Resistive or reactive components can be used in potential dividers to give:—

$$V_{out} = \frac{Z_2}{Z_1 + Z_2} V_{in}$$

When the term $\frac{Z_2}{Z_1+Z_2}$ is put into the form $|A|\, e^{j\phi}$ then

$|A|$ is the attenuation of the potential divider and

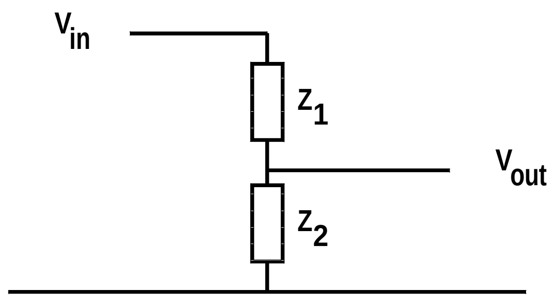
ϕ is the phase shift.

Mathematical interlude!

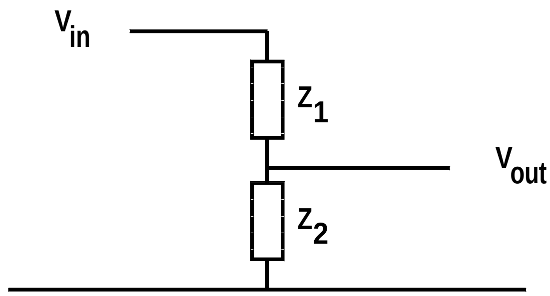
Two important results from complex algebra
When a complex number, c, is in the form $c = a + jb$, the modulus and the phase angle for c and $\frac{1}{c}$ are given by:–

$$|a + jb| = \sqrt{a^2 + b^2} \quad \text{and} \quad \tan\phi = \frac{b}{a}$$

$$\left|\frac{1}{a + jb}\right| = \frac{1}{\sqrt{a^2 + b^2}} \quad \text{and} \quad \tan\phi = \frac{-b}{a}$$



Replace the resistors of potential divider by any combination of resistors, capacitors or inductors in series or parallel.
A resultant impedance can be calculated for each half of the potential divider.
The current in each of the two impedances is given by $\frac{V_{in}}{Z_1+Z_2}$.
This current flowing through Z_2 gives an output voltage $Z_2 I$.



The ratio of output to input voltage is then

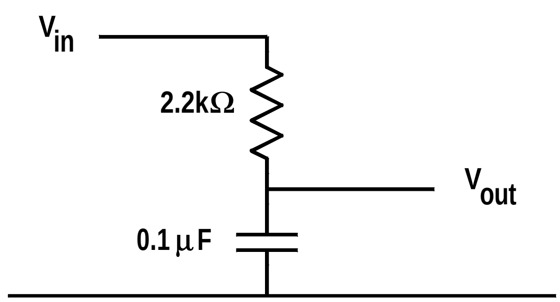
$$\frac{V_{out}}{V_{in}} = \frac{Z_2}{Z_1 + Z_2}$$

but since Z_1 and Z_2 are complex then $\frac{Z_2}{Z_1+Z_2}$ is usually also complex and has a magnitude less than 1.

If we express $\frac{Z_2}{Z_1+Z_2}$ in the form $|A|\, e^{j\phi}$ then $|A|$ gives the attenuation of the potential divider and ϕ gives the phase shift in radians.

Calculate the attenuation and phase shift in an RC network where $R = 2.2k\Omega$, $C = 0.1\mu F$ and the frequency is 1.5kHz.

Calculate the amplitude of the output signal if the amplitude of the input signal is 1V.



The network response is given by:–

$$\frac{V_{out}}{V_{in}} = \frac{Z_2}{Z_1 + Z_2} = \frac{\frac{1}{j2\pi fC}}{R + \frac{1}{j2\pi fC}}$$

$$= \frac{1}{1 + j2\pi fCR}$$

$$\text{Calculate} \quad \tan\phi = -2\pi fCR$$

$$= -2\pi 1500 \times 0.1 \times 10^{-6} \times 2200$$

$$= -2.07$$

$$\text{So that} \quad \phi = \tan^{-1}(-2.07)$$

$$= -1.12\,\text{rads or} - 64.3\text{degrees}$$

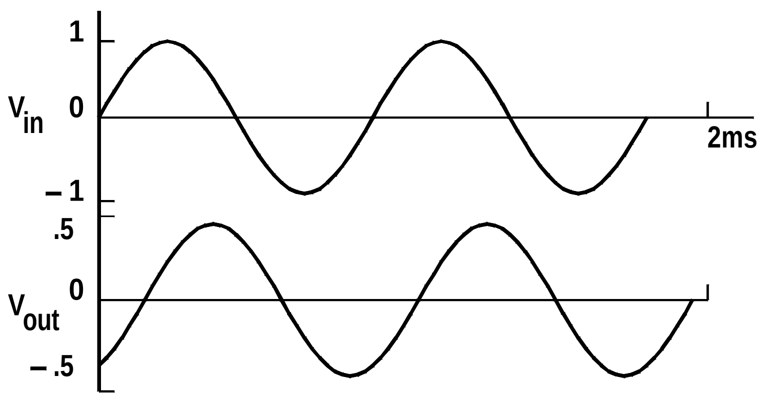
$$\text{Attenuation} \left|\frac{V_{out}}{V_{in}}\right| = \frac{1}{\sqrt{1 + \tan^2\phi}}$$

$$= \frac{1}{\sqrt{1 + 2.07^2}}$$

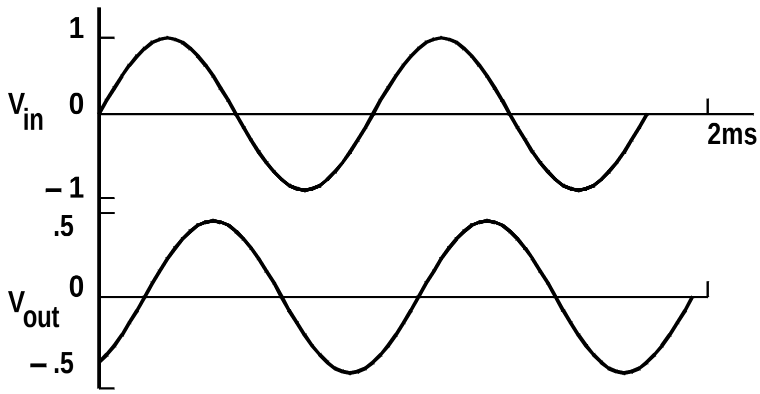
$$= 0.435$$

$$= 20\log 0.435 \quad \text{dB} = -7.23\ \text{dB}.$$

Construct the circuiit.
Display the input and output waveforms on an oscilloscope



We calculated a phase shift of −1.12 radians. In the oscilloscope diagram the output waveform is displaced to the right by 1.12 radians or 64 degrees relative to the input voltage waveform.



So we obtain the useful rule that:–

- If the phase shift is positive then the output waveform is shifted to the left and is said to lead the input waveform.

- If the phase shift is negative then the output waveform is shifted to the right and is said to lag the input waveform.