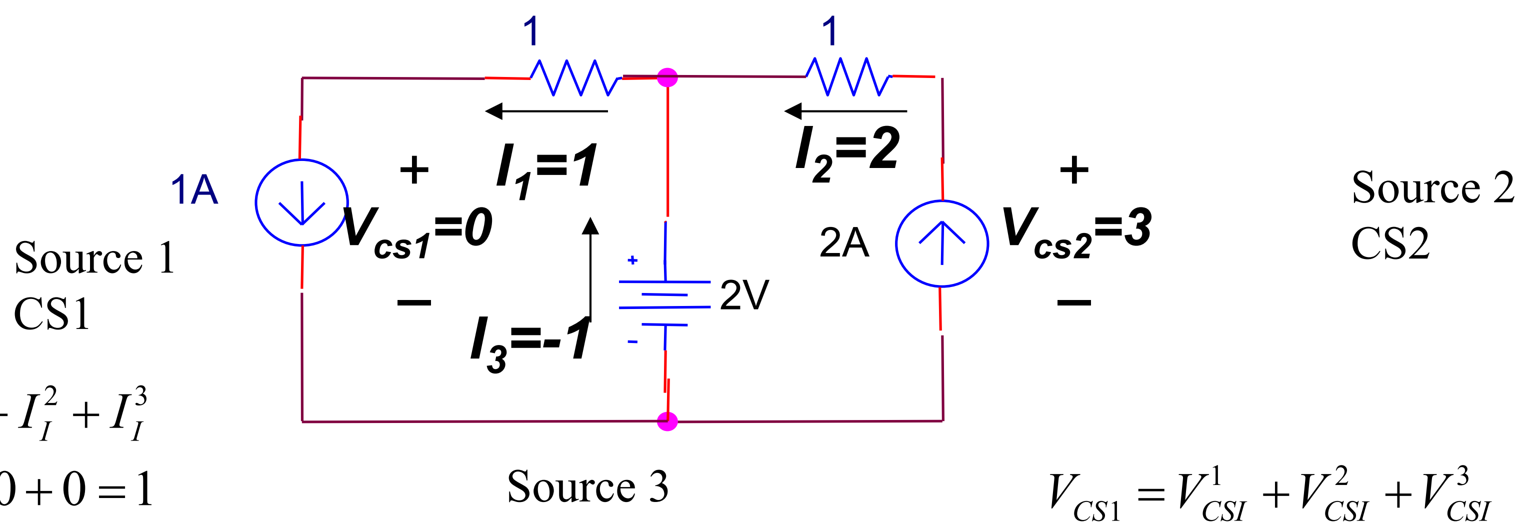
$$V_{CS1} = -I_1^2 \times 1 + 1 = 1$$

$$V_{CS2}^2 = I_2^2 \times 1 + 1 = 1$$

Quiz #1 Answers

3f. Calculate the Currents and Voltages for the following circuits:

For Superposition



$$I_1 = I_I^1 + I_I^2 + I_I^3$$

$$I_1 = 1 + 0 + 0 = 1$$

$$I_2 = I_2^1 + I_2^2 + I_2^3$$

$$I_2 = 0 + 2 + 0 = 2$$

$$I_3 = I_3^1 + I_3^2 + I_3^3$$

$$I_3 = 1 - 2 + 0 = -1$$

$$V_{CS1} = V_{CSI}^1 + V_{CSI}^2 + V_{CSI}^3$$

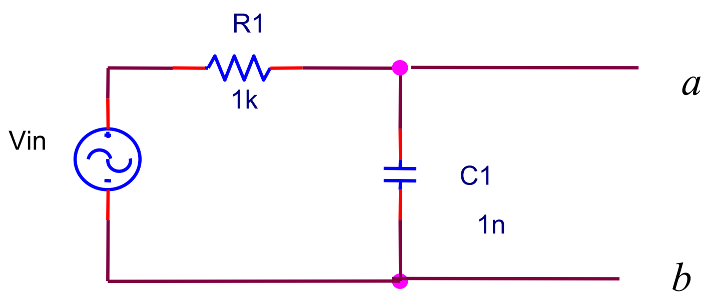
$$V_{CS1} = -1 + 0 + 1 = 0$$

$$V_{CS2} = V_{CS2}^1 + V_{CS2}^2 + V_{CS2}^3$$

$$V_{CS2} = 0 + 1 + 2 = 3$$

Quiz #1 Answers

4. Find the Voltage, V_{ab} for both circuits and sketch the Bode Plots of V_{ab}/V_{in}. Describe (use **words** and **calculations**) what happens to the circuit elements for $\omega = 0$ and $\omega \rightarrow \infty$ and show this mathematically. In addition, choose another interesting value of ω. What is the cutoff frequency in Hertz?



Using voltage division:

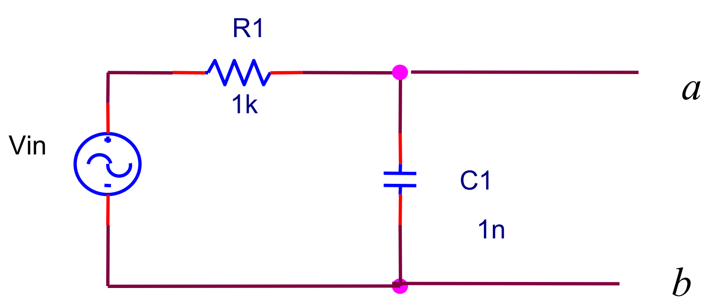
$$\frac{Vab}{Vin} = \frac{\frac{1}{j\omega C_1}}{\frac{1}{j\omega C_1} + R_1} = \frac{1}{1 + j\omega R_1 C_1}$$

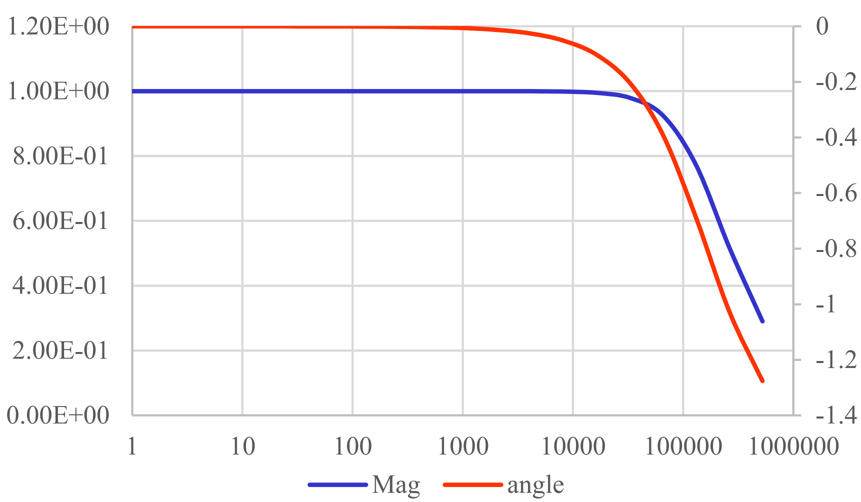
$$= \frac{1}{\sqrt{1 + (\omega R_1 C_1)^2} \angle \tan^{-1}(\omega R_1 C_1)}$$

$$= \frac{1}{\sqrt{1 + (\omega R_1 C_1)^2}} \angle -\tan^{-1}(\omega R_1 C_1)$$

Quiz #1 Answers

4. Find the Voltage, V_{ab} for both circuits and sketch the Bode Plots of V_{ab}/V_{in}. Describe (use **words** and **calculations**) what happens to the circuit elements for ω= 0 and ω ➔ ∞ and show this mathematically. In addition, choose another interesting value of ω. What is the cutoff frequency in Hertz?





$$\frac{Vab}{Vin}\Big|_{\omega=0} = \frac{1}{1+j0R_1C_1} = 1\angle 0$$

When $\omega = 0$ capacitor is infinite impedance or an open circuit and all of Vin appears at the output.

$$\frac{Vab}{Vin}\Big|_{\omega\to\infty} \to \frac{1}{j\omega R_1C_1} \to \frac{-j}{\omega R_1C_1} \to 0\angle -\frac{\pi}{2}$$

When $\omega \to \infty$ capacitor is zero impedance or a short circuit and none of Vin appears at the output.

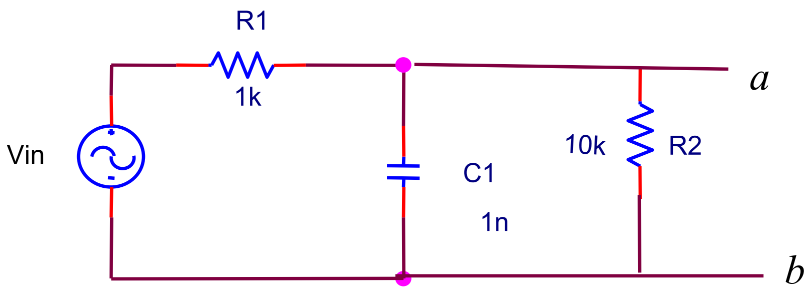
$$\frac{Vab}{Vin}\Big|_{\omega=\frac{1}{R_1C_1}} = \frac{1}{1+j\frac{1}{R_1C_1}R_1C_1} = \frac{1}{1+j1} = \frac{1}{\sqrt{2}\angle\frac{\pi}{4}} = \frac{1}{\sqrt{2}}\angle -\frac{\pi}{4} = 0.707\angle -\frac{\pi}{4}$$

When $\omega = \frac{1}{R_1C_1}$, $\frac{Vab}{Vin} = \frac{1}{\sqrt{2}}$ times the maxium value of $\frac{Vab}{Vin}$=1 which makes $\frac{1}{R_1C_1}$ the cutoff frequency. To convert it th Hz divide by 2π

Then cutoff frequency is $\frac{1}{2\pi R_1C_1} = \frac{1}{2\pi 1k1n_1} = \frac{1}{2\pi 10^{-6}{}_1} = 0.159\times 10^6 = 159kHz$

Quiz #1 Answers

4. Find the Voltage, V_{ab} for both circuits and sketch the Bode Plots of V_{ab}/V_{in}. Describe (use **words** and **calculations**) what happens to the circuit elements for ω= 0 and ω ➔ ∞ and show this mathematically. In addition, choose another interesting value of ω.



Using voltage division:

$$\frac{Vab}{Vin}=\frac{\frac{1}{j\omega C_1}\,||\,R_2}{\frac{1}{j\omega C_1}\,||\,R_2+R_1}$$

$$\frac{1}{j\omega C_1}\,||\,R_2=\frac{\frac{1}{j\omega C_1}\times R_2}{\frac{1}{j\omega C_1}+R_2}=\frac{R_2}{1+j\omega R_2C_1}$$

$$\frac{Vab}{Vin}=\frac{\frac{1}{j\omega C_1}\,||\,R_2}{\frac{1}{j\omega C_1}\,||\,R_2+R_1}=\frac{\frac{R_2}{1+j\omega R_2C_1}}{\frac{R_2}{1+j\omega R_2C_1}+R_1}=\frac{R_2}{R_2+R_1(1+j\omega R_2C_1)}$$

$$=\frac{R_2}{R_2+R_1+j\omega R_1R_2C_1)}=\frac{R_2}{R_2+R_1+j\omega R_1R_2C_1)}$$

$$\frac{Vab}{Vin}=\frac{R_2}{R_2+R_1+j\omega R_1R_2C_1)}=\frac{R_2}{R_2+R_1+j\omega R_1R_2C_1)}$$

$$=\frac{R_2}{R_2+R_1}\times\frac{1}{1+j\omega\frac{R_1R_2}{R_2+R_1}C_1}=\frac{R_2}{R_2+R_1}\times\frac{1}{\sqrt{1+(\omega\frac{R_1R_2}{R_2+R_1}C_1)^2}\angle\tan^{-1}(\omega\frac{R_1R_2}{R_2+R_1}C_1)}$$

$$=\frac{R_2}{R_2+R_1}\times\frac{1}{\sqrt{1+(\omega\frac{R_1R_2}{R_2+R_1}C_1)^2}}\angle\tan^{-1}(\omega\frac{R_1R_2}{R_2+R_1}C_1)$$

$$\frac{Vab}{Vin}\Big|_{\omega=0}=\frac{R_2}{R_2+R_1}\times\frac{1}{1+j0\frac{R_1R_2}{R_2+R_1}C_1}=\frac{R_2}{R_2+R_1}\angle 0$$

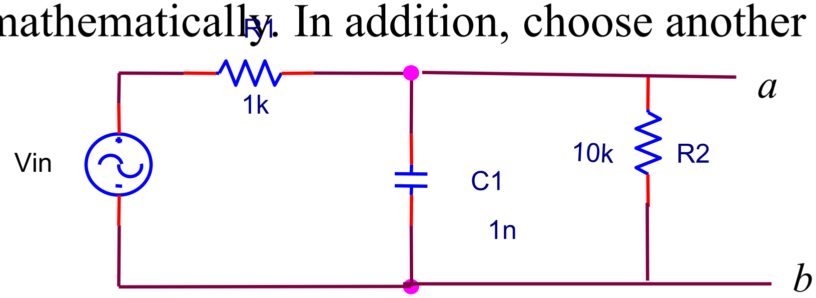
$$\frac{Vab}{Vin}\Big|_{\omega\to\infty}\to\frac{R_2}{R_2+R_1}\times\frac{1}{j\omega\frac{R_1R_2}{R_2+R_1}C_1}\to 0\angle-\frac{\pi}{2}$$

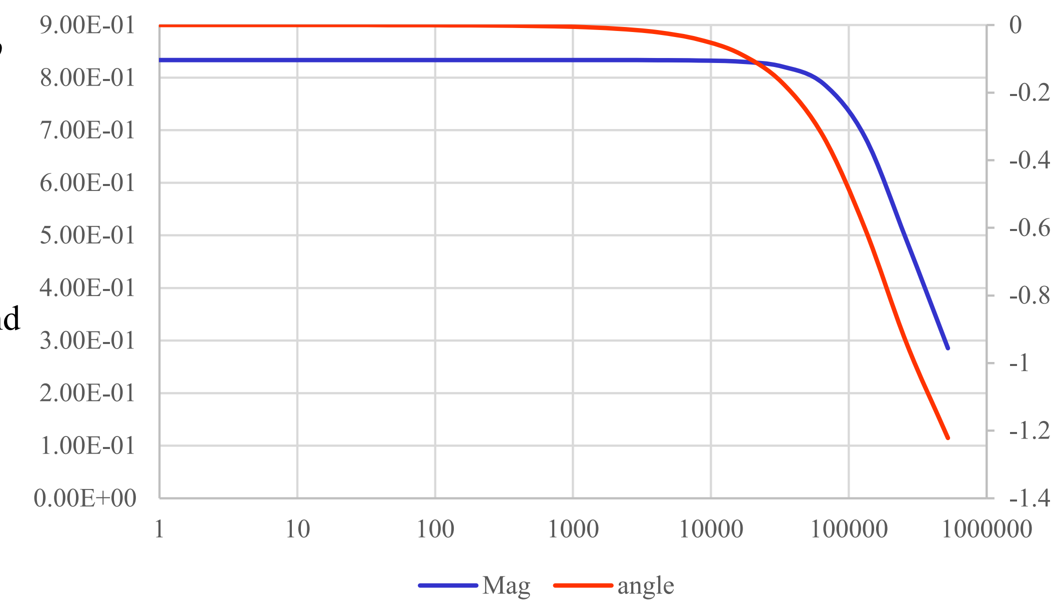
$$\frac{Vab}{Vin}\Big|_{\omega=\frac{1}{\frac{R_1R_2}{R_2+R_1}C_1}}=\frac{R_2}{R_2+R_1}\times\frac{1}{1+j\frac{1}{\frac{R_1R_2}{R_2+R_1}C_1}\frac{R_1R_2}{R_2+R_1}C_1}$$

$$=\frac{R_2}{R_2+R_1}\times\frac{1}{1+j1}=\frac{R_2}{R_2+R_1}\times\frac{1}{\sqrt{2}\angle\frac{\pi}{4}}=\frac{R_2}{R_2+R_1}\times\frac{1}{\sqrt{2}}\angle-\frac{\pi}{4}$$

Quiz #1 Answers

4. Find the Voltage, V_{ab} for both circuits and sketch the Bode Plots of V_{ab}/V_{in}. Describe (use **words** and **calculations**) what happens to the circuit elements for $\omega = 0$ and $\omega \rightarrow \infty$ and show this mathematically. In addition, choose another interesting value of ω.





$$\frac{Vab}{Vin}\Big|_{\omega=0} = \frac{R_2}{R_2+R_1} \times \frac{1}{1+j0\dfrac{R_1R_2}{R_2+R_1}C_1} = \frac{R_2}{R_2+R_1}\angle 0$$

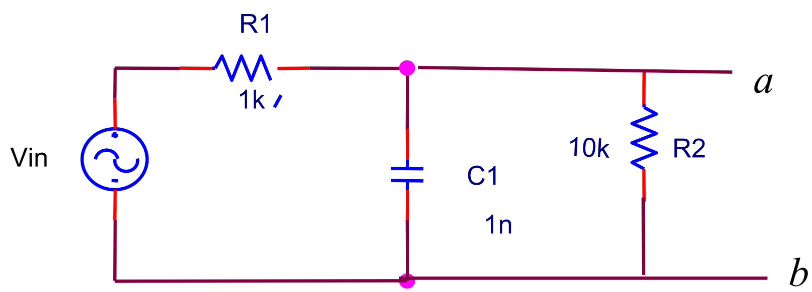
When $\omega = 0$ capacitor is infinite impedance or an open circuit and the circuit becomes R_1 in series with R_2 with the output at R_2.

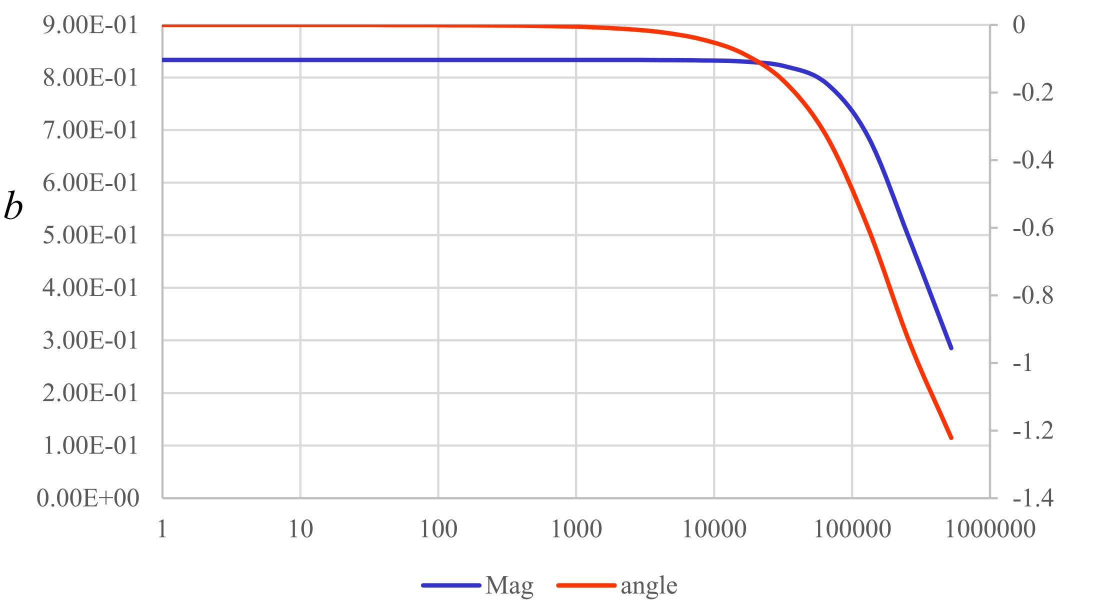
$$\frac{Vab}{Vin}\Big|_{\omega\to\infty} \rightarrow \frac{R_2}{R_2+R_1} \times \frac{1}{j\omega\dfrac{R_1R_2}{R_2+R_1}C_1} \rightarrow 0\angle -\frac{\pi}{2}$$

When $\omega \rightarrow \infty$ capacitor is zero impedance or a short circuit and none of Vin appears at the output.

Quiz #1 Answers

4. Find the Voltage, V_{ab} for both circuits and sketch the Bode Plots of V_{ab}/V_{in}. Describe (use **words** and **calculations**) what happens to the circuit elements for ω= 0 and ω ➔ ∞ and show this mathematically. In addition, choose another interesting value of ω.





$$\frac{Vab}{Vin}\Big|_{\omega=\frac{1}{\frac{R_1R_2}{R_2+R_1}C_1}} = \frac{R_2}{R_2+R_1}\times\frac{1}{1+j\dfrac{1}{\frac{R_1R_2}{R_2+R_1}C_1}\dfrac{R_1R_2}{R_2+R_1}C_1}$$

$$=\frac{R_2}{R_2+R_1}\times\frac{1}{1+j1}=\frac{R_2}{R_2+R_1}\times\frac{1}{\sqrt{2}\angle\frac{\pi}{4}}=\frac{R_2}{R_2+R_1}\times\frac{1}{\sqrt{2}}\angle-\frac{\pi}{4}$$

$$=\frac{10}{11}\times\frac{1}{\sqrt{2}}\angle-\frac{\pi}{4}=0.59\angle-\frac{\pi}{4}$$

When $\omega=\dfrac{1}{\frac{R_1R_2}{R_2+R_1}C_1}$, $\dfrac{Vab}{Vin}=\dfrac{1}{\sqrt{2}}$ times the maxium value of $\dfrac{Vab}{Vin}=\dfrac{R_2}{R_2+R_1}=\dfrac{10}{11}$ which makes $\dfrac{1}{\frac{R_1R_2}{R_2+R_1}C_1}$ the cutoff frequency.

$$\frac{R_1R_2}{R_2+R_1}=\frac{10\times10^6}{11\times10^3}=\frac{10}{11}\times10^3;\ \frac{R_1R_2}{R_2+R_1}C=\frac{10}{11}\times10^3\times1\times10^{-9}=\frac{10}{11}\times10^{-6}$$

$$\frac{1}{\frac{R_1R_2}{R_2+R_1}C_1}=\frac{1}{2\pi\frac{10}{11}10^{-6}}=\frac{1}{5.710^{-6}}=1.1\times10^6$$

In Hz $\dfrac{1}{2\pi\frac{R_1R_2}{R_2+R_1}C_1}=\dfrac{1.1\times10^6}{2\pi}=175kHz$

Quiz #1 Answers

5. For the Arduino Uno describe the following:

a. What are the two type of pins, what type of signal is used at each pin and describe whether they are input or outputs or both.

- *There are digital pins which can be used as an input or output. The signal at the digital pins take on 2 levels low or high (0 or 5 volts).*
- *There are analog pins which can only be used as an input. The signal at the analog pins can take on any value from 0 – 5 volts.*

b. What is PWM mean and how does one implement it.

PWM stands for Pulse Width Modulation which is a square wave with various duty cycles. It can be implemented at the digital pins which has tilde ~ with the pin number. One sets the duty cycle by performing an analog write to that digital pin.

c. What is the IDE?

IDE stand for Integrated Development Environment and is used to write and manage Arduino programs.

d. What is the Arduino program called and what computer language used to create an Arduino program.

An Arduino program is called a Sketch and uses the C/C++ language.

e. What are the necessary sections of an Arduino program and what are they used for.

The two necessary sections are the setup and loop sections of the Sketch. The setup setup is used for programming what is used only once. The loop section is used for the programming which gets repeated as needed.