

# Complexe getallen

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The background image shows a vast, arid desert landscape under a clear blue sky. In the foreground and middle ground, there are numerous ancient, circular mud-brick structures, likely tombs or dwellings, arranged in a somewhat organized pattern. The structures are made of reddish-brown earth and have small, dark openings. In the distance, there are low, hazy mountains on the horizon.

Simpel en elegant...

Vector optelling:

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Bijvoorbeeld:

$$\begin{pmatrix} 2 \\ 1 \end{pmatrix} + \begin{pmatrix} 0 \\ 1.5 \end{pmatrix} = \begin{pmatrix} 2+0 \\ 1+1.5 \end{pmatrix} = \begin{pmatrix} 2 \\ 2.5 \end{pmatrix}$$

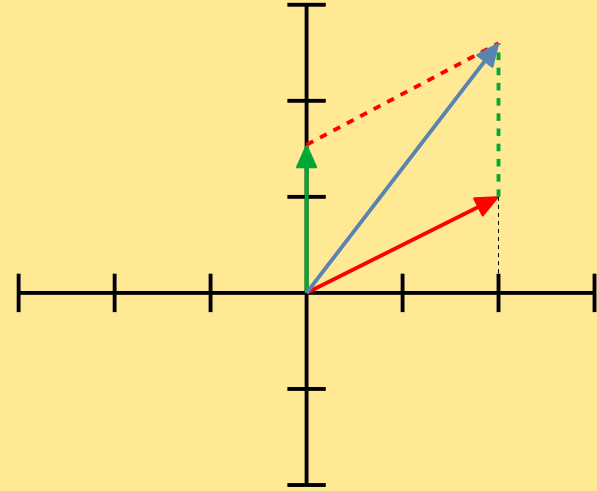
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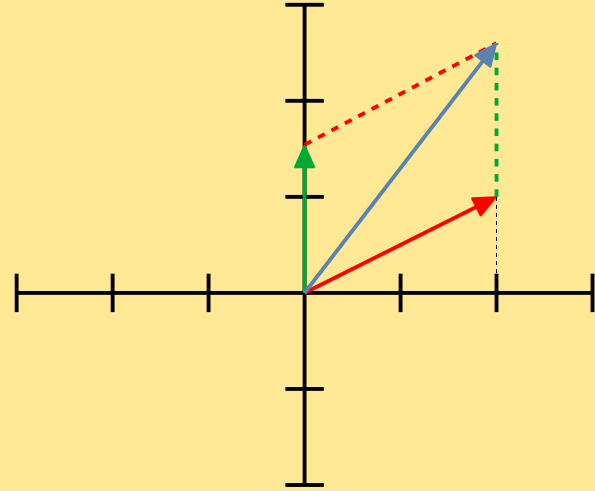
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Een nieuw soort vector vermenigvuldiging:

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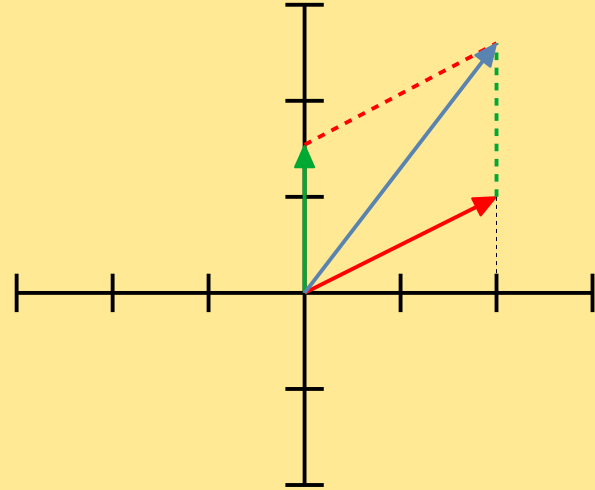
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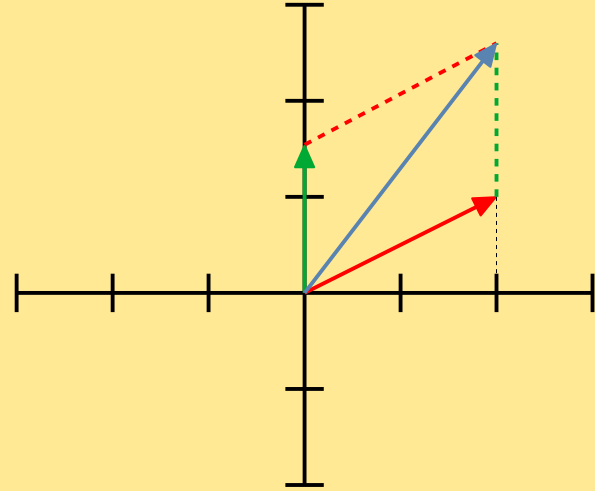


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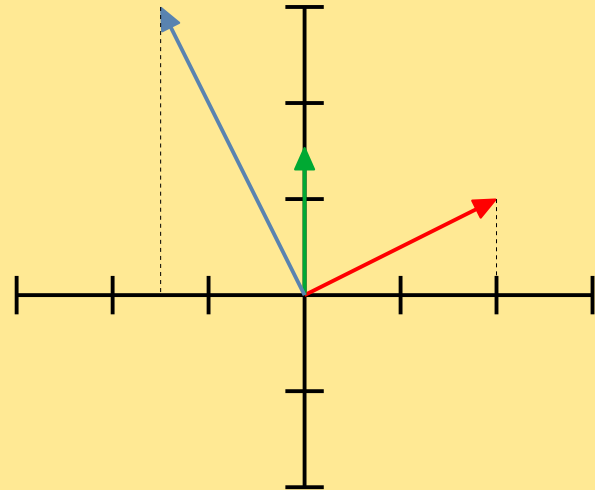


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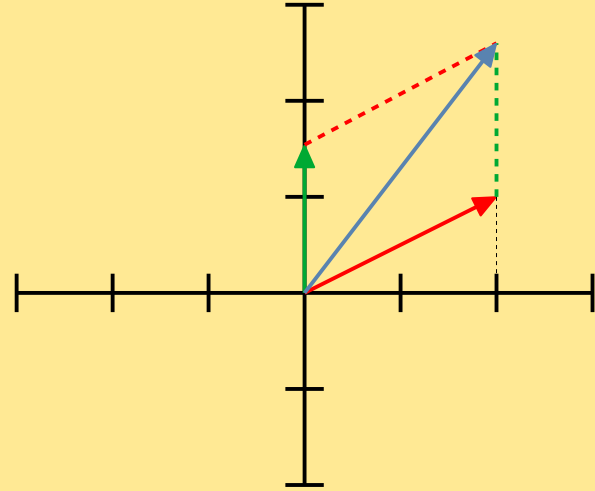


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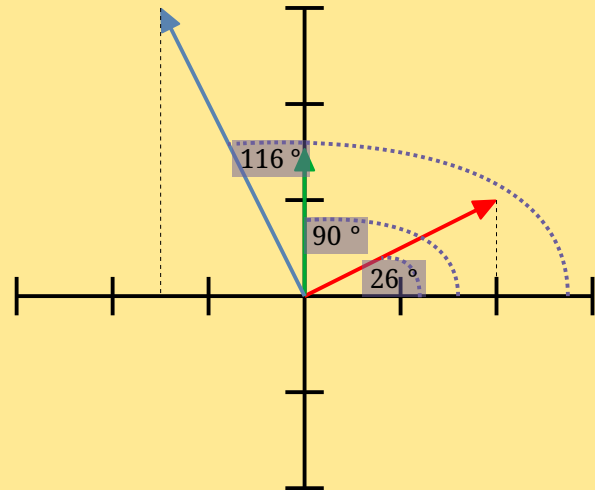


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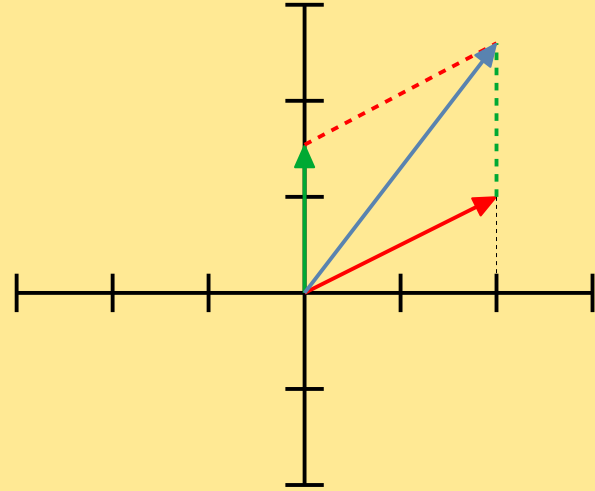


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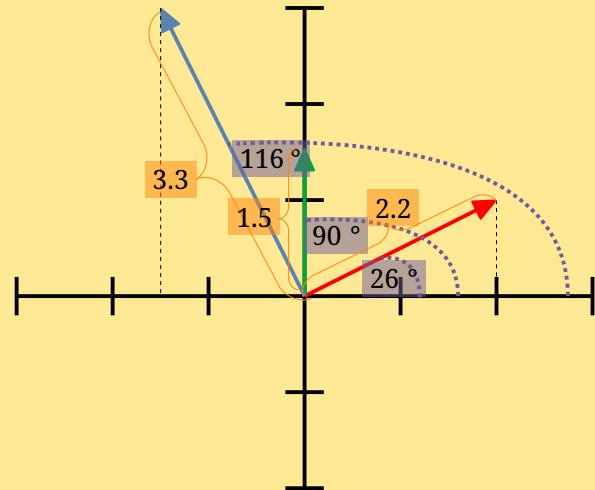


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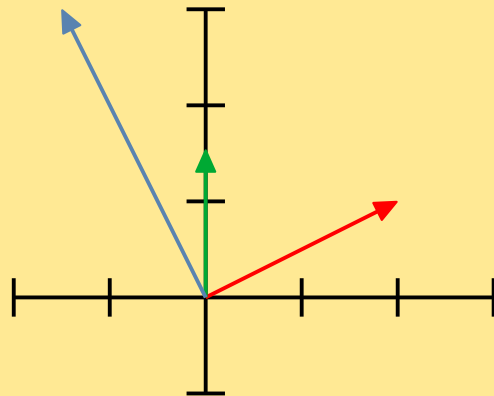
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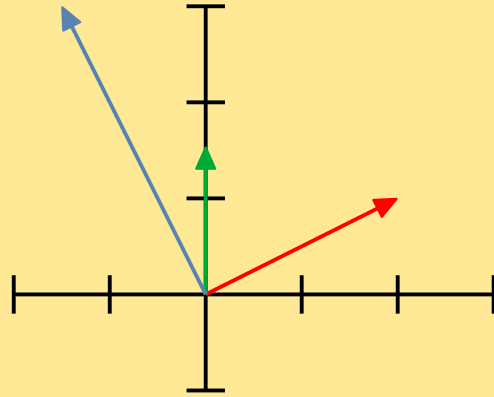


$$\begin{pmatrix} 2 \\ 1 \end{pmatrix} \otimes \begin{pmatrix} 0 \\ 1.5 \end{pmatrix} = \begin{pmatrix} 2 \times 0 - 1 \times 1.5 \\ 2 \times 1.5 + 1 \times 0 \end{pmatrix} = \begin{pmatrix} -1.5 \\ 3 \end{pmatrix}$$

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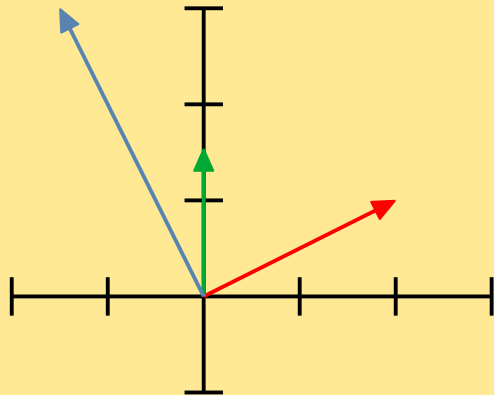


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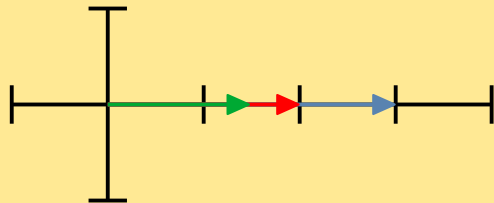


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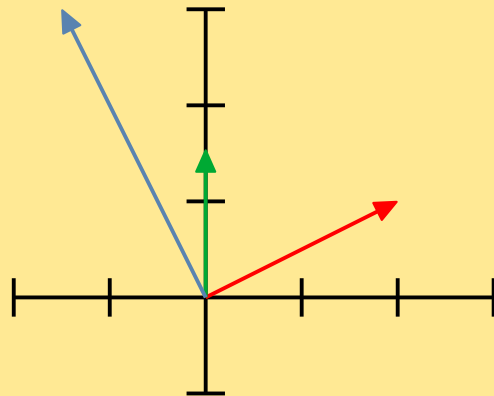
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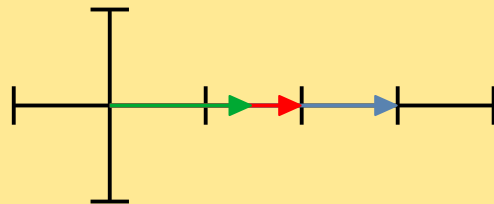
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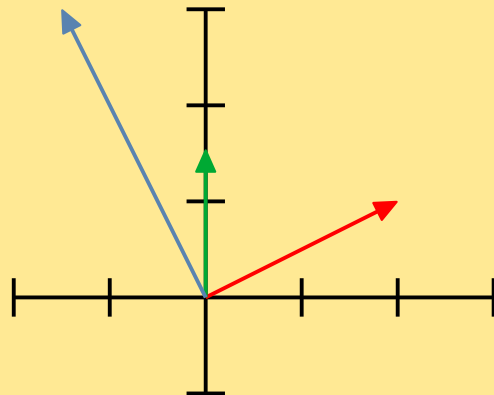
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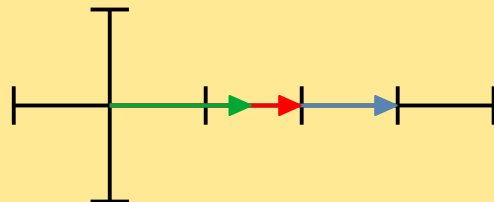
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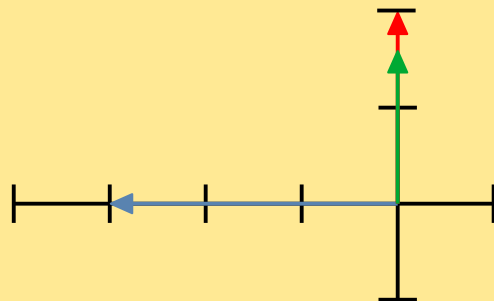
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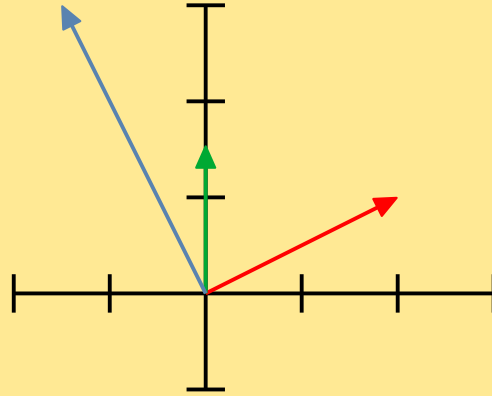


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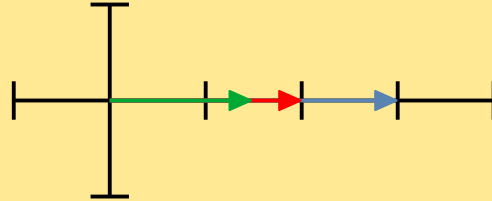


$$(2+1j) \times (0+1.5j) =$$

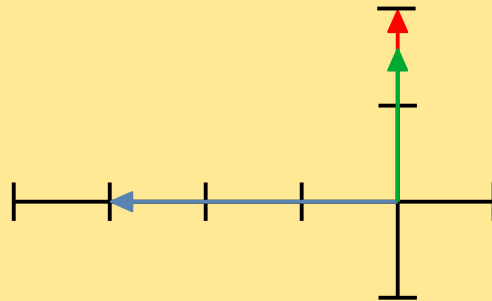
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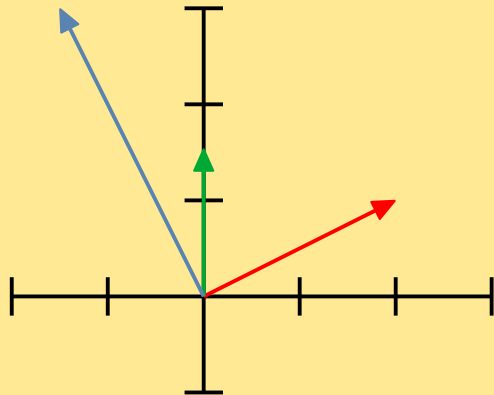
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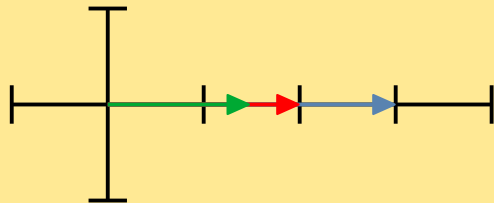
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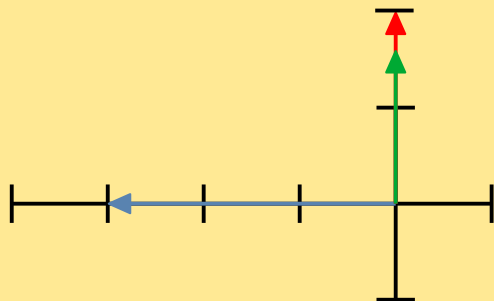
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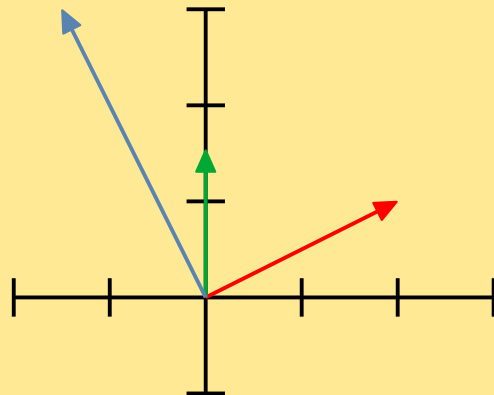
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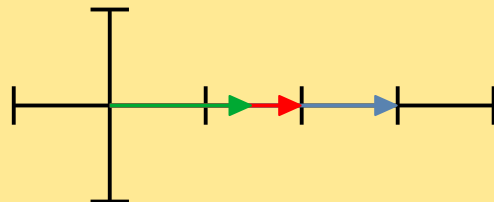


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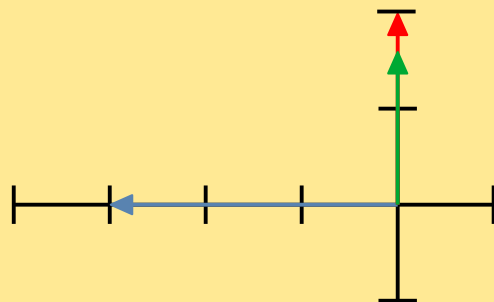


$$\begin{aligned} (2+1j) \times (0+1.5j) &= \\ 2 \times 0 + 2 \times 1.5j + 1j \times 0 + 1j \times 1.5j &= \\ 0 + 3j + 0j + 1.5j^2 &= \end{aligned}$$

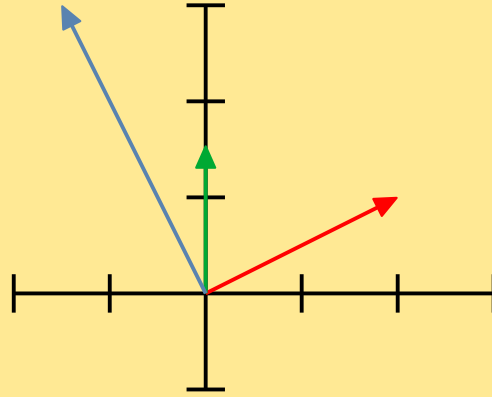
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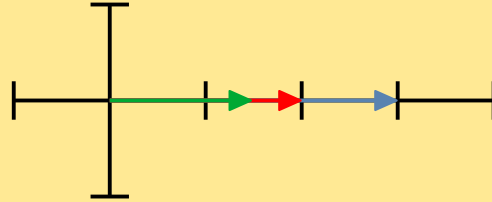


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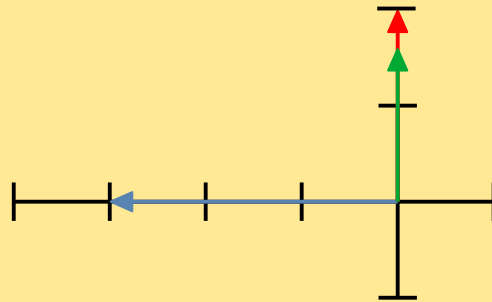


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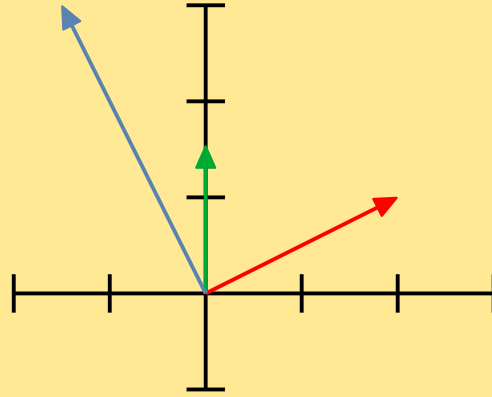
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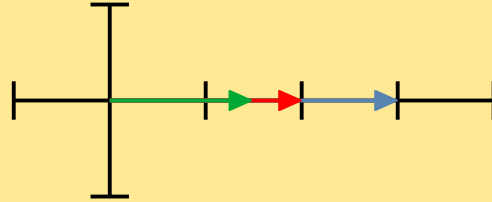


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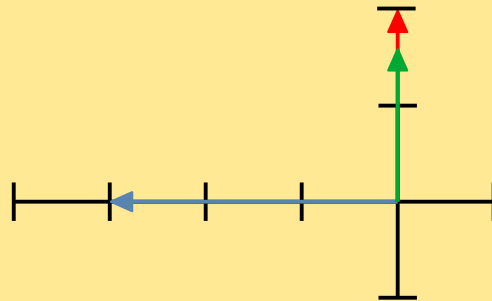


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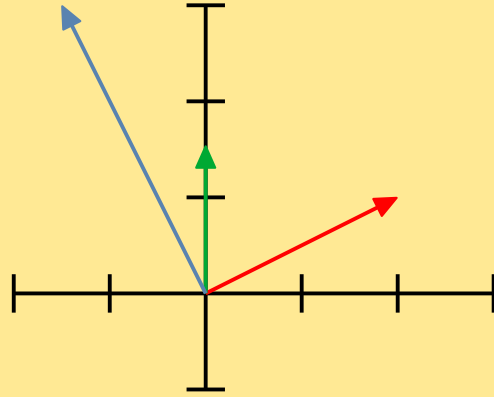
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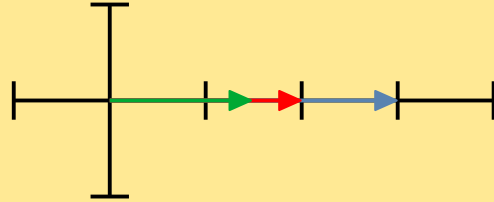


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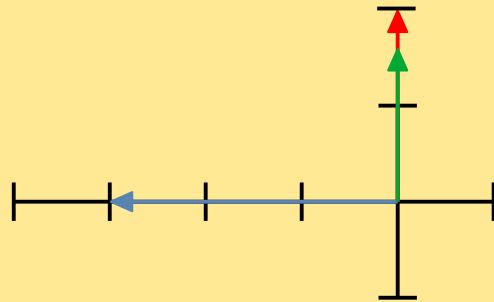


$$\begin{aligned} (2+1j) \times (0+1.5j) &= \\ 2 \times 0 + 2 \times 1.5j + 1j \times 0 + 1j \times 1.5j &= \\ 0 + 3j + 0j + 1.5j^2 &= \\ 3j + 1.5j^2 &= \\ -1.5 + 3j & \quad j^2 \stackrel{\text{def}}{=} -1 \Leftrightarrow j = \sqrt{-1} \end{aligned}$$

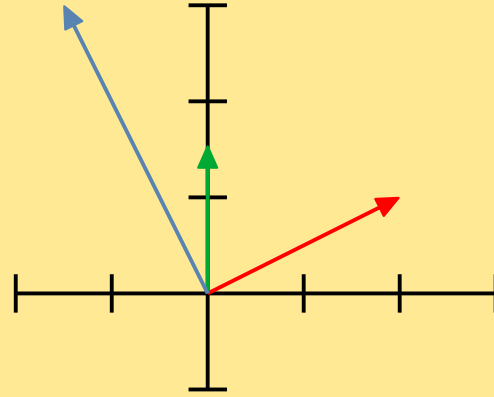
$$\begin{pmatrix} 2 \\ 0 \end{pmatrix} \otimes \begin{pmatrix} 1.5 \\ 0 \end{pmatrix} = \begin{pmatrix} 2 \times 1.5 - 0 \times 0 \\ 2 \times 0 + 0 \times 1.5 \end{pmatrix} = \begin{pmatrix} 3 \\ 0 \end{pmatrix}$$



$$\begin{pmatrix} 0 \\ 2 \end{pmatrix} \otimes \begin{pmatrix} 0 \\ 1.5 \end{pmatrix} = \begin{pmatrix} 0 \times 0 - 2 \times 1.5 \\ 0 \times 1.5 + 2 \times 0 \end{pmatrix} = \begin{pmatrix} -3 \\ 0 \end{pmatrix}$$

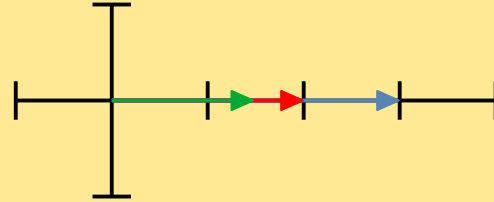


$$\begin{pmatrix} 2 \\ 1 \end{pmatrix} \otimes \begin{pmatrix} 0 \\ 1.5 \end{pmatrix} = \begin{pmatrix} 2 \times 0 - 1 \times 1.5 \\ 2 \times 1.5 + 1 \times 0 \end{pmatrix} = \begin{pmatrix} -1.5 \\ 3 \end{pmatrix}$$



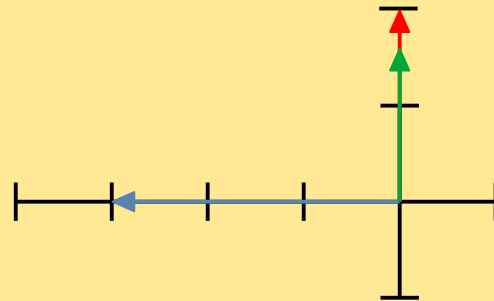
$$\begin{aligned} (2+1j) \times (0+1.5j) &= \\ 2 \times 0 + 2 \times 1.5j + 1j \times 0 + 1j \times 1.5j &= \\ 0 + 3j + 0j + 1.5j^2 &= \\ 3j + 1.5j^2 &= \\ -1.5 + 3j & \quad j^2 \stackrel{\text{def}}{=} -1 \Leftrightarrow j = \sqrt{-1} \end{aligned}$$

$$\begin{pmatrix} 2 \\ 0 \end{pmatrix} \otimes \begin{pmatrix} 1.5 \\ 0 \end{pmatrix} = \begin{pmatrix} 2 \times 1.5 - 0 \times 0 \\ 2 \times 0 + 0 \times 1.5 \end{pmatrix} = \begin{pmatrix} 3 \\ 0 \end{pmatrix}$$



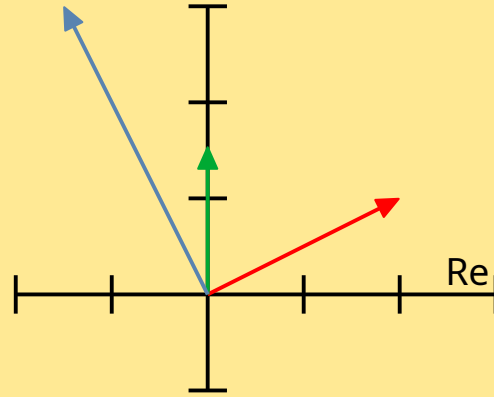
$$2 \times 1.5 = 3$$

$$\begin{pmatrix} 0 \\ 2 \end{pmatrix} \otimes \begin{pmatrix} 0 \\ 1.5 \end{pmatrix} = \begin{pmatrix} 0 \times 0 - 2 \times 1.5 \\ 0 \times 1.5 + 2 \times 0 \end{pmatrix} = \begin{pmatrix} -3 \\ 0 \end{pmatrix}$$



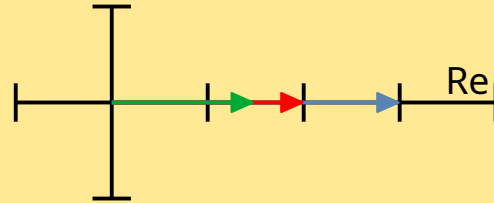


$$\begin{pmatrix} 2 \\ 1 \end{pmatrix} \otimes \begin{pmatrix} 0 \\ 1.5 \end{pmatrix} = \begin{pmatrix} 2 \times 0 - 1 \times 1.5 \\ 2 \times 1.5 + 1 \times 0 \end{pmatrix} = \begin{pmatrix} -1.5 \\ 3 \end{pmatrix}$$



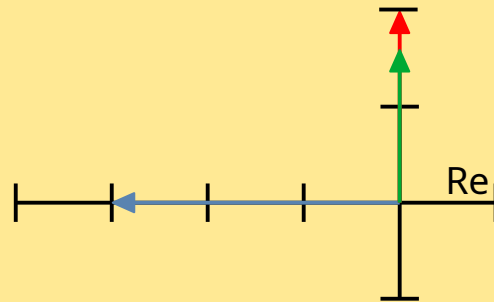
$$\begin{aligned} (2+1j) \times (0+1.5j) &= \\ 2 \times 0 + 2 \times 1.5j + 1j \times 0 + 1j \times 1.5j &= \\ 0 + 3j + 0j + 1.5j^2 &= \\ 3j + 1.5j^2 &= \\ -1.5 + 3j & \quad j^2 \stackrel{\text{def}}{=} -1 \Leftrightarrow j = \sqrt{-1} \end{aligned}$$

$$\begin{pmatrix} 2 \\ 0 \end{pmatrix} \otimes \begin{pmatrix} 1.5 \\ 0 \end{pmatrix} = \begin{pmatrix} 2 \times 1.5 - 0 \times 0 \\ 2 \times 0 + 0 \times 1.5 \end{pmatrix} = \begin{pmatrix} 3 \\ 0 \end{pmatrix}$$

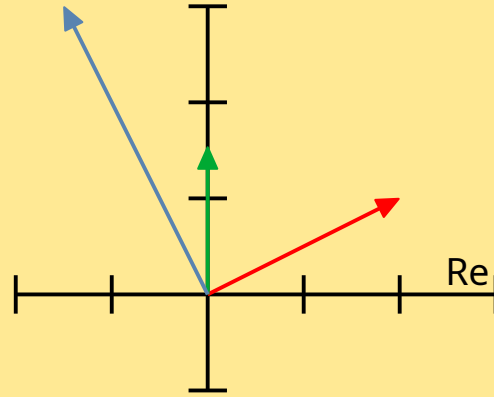


$$2 \times 1.5 = 3$$

$$\begin{pmatrix} 0 \\ 2 \end{pmatrix} \otimes \begin{pmatrix} 0 \\ 1.5 \end{pmatrix} = \begin{pmatrix} 0 \times 0 - 2 \times 1.5 \\ 0 \times 1.5 + 2 \times 0 \end{pmatrix} = \begin{pmatrix} -3 \\ 0 \end{pmatrix}$$

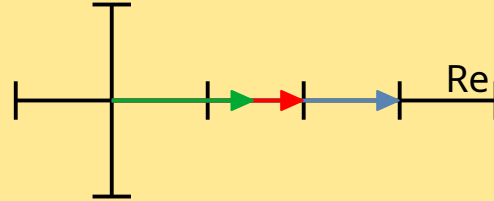


$$\begin{pmatrix} 2 \\ 1 \end{pmatrix} \otimes \begin{pmatrix} 0 \\ 1.5 \end{pmatrix} = \begin{pmatrix} 2 \times 0 - 1 \times 1.5 \\ 2 \times 1.5 + 1 \times 0 \end{pmatrix} = \begin{pmatrix} -1.5 \\ 3 \end{pmatrix}$$



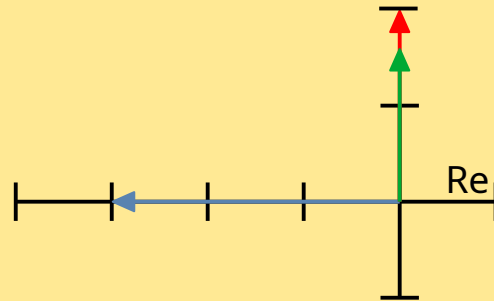
$$\begin{aligned} (2+1j) \times (0+1.5j) &= \\ 2 \times 0 + 2 \times 1.5j + 1j \times 0 + 1j \times 1.5j &= \\ 0 + 3j + 0j + 1.5j^2 &= \\ 3j + 1.5j^2 &= \\ -1.5 + 3j & \quad j^2 \stackrel{\text{def}}{=} -1 \Leftrightarrow j = \sqrt{-1} \end{aligned}$$

$$\begin{pmatrix} 2 \\ 0 \end{pmatrix} \otimes \begin{pmatrix} 1.5 \\ 0 \end{pmatrix} = \begin{pmatrix} 2 \times 1.5 - 0 \times 0 \\ 2 \times 0 + 0 \times 1.5 \end{pmatrix} = \begin{pmatrix} 3 \\ 0 \end{pmatrix}$$



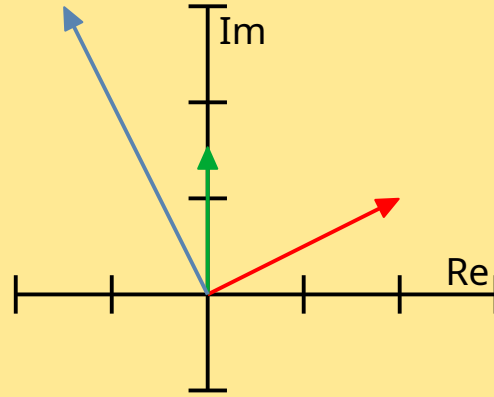
$$2 \times 1.5 = 3$$

$$\begin{pmatrix} 0 \\ 2 \end{pmatrix} \otimes \begin{pmatrix} 0 \\ 1.5 \end{pmatrix} = \begin{pmatrix} 0 \times 0 - 2 \times 1.5 \\ 0 \times 1.5 + 2 \times 0 \end{pmatrix} = \begin{pmatrix} -3 \\ 0 \end{pmatrix}$$



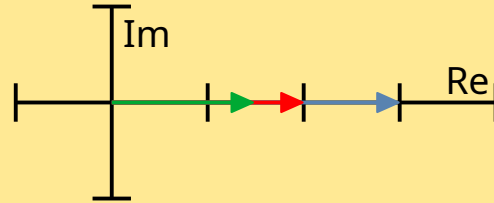
$$2j \times 1.5j = 3j^2 = -3$$

$$\begin{pmatrix} 2 \\ 1 \end{pmatrix} \otimes \begin{pmatrix} 0 \\ 1.5 \end{pmatrix} = \begin{pmatrix} 2 \times 0 - 1 \times 1.5 \\ 2 \times 1.5 + 1 \times 0 \end{pmatrix} = \begin{pmatrix} -1.5 \\ 3 \end{pmatrix}$$



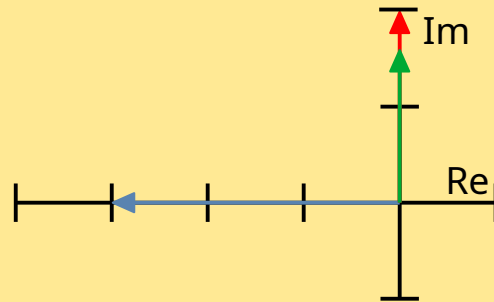
$$\begin{aligned} (2+1j) \times (0+1.5j) &= \\ 2 \times 0 + 2 \times 1.5j + 1j \times 0 + 1j \times 1.5j &= \\ 0 + 3j + 0j + 1.5j^2 &= \\ 3j + 1.5j^2 &= \\ -1.5 + 3j & \quad j^2 \stackrel{\text{def}}{=} -1 \Leftrightarrow j = \sqrt{-1} \end{aligned}$$

$$\begin{pmatrix} 2 \\ 0 \end{pmatrix} \otimes \begin{pmatrix} 1.5 \\ 0 \end{pmatrix} = \begin{pmatrix} 2 \times 1.5 - 0 \times 0 \\ 2 \times 0 + 0 \times 1.5 \end{pmatrix} = \begin{pmatrix} 3 \\ 0 \end{pmatrix}$$



$$2 \times 1.5 = 3$$

$$\begin{pmatrix} 0 \\ 2 \end{pmatrix} \otimes \begin{pmatrix} 0 \\ 1.5 \end{pmatrix} = \begin{pmatrix} 0 \times 0 - 2 \times 1.5 \\ 0 \times 1.5 + 2 \times 0 \end{pmatrix} = \begin{pmatrix} -3 \\ 0 \end{pmatrix}$$



$$2j \times 1.5j = 3j^2 = -3$$

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ZU-LINE

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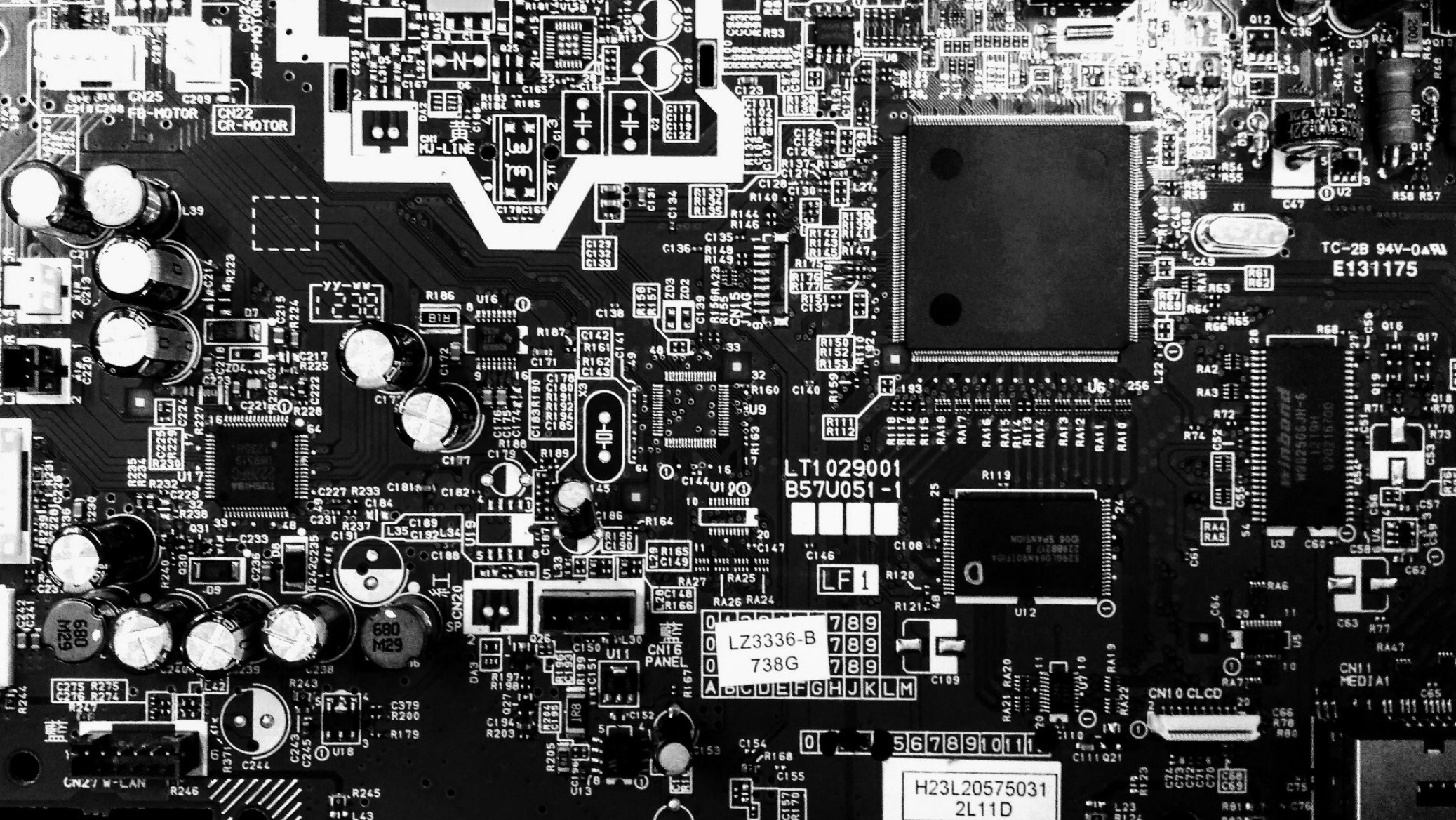
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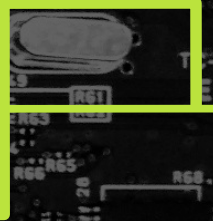
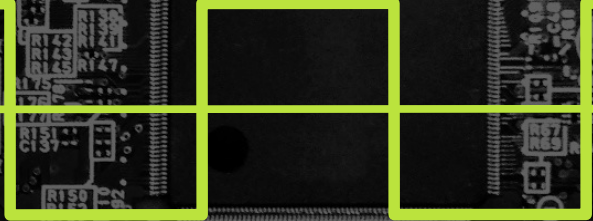
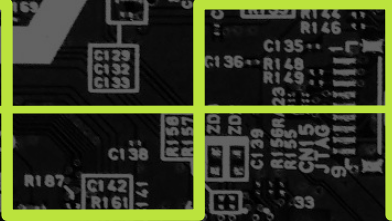
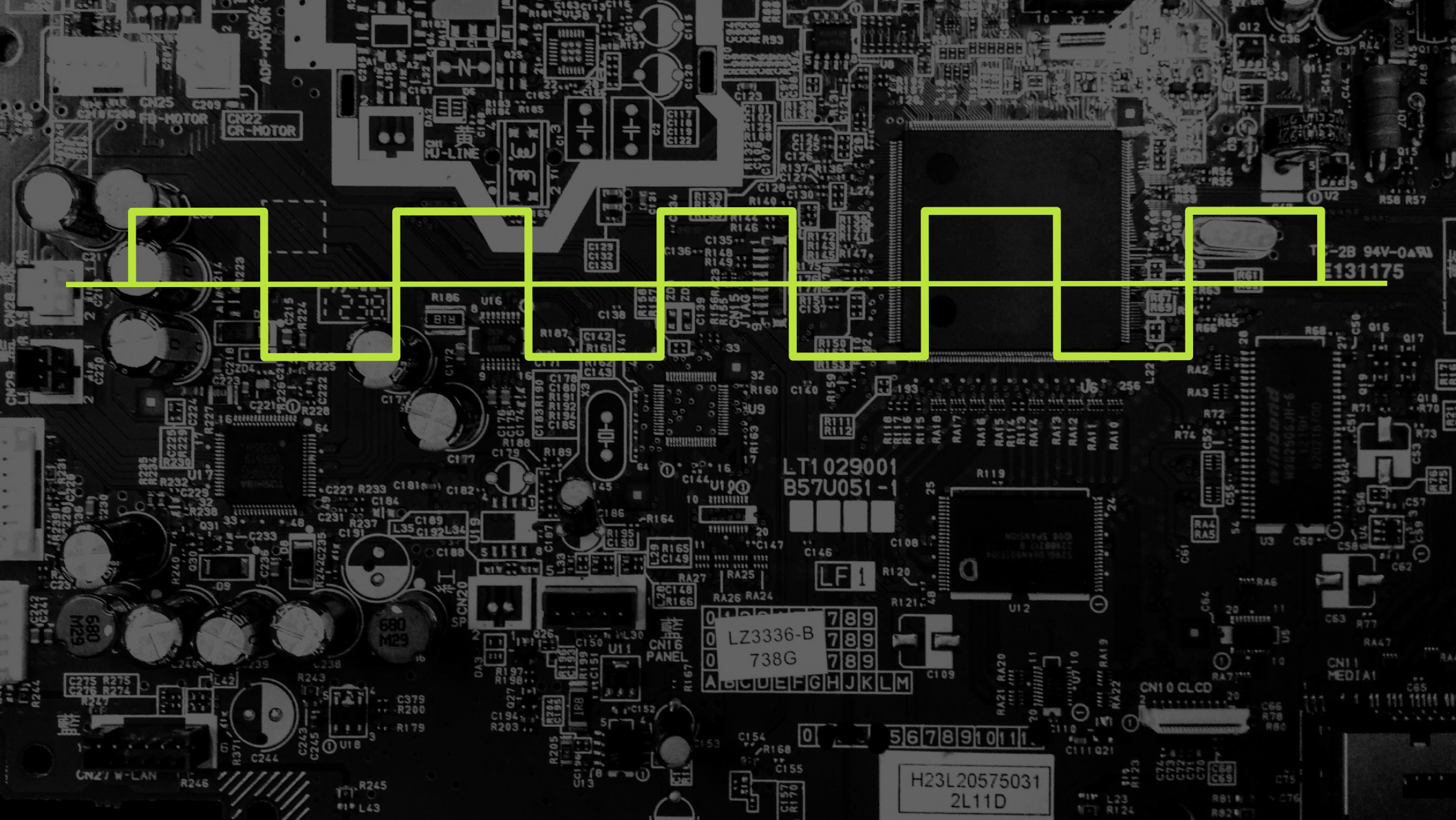
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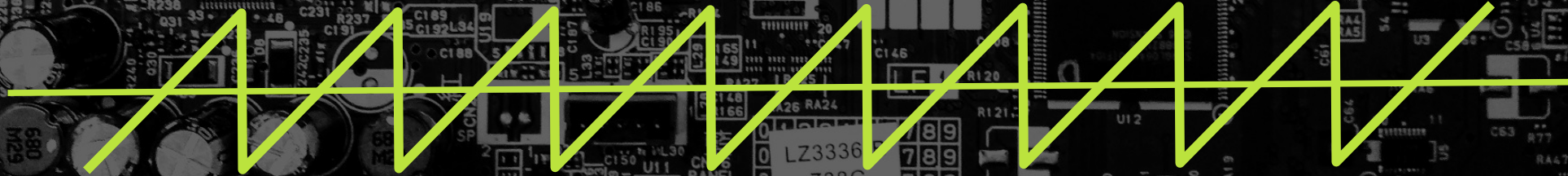
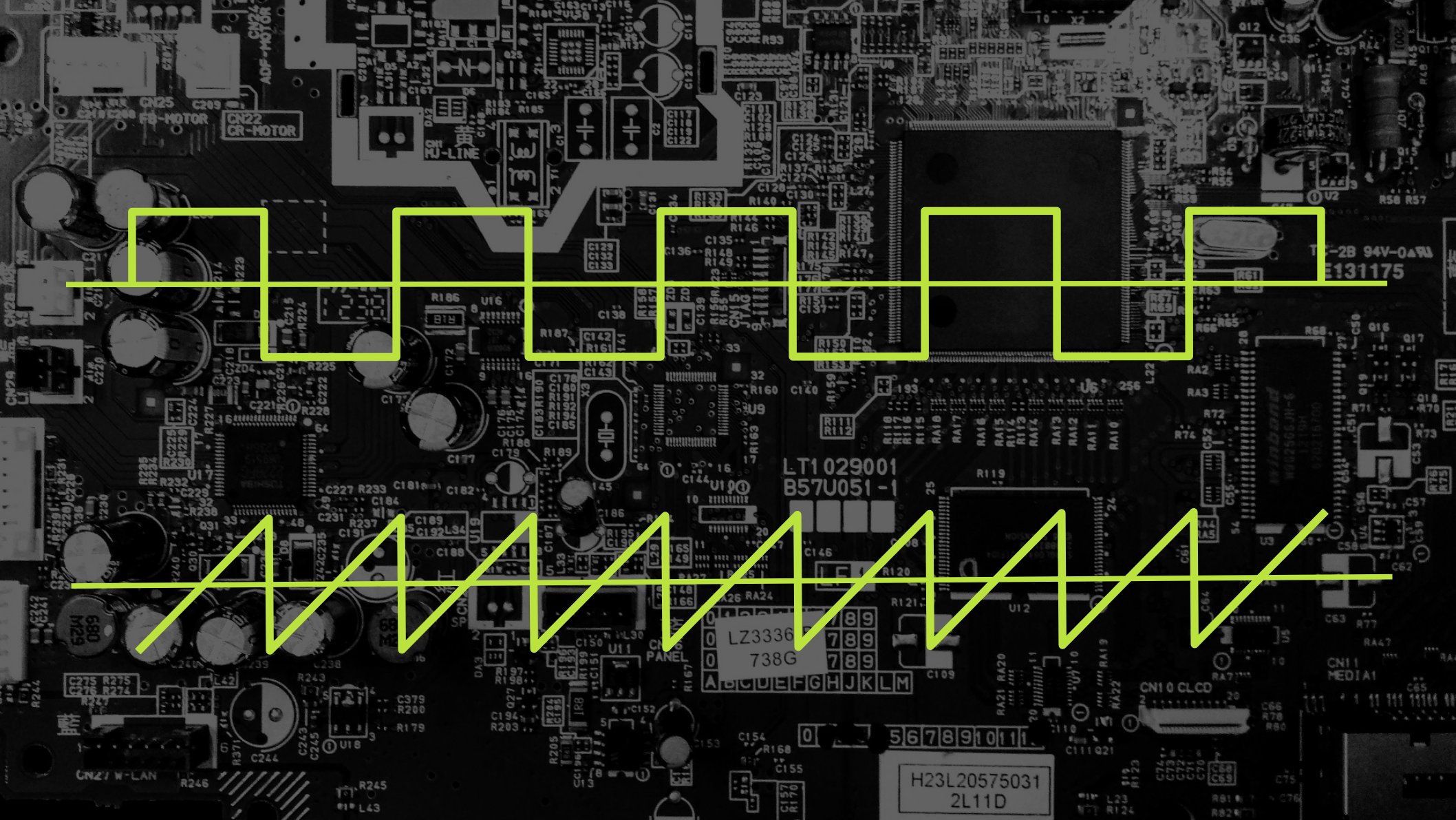
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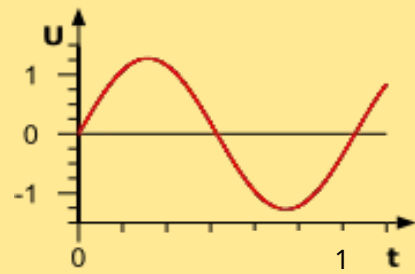
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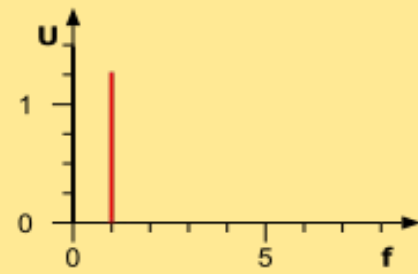
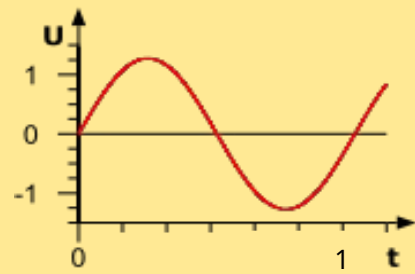
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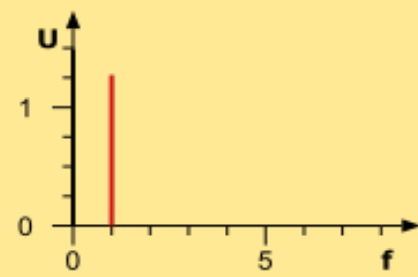
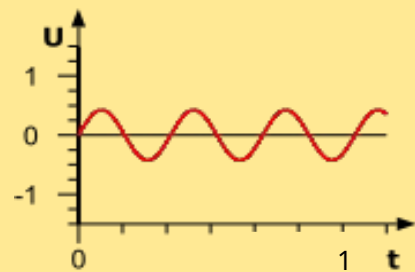
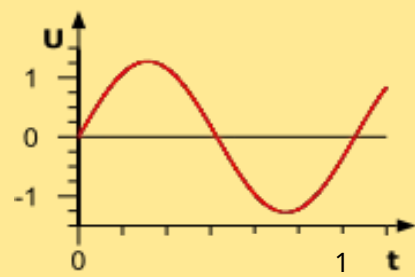


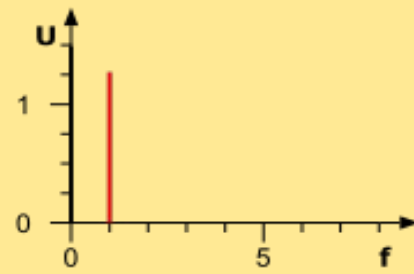
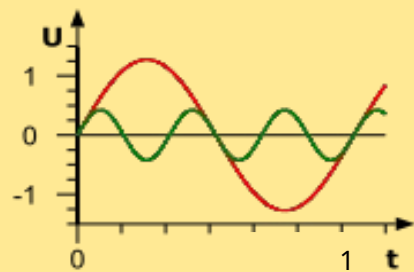
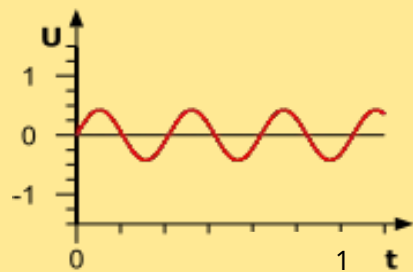
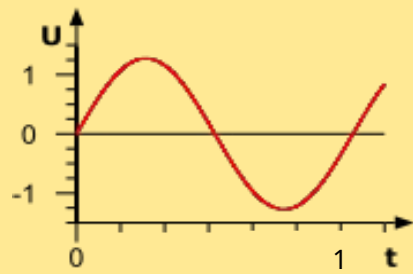


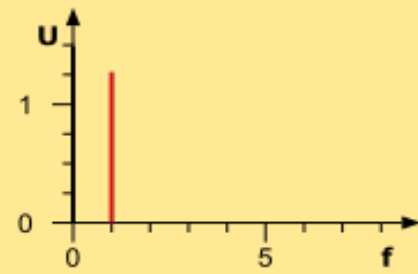
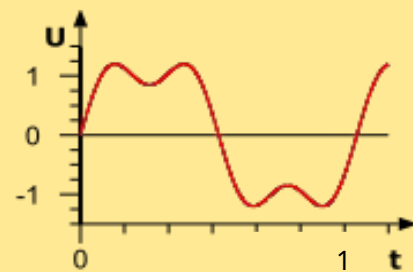
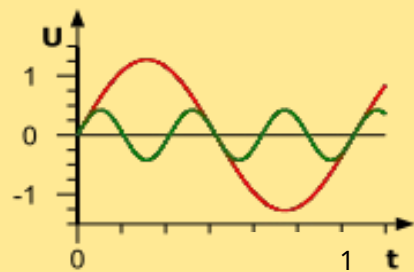
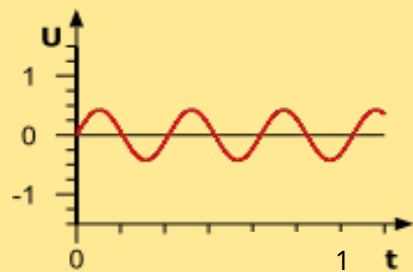
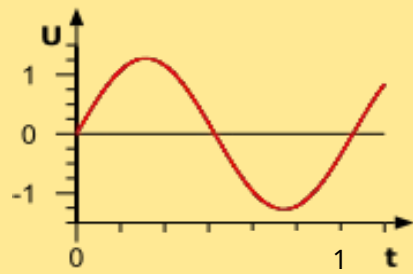


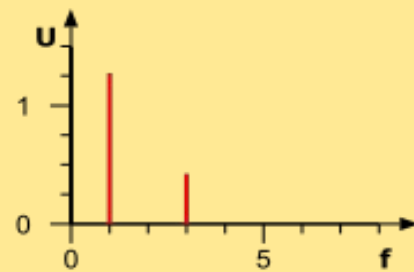
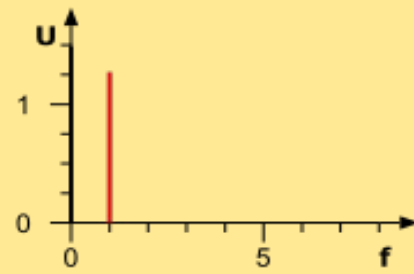
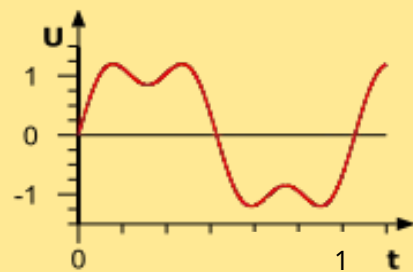
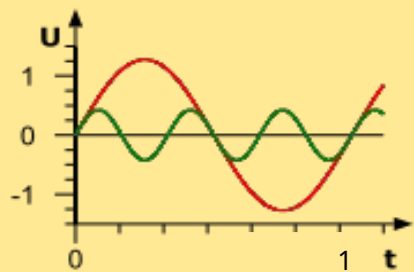
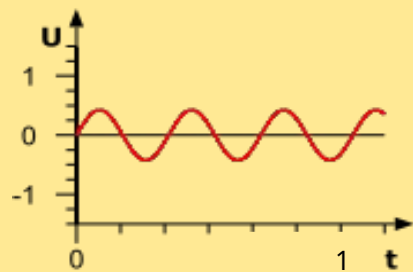
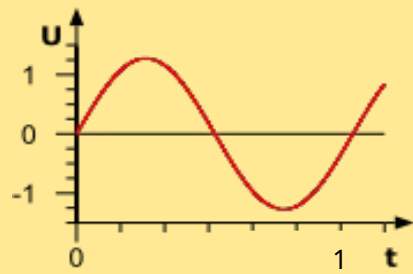


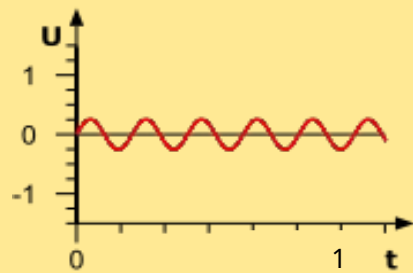
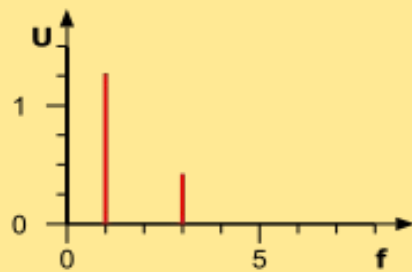
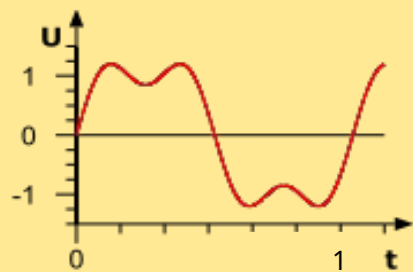
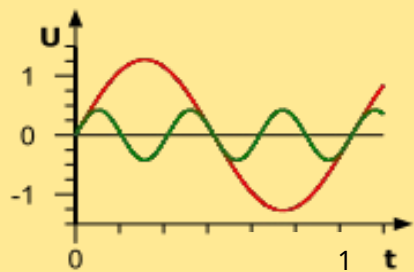
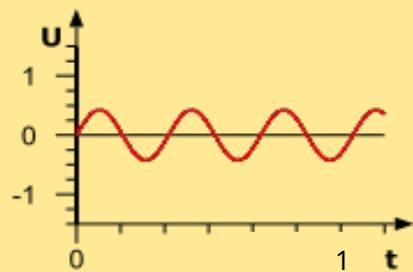
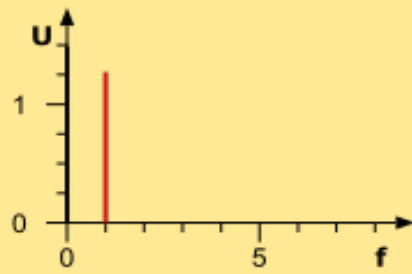
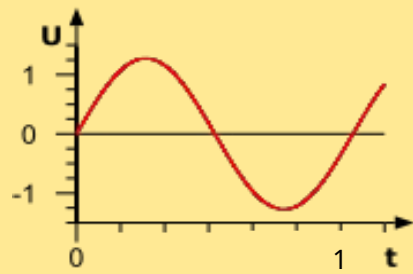


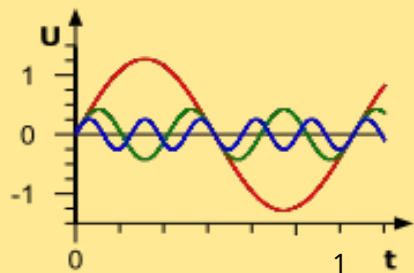
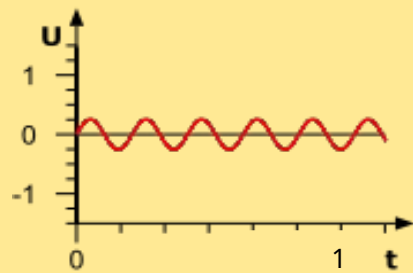
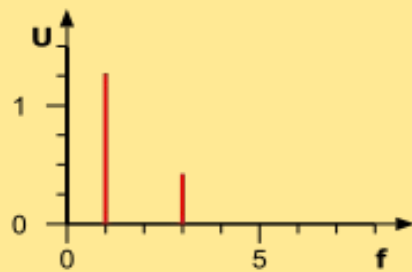
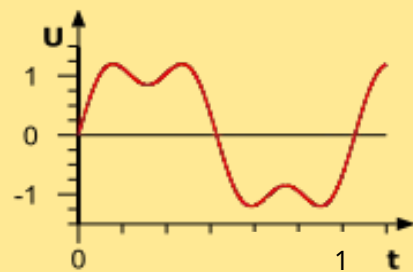
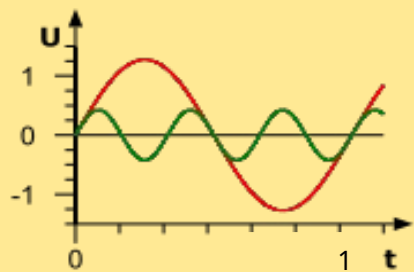
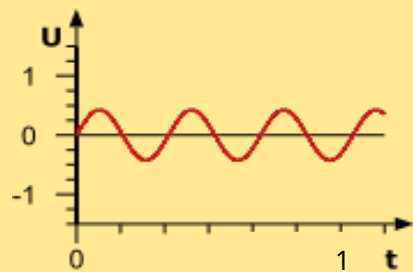
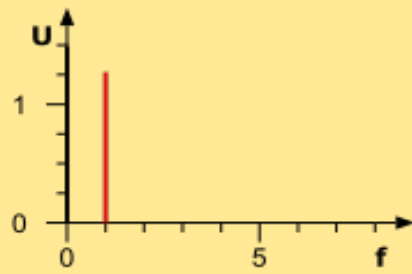
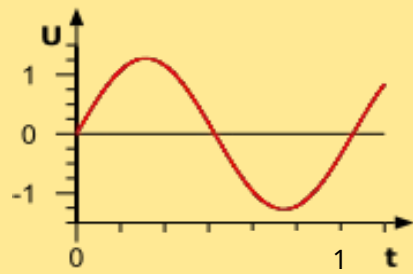


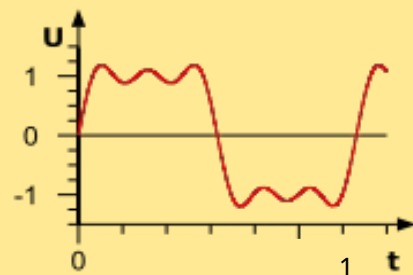
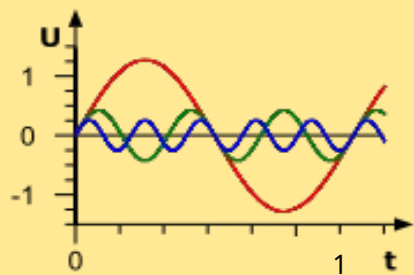
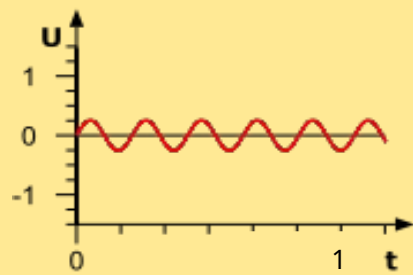
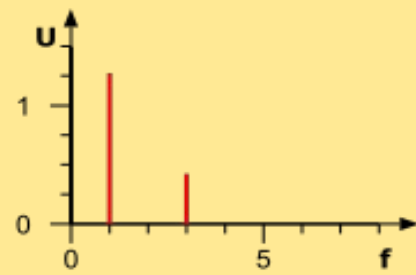
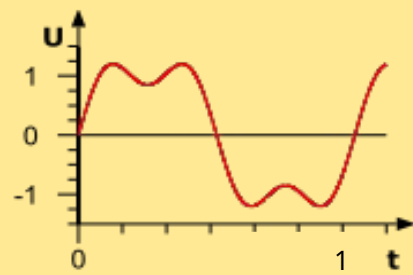
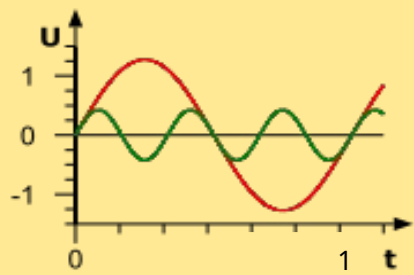
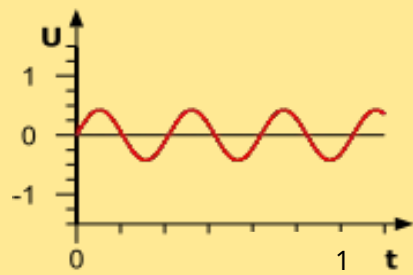
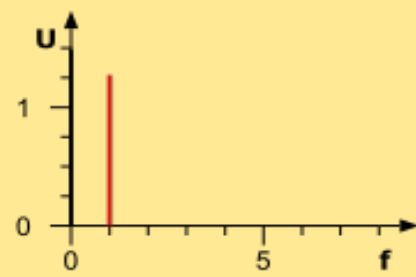
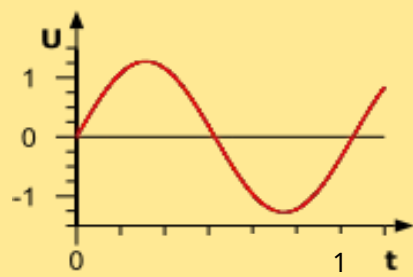


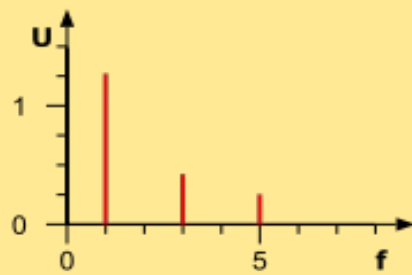
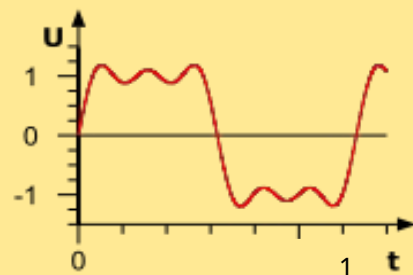
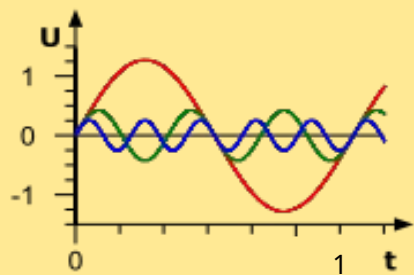
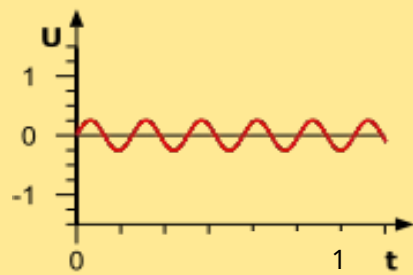
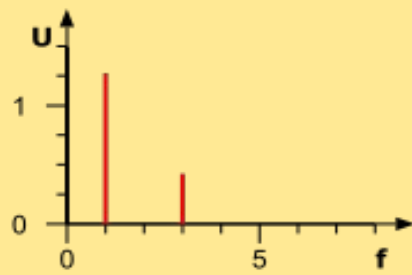
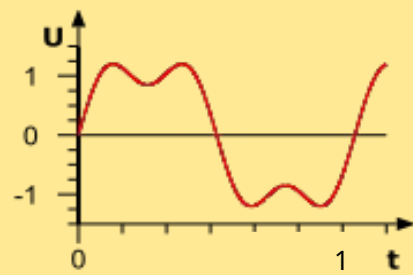
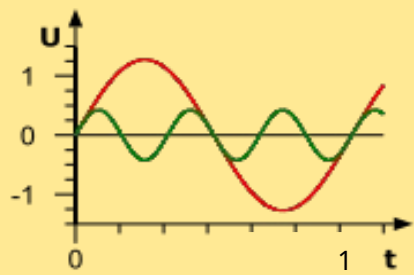
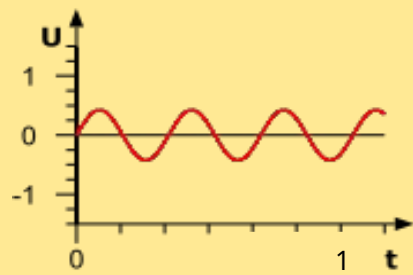
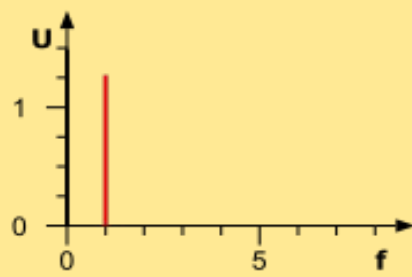
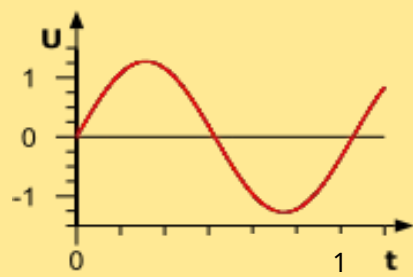




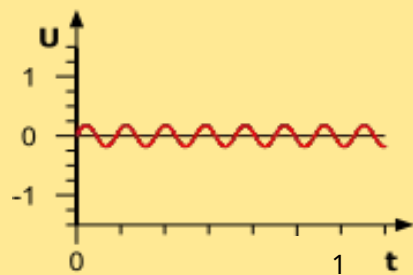
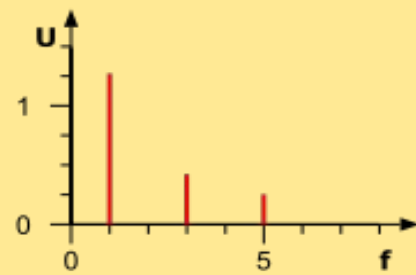
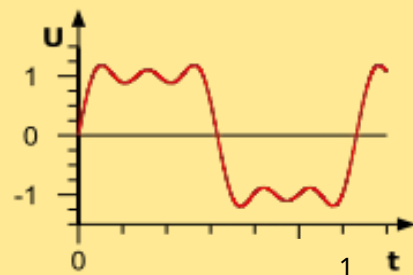
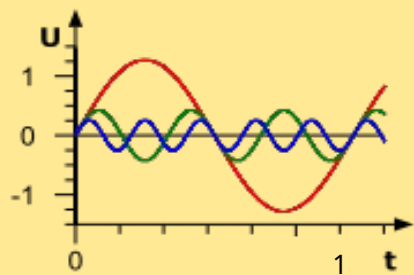
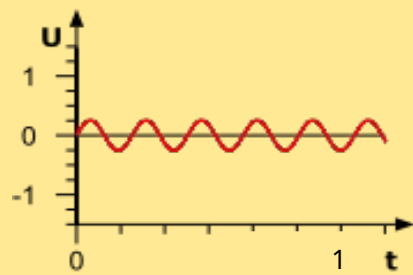
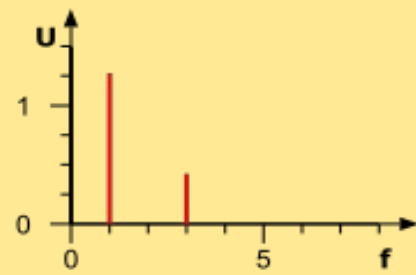
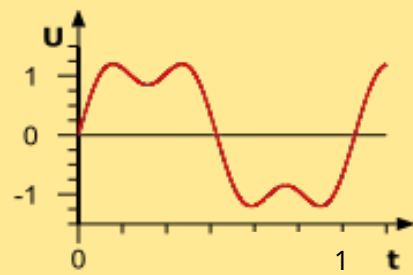
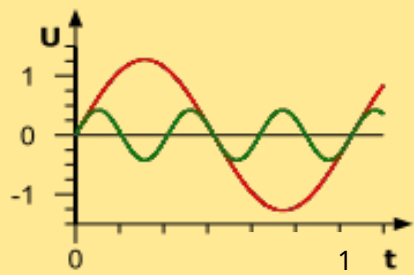
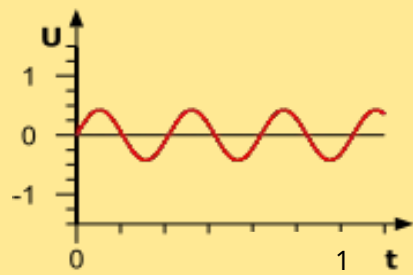
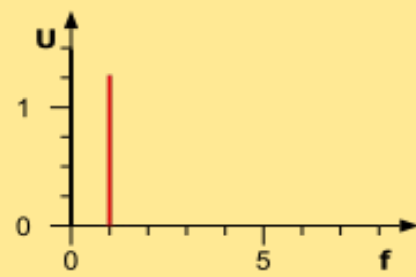
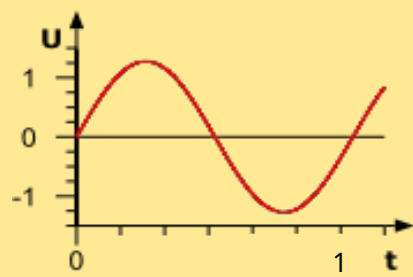


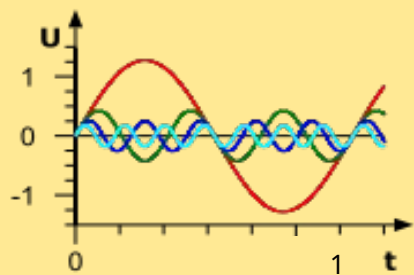
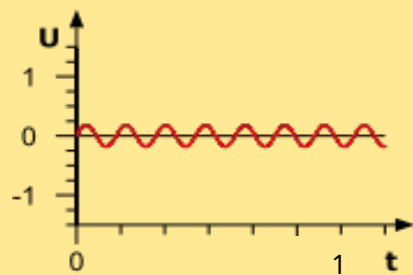
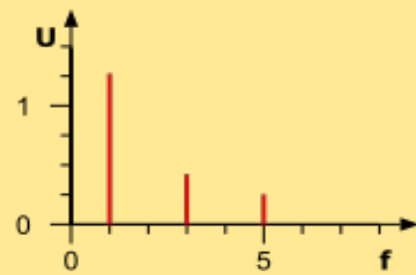
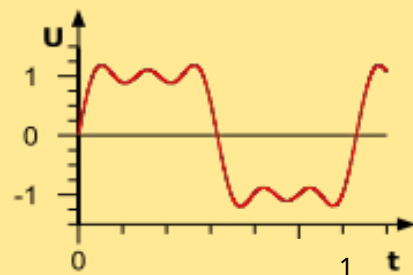
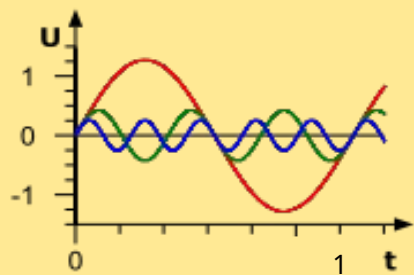
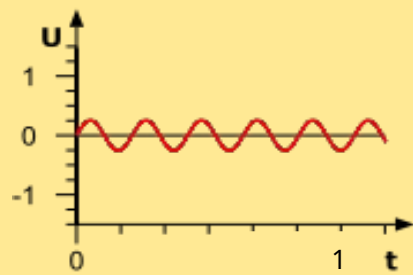
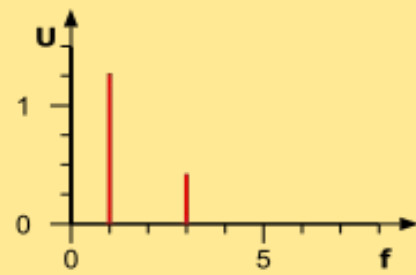
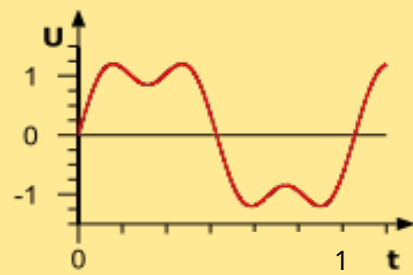
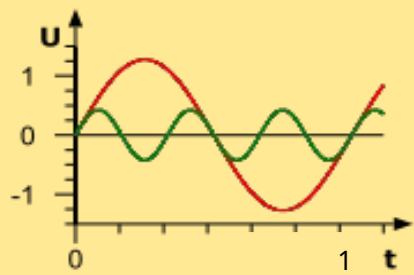
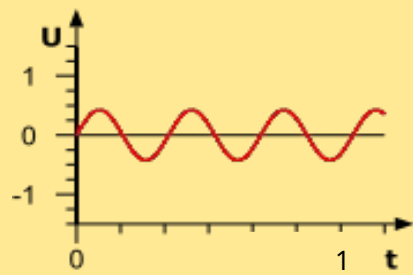
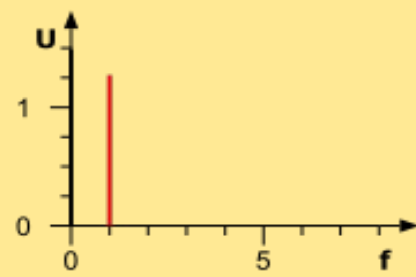
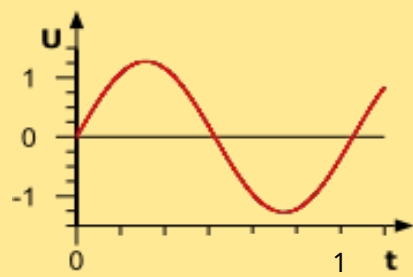


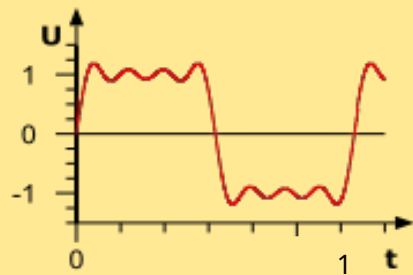
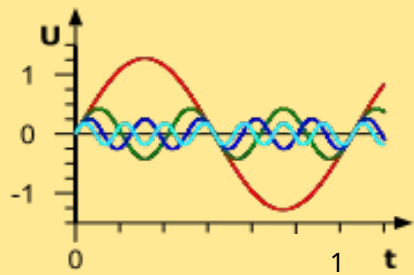
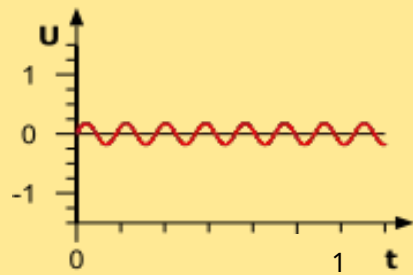
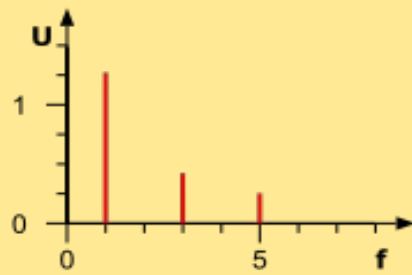
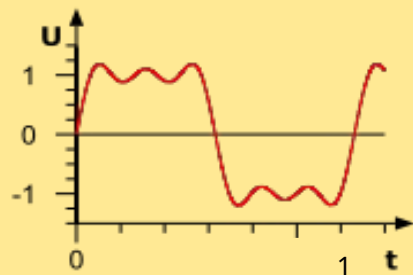
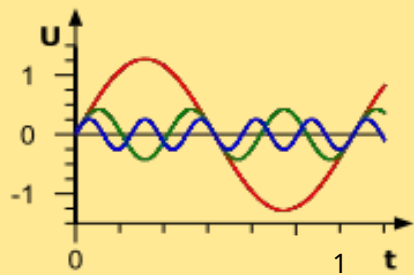
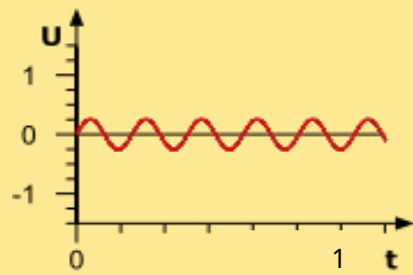
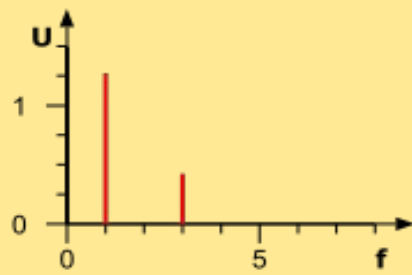
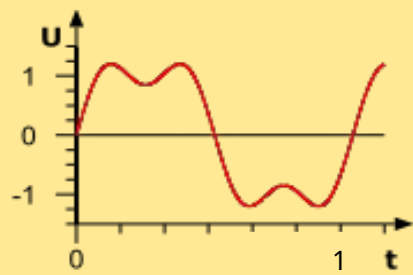
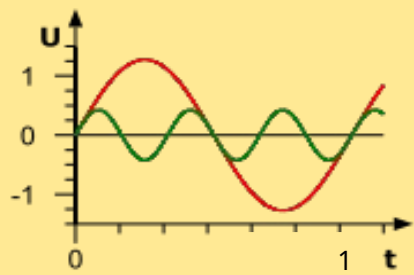
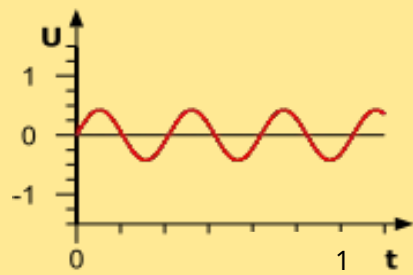
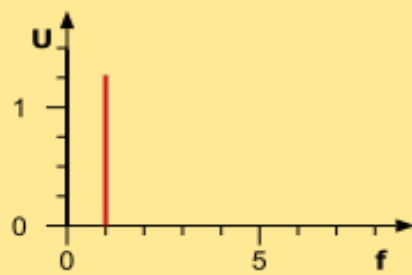
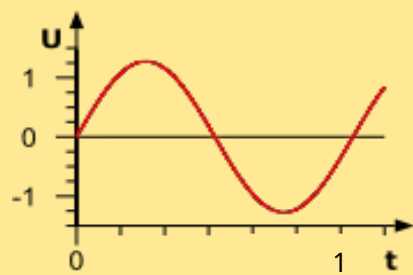


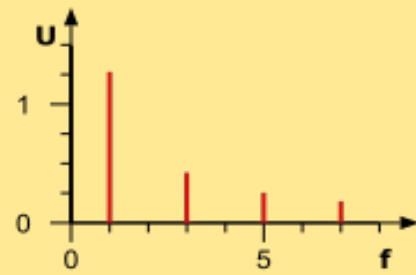
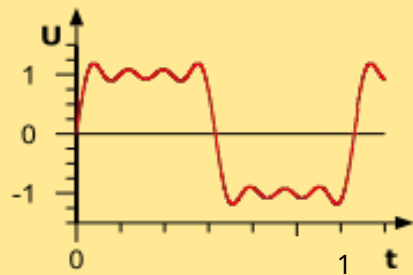
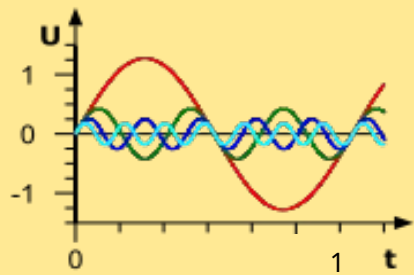
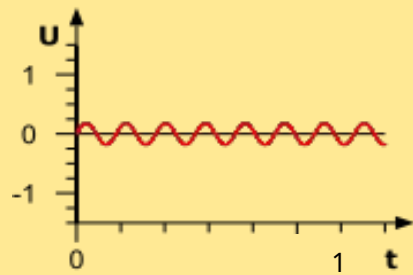
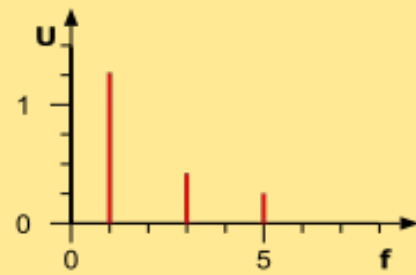
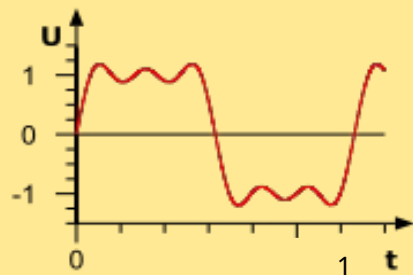
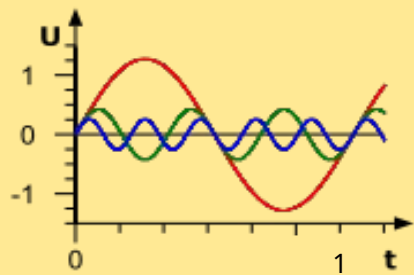
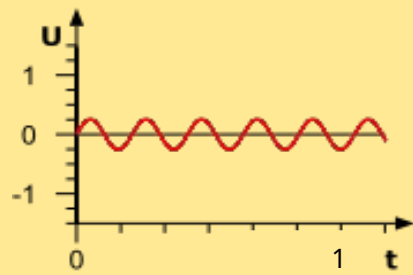
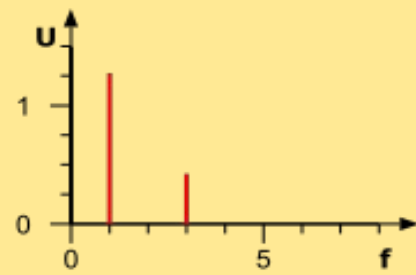
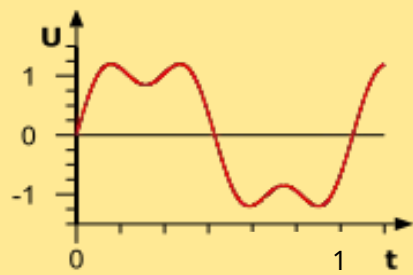
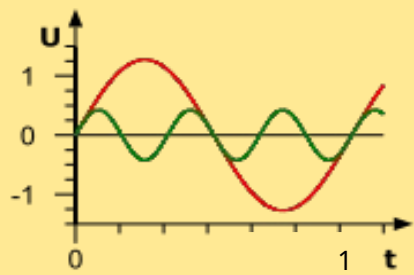
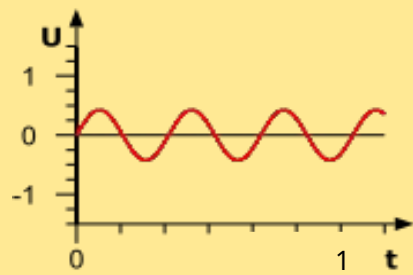
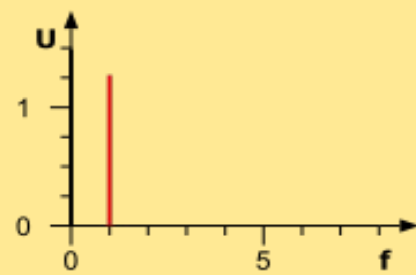
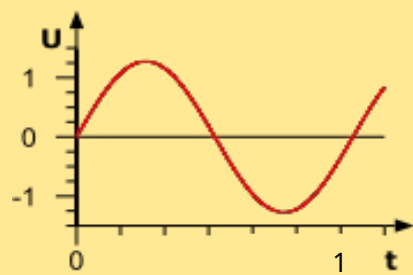


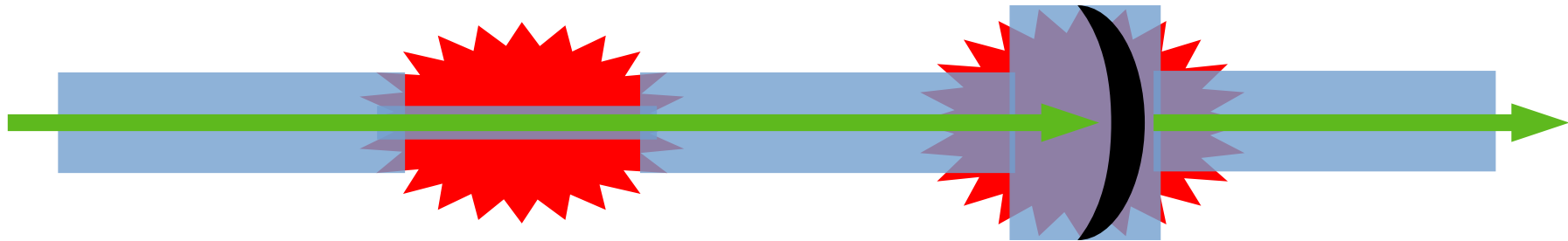


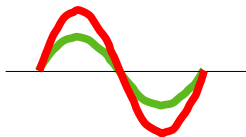
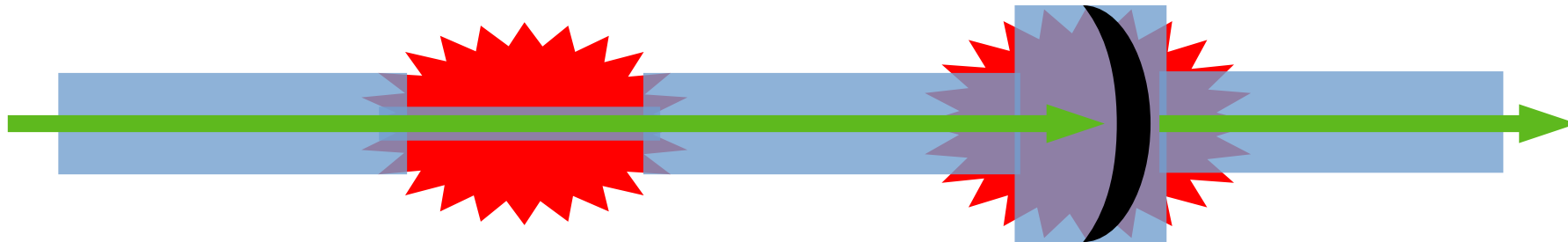


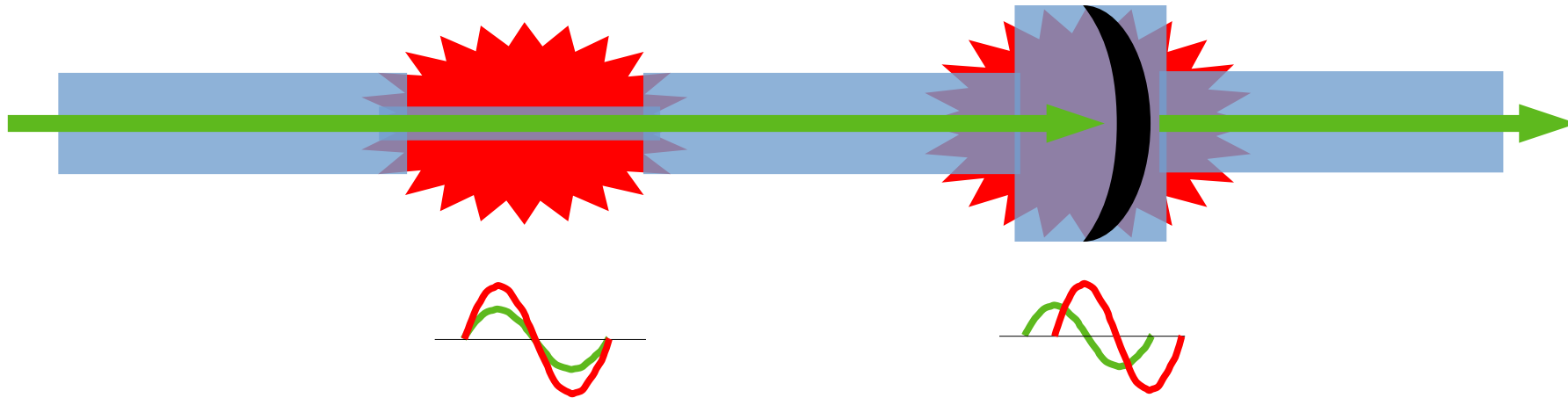


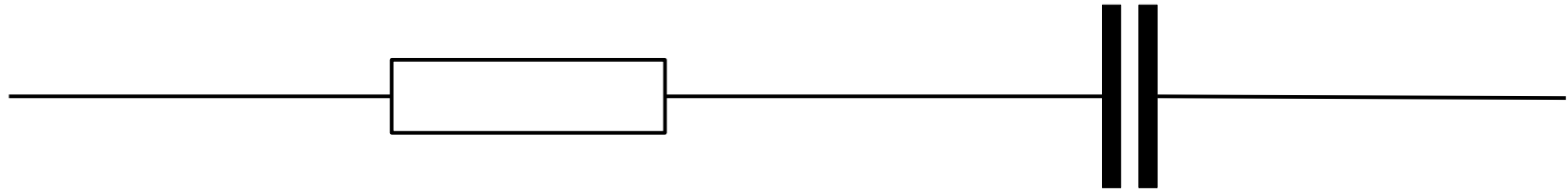
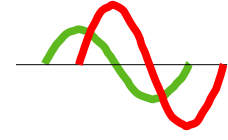
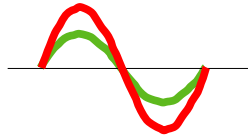
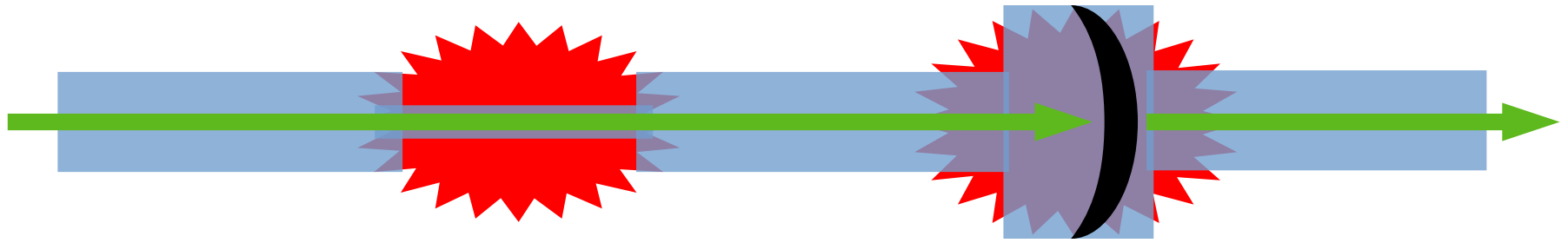




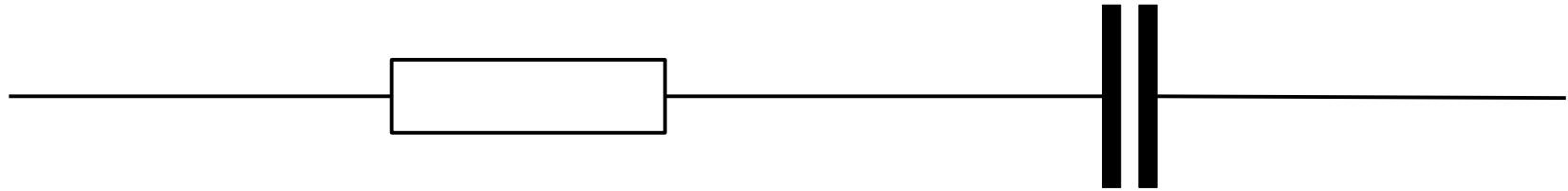
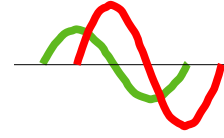
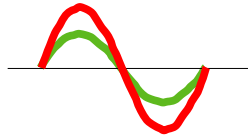
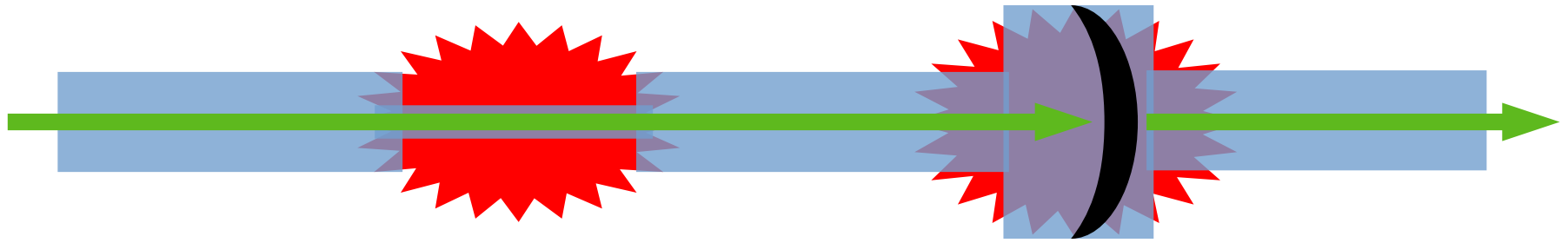




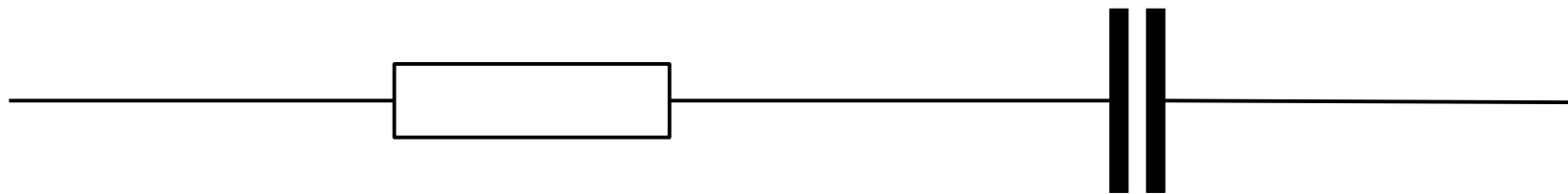
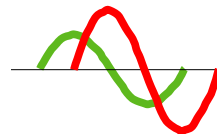
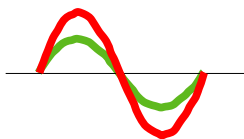
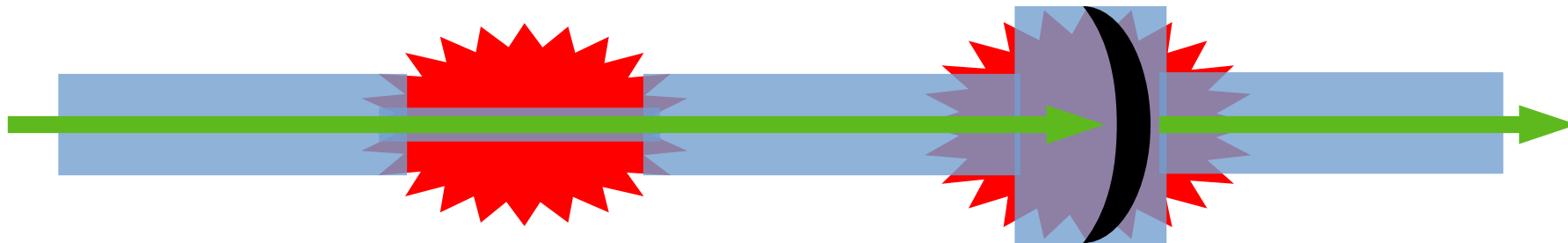






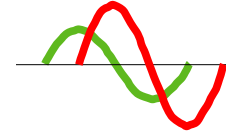
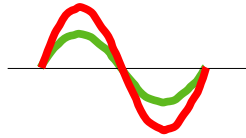
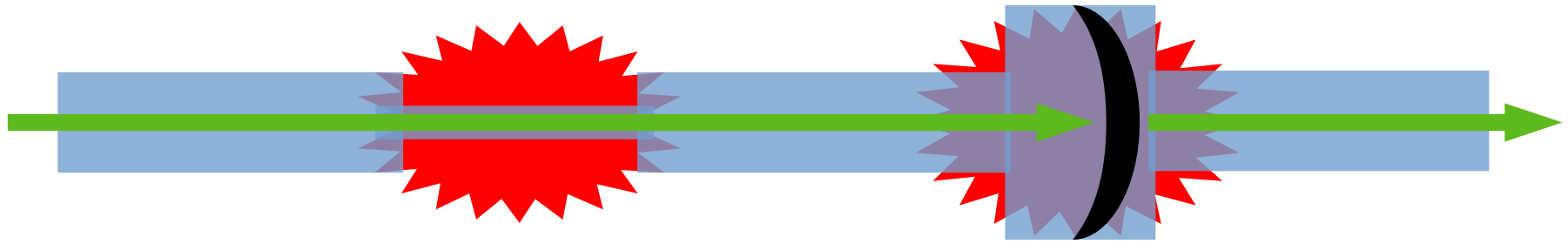


$$U_R = RI$$



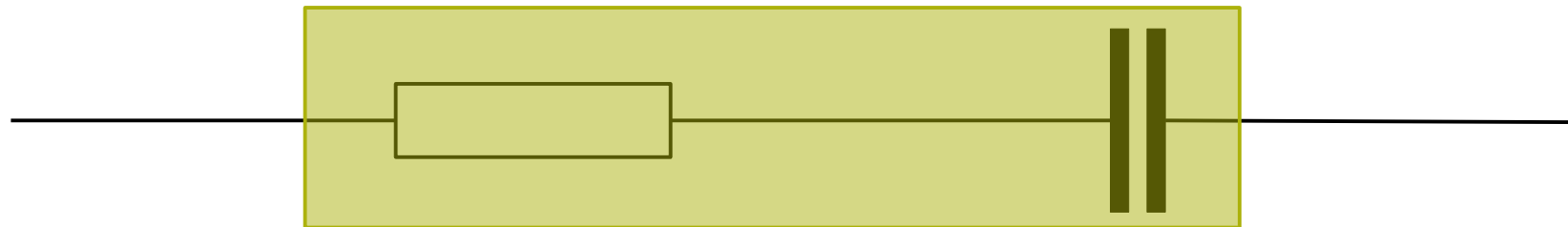
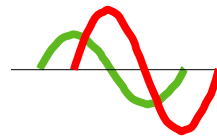
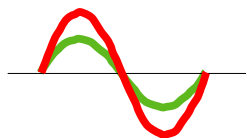
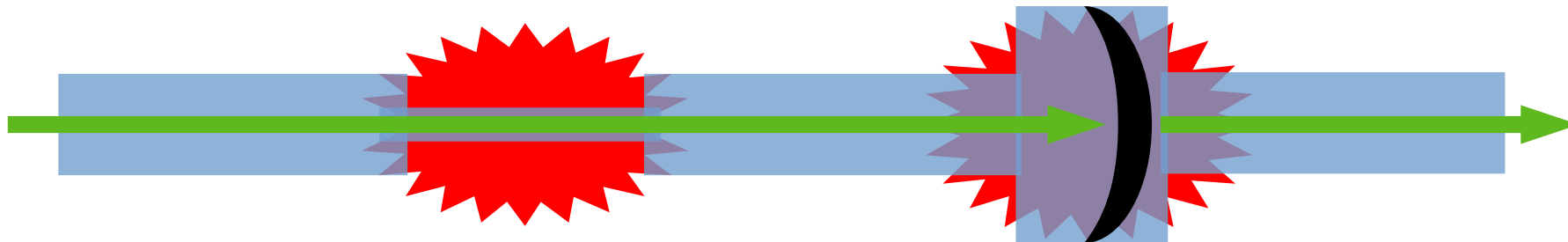
$$U_R = RI$$

$$U_c = \frac{1}{2\pi f C} I$$



$$U_R = RI$$

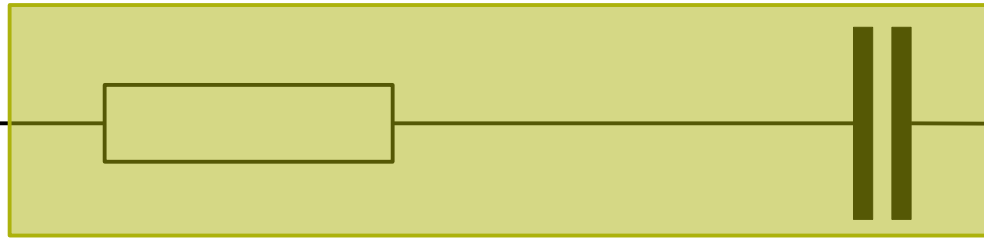
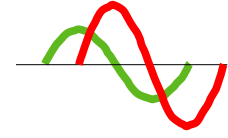
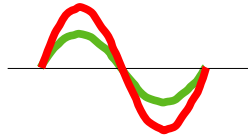
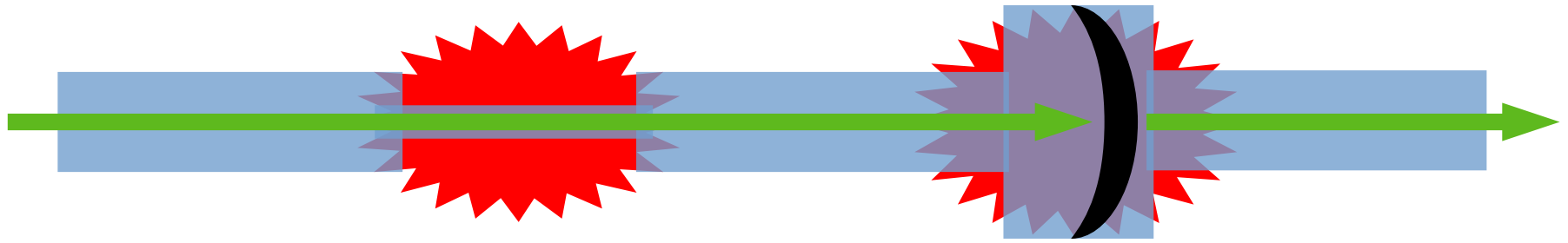
$$U_c = \frac{1}{2\pi f C} I$$



$$U_R = RI$$

$$U_C = \frac{1}{2\pi f C} I$$

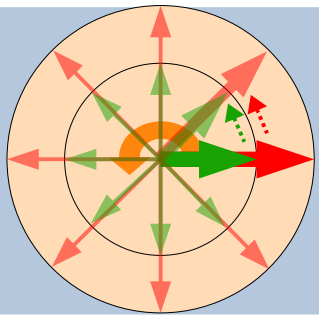
$$U_v = U_R + U_C = RI + \frac{1}{2\pi f C} I = \left( R + \frac{1}{2\pi f C} \right) I$$

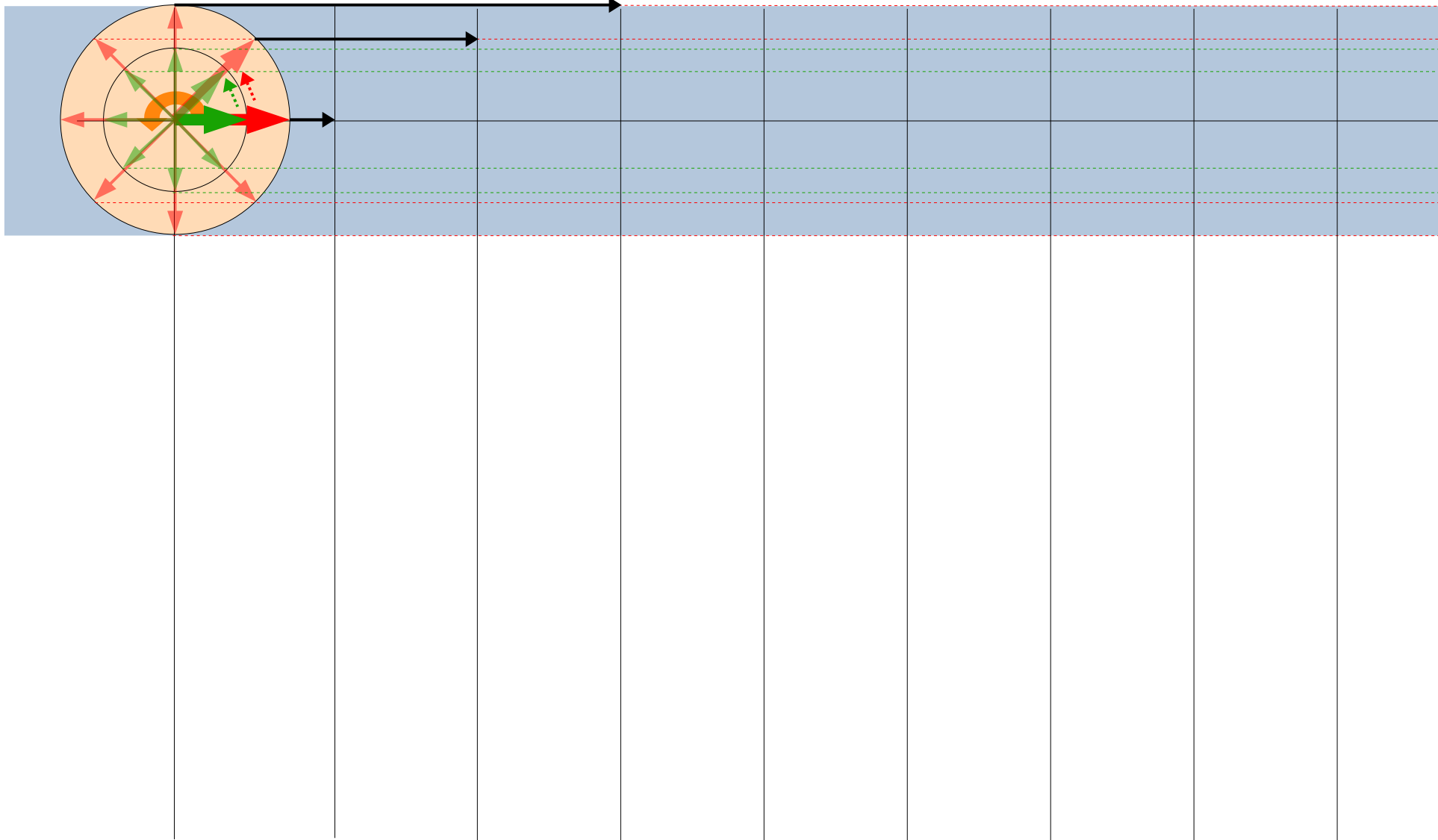


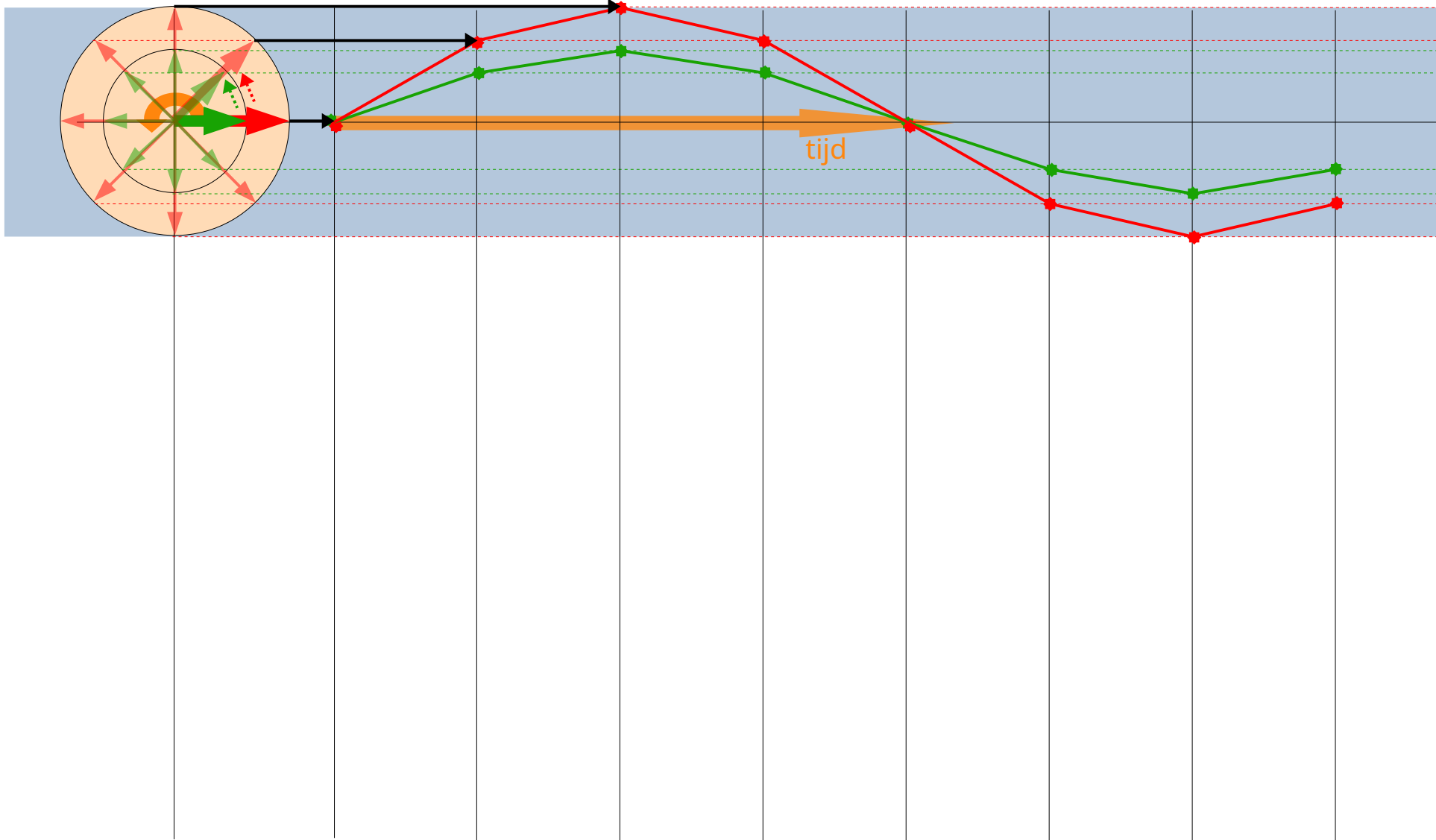
$$U_R = RI$$

$$U_C = \frac{1}{2\pi f C} I$$

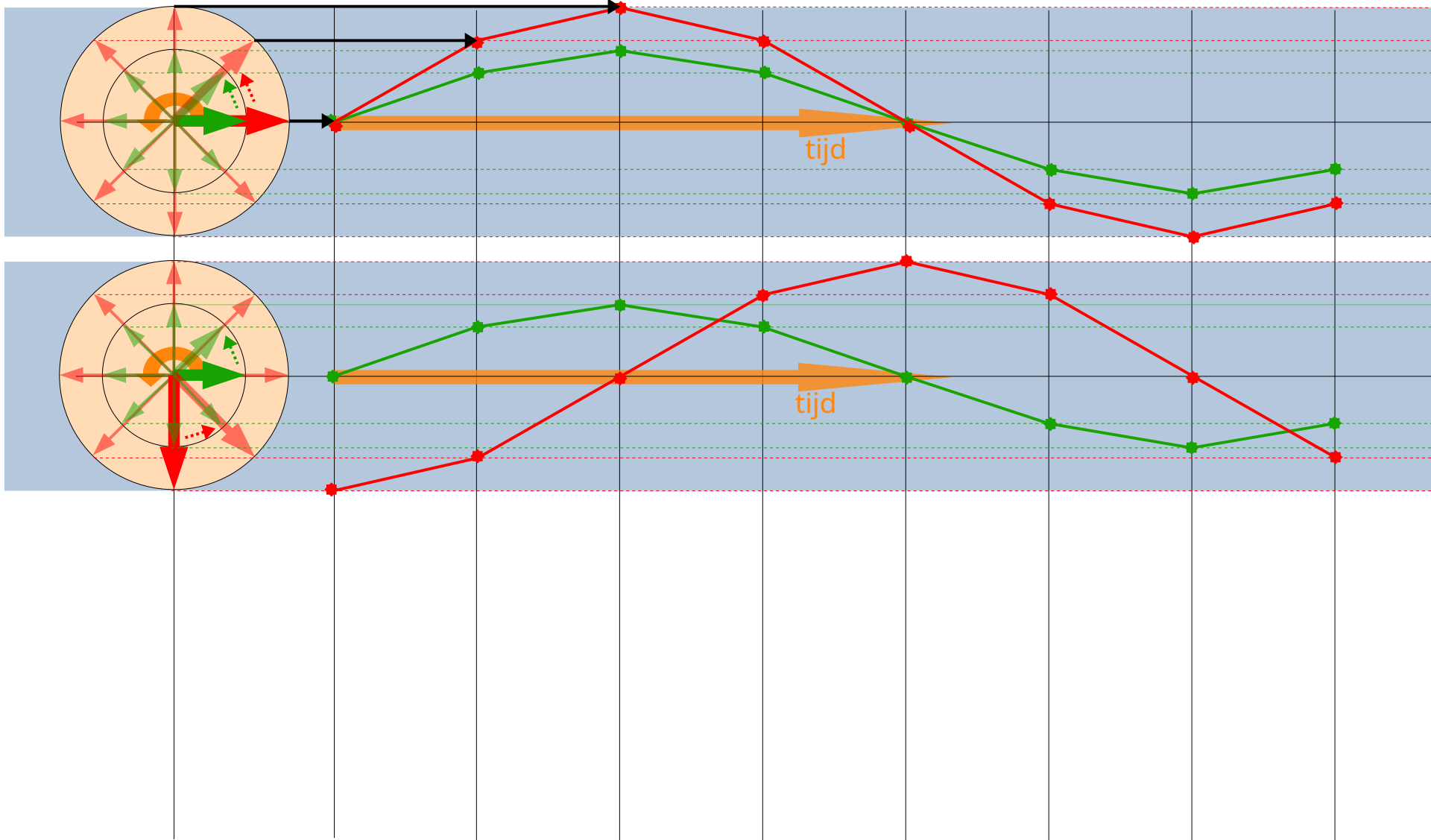
~~$$U_v = U_R + U_C = RI + \frac{1}{2\pi f C} I = \left( R + \frac{1}{2\pi f C} \right) I$$~~

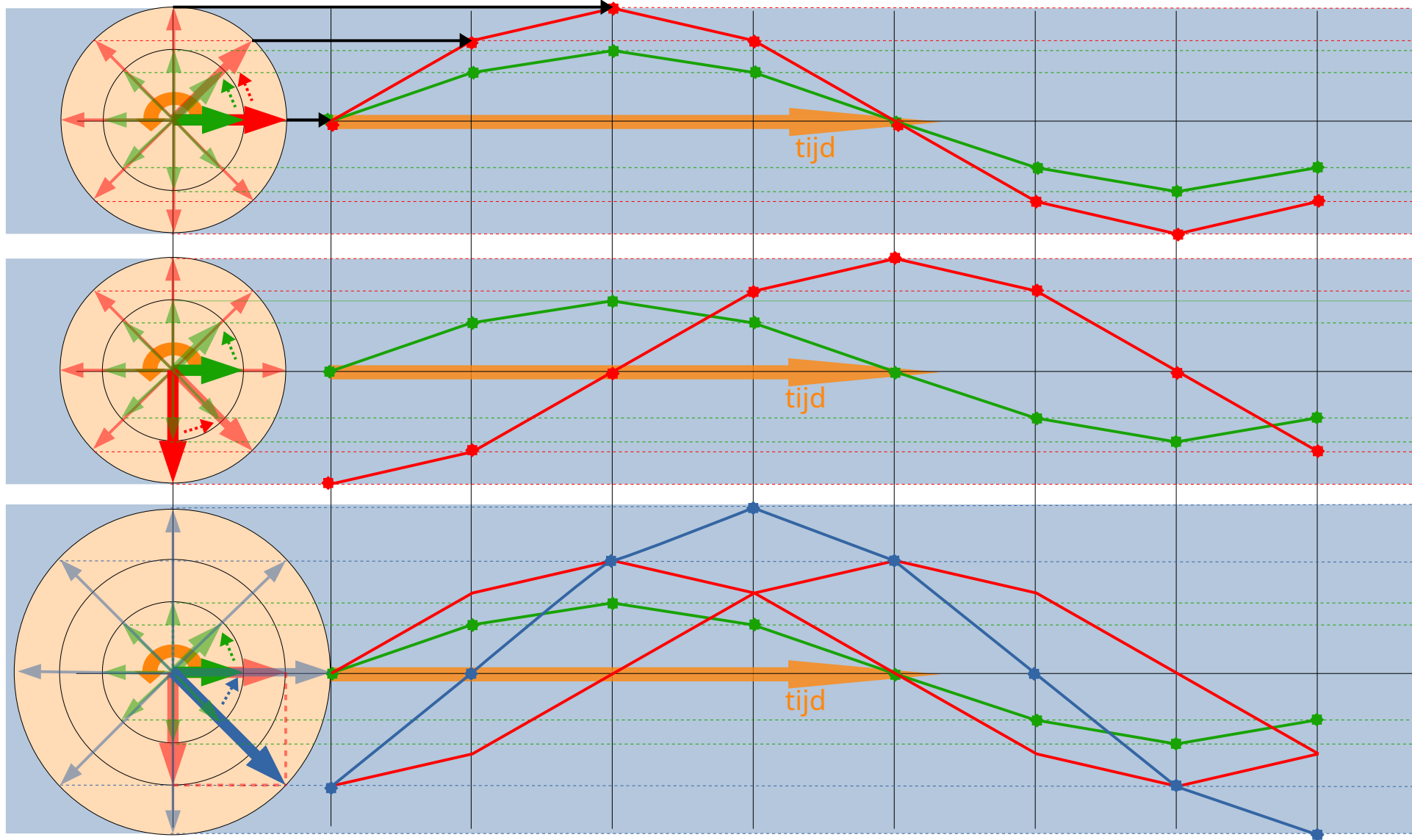


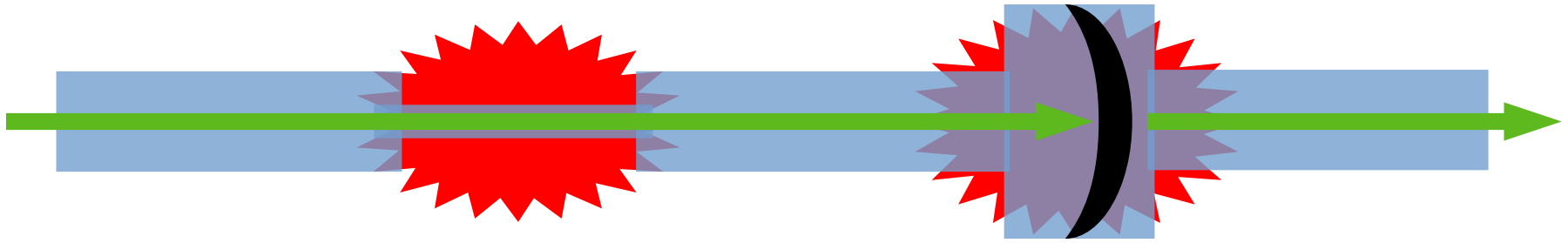


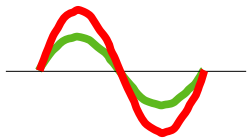
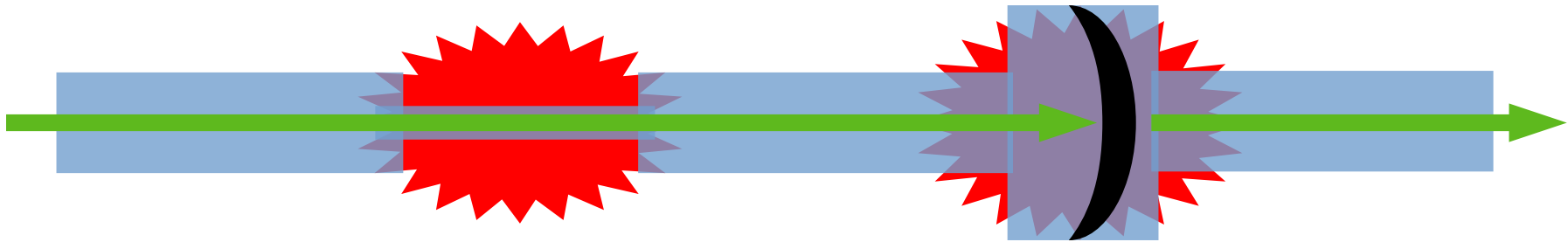


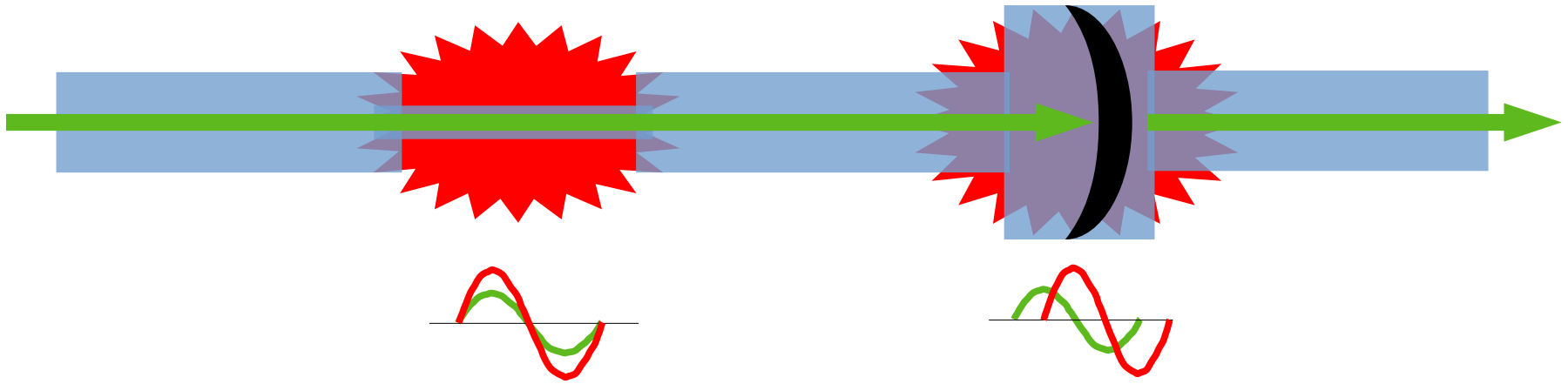


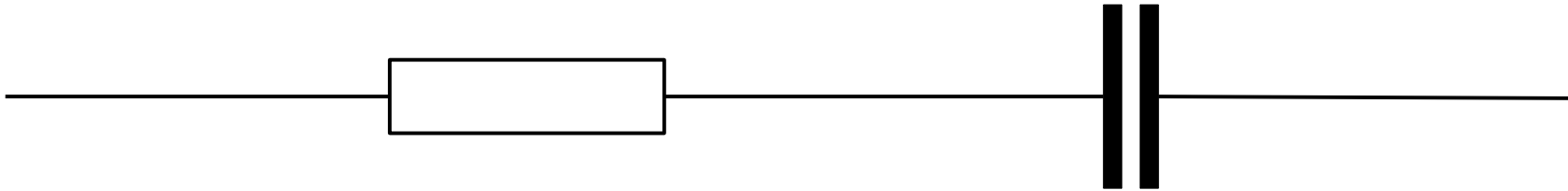
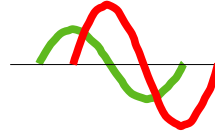
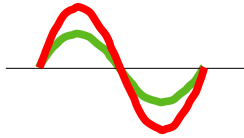
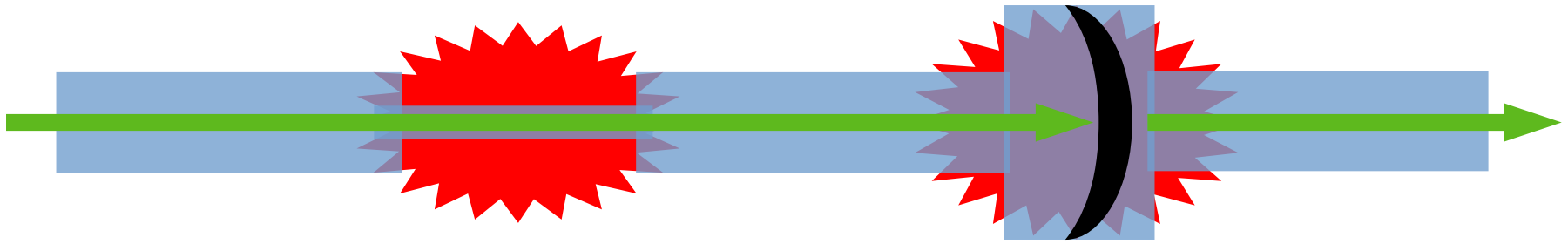


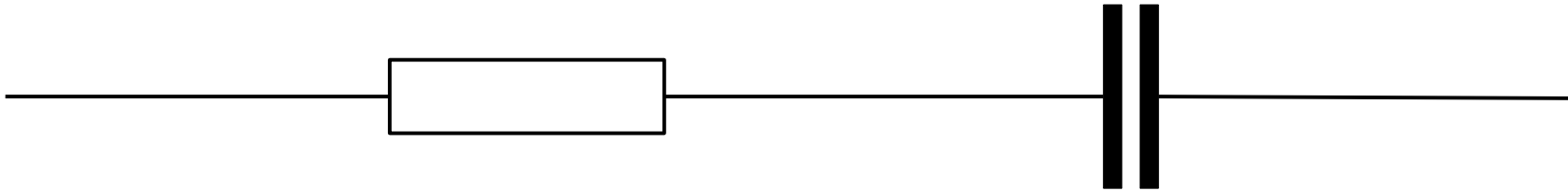
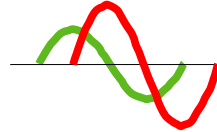
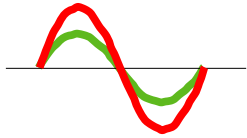
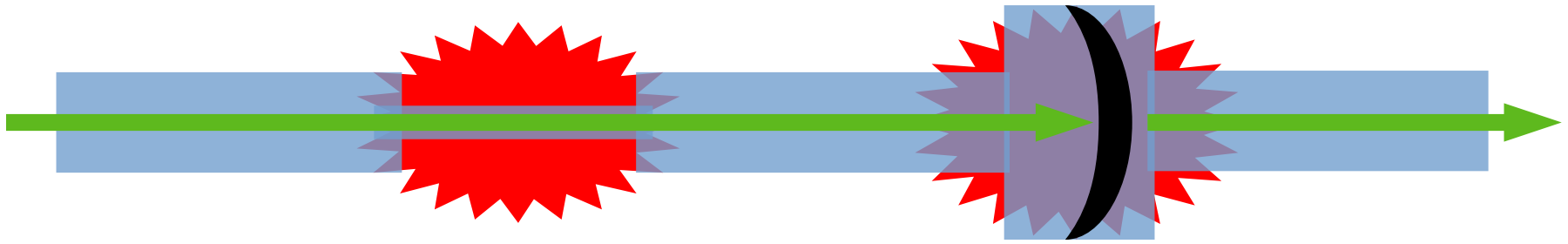




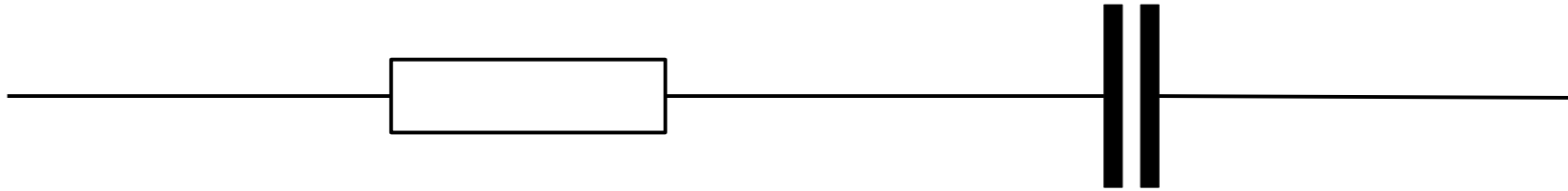
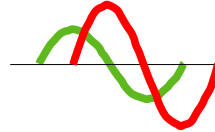
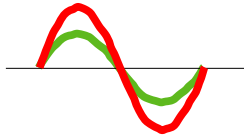
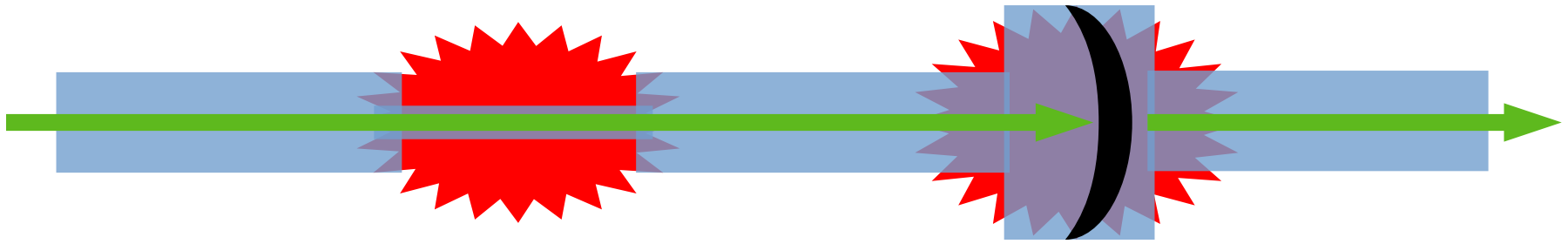








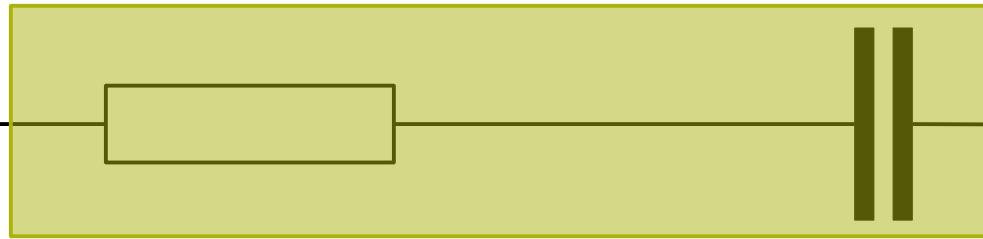
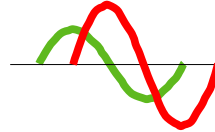
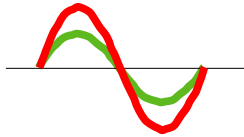
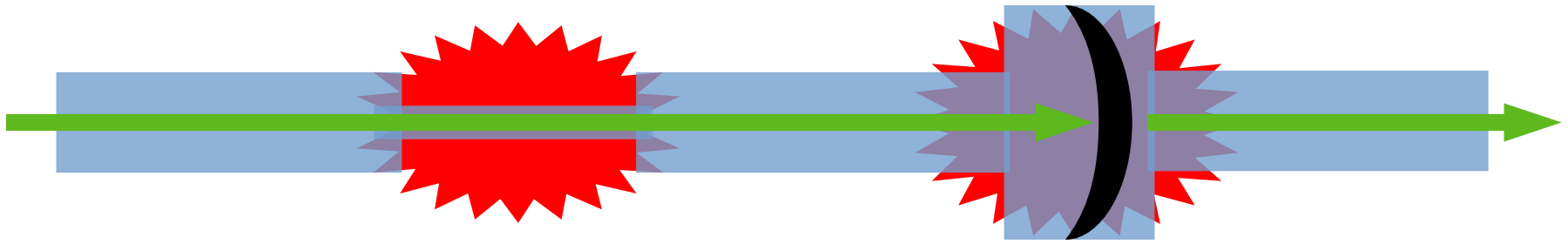
$$U_R = RI$$



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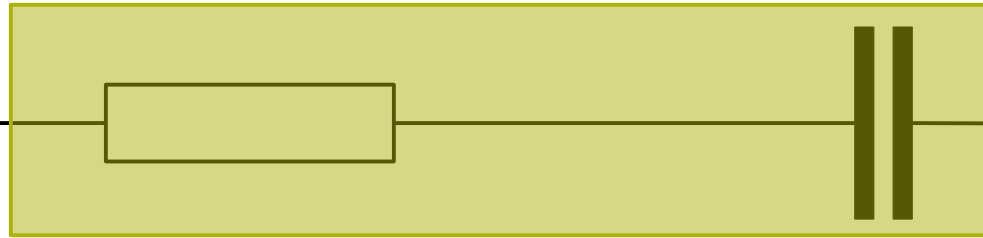
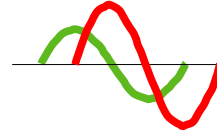
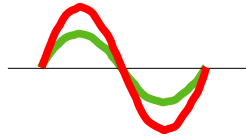
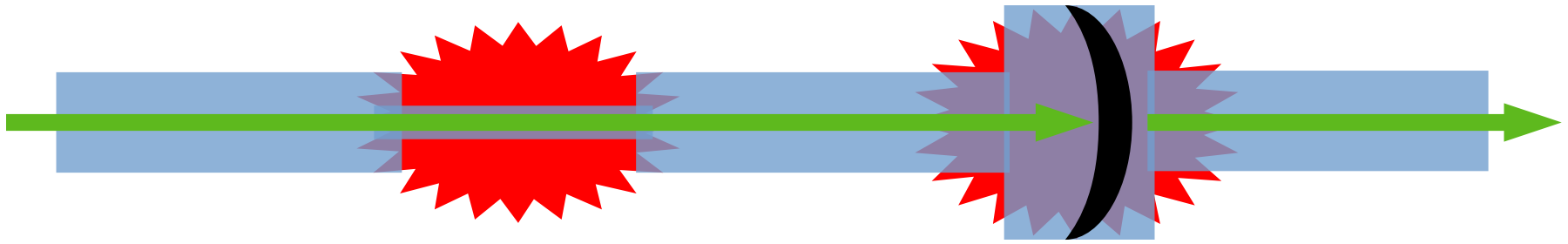
$$U_C = \frac{-1}{2\pi f C} j I = \frac{-j}{2\pi f C} I = \frac{1}{j 2\pi f C} I$$





$$U_R = RI$$

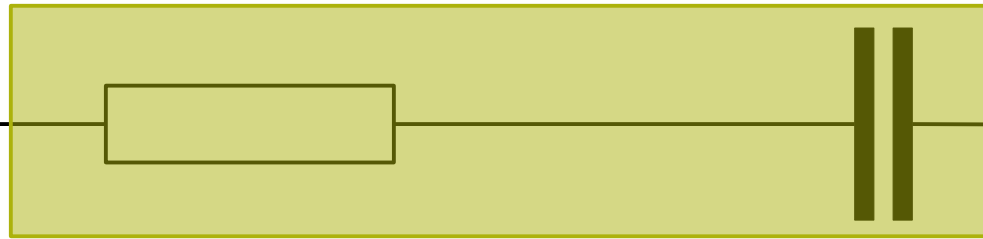
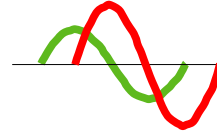
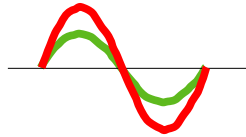
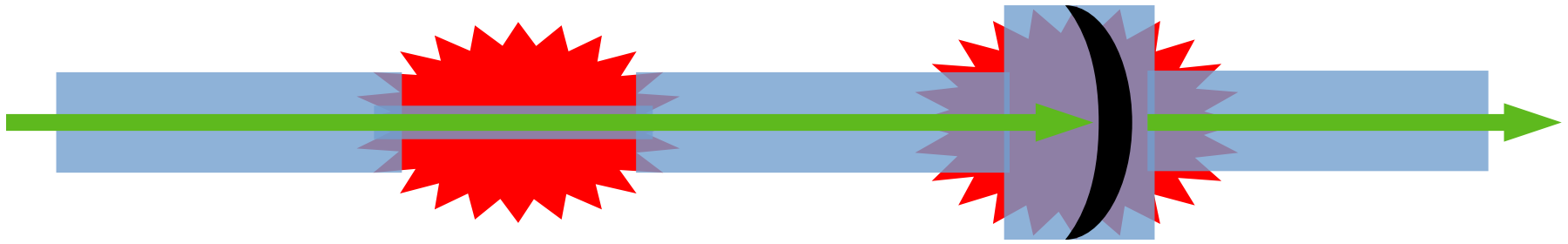
$$U_C = \frac{-1}{2\pi f C} j I = \frac{-j}{2\pi f C} I = \frac{1}{j 2\pi f C} I$$



$$U_R = RI$$

$$U_C = \frac{-1}{2\pi f C} j I = \frac{-j}{2\pi f C} I = \frac{1}{j 2\pi f C} I$$

$$U_v = U_R + U_C = RI + \frac{1}{j 2\pi f C} I = \left( R + \frac{1}{j 2\pi f C} \right) I$$

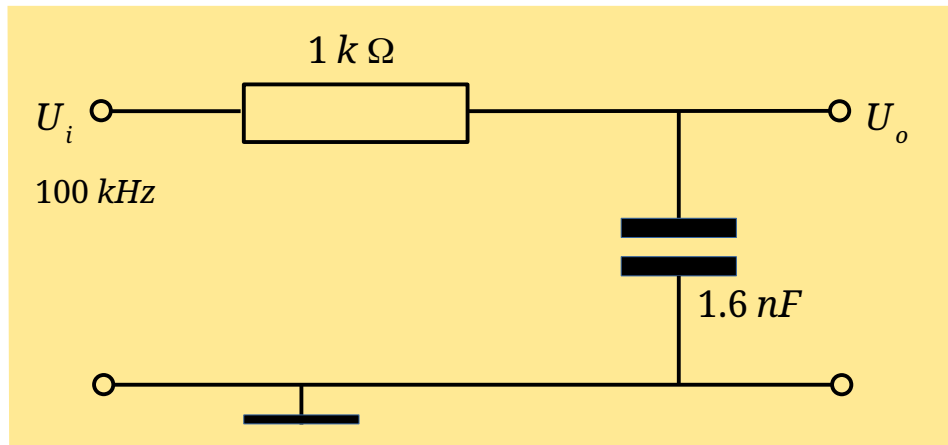


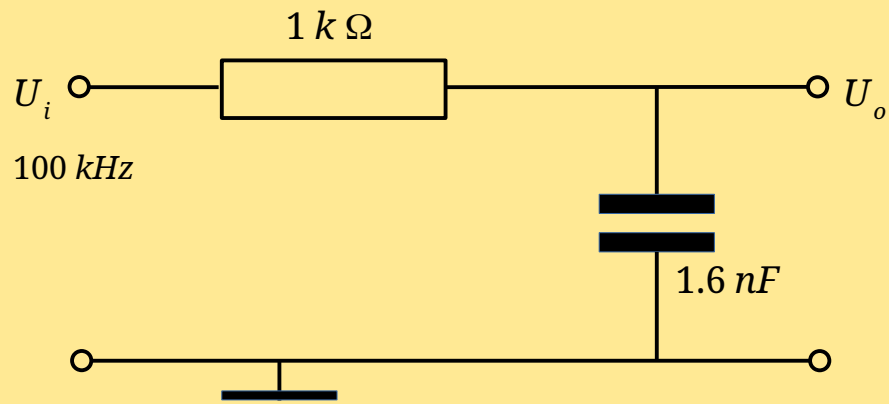
$$U_R = RI$$

$$U_C = \frac{-1}{2\pi f C} j I = \frac{-j}{2\pi f C} I = \frac{1}{j2\pi f C} I$$

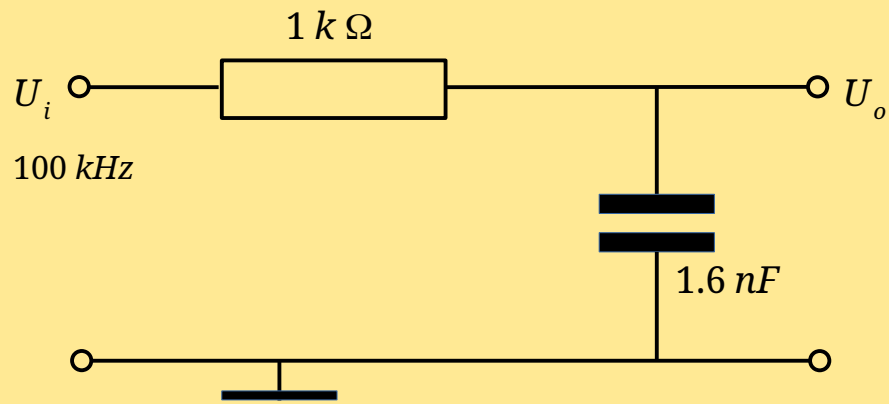
$$U_v = U_R + U_C = RI + \frac{1}{j2\pi f C} I = \left( R + \frac{1}{j2\pi f C} \right) I$$



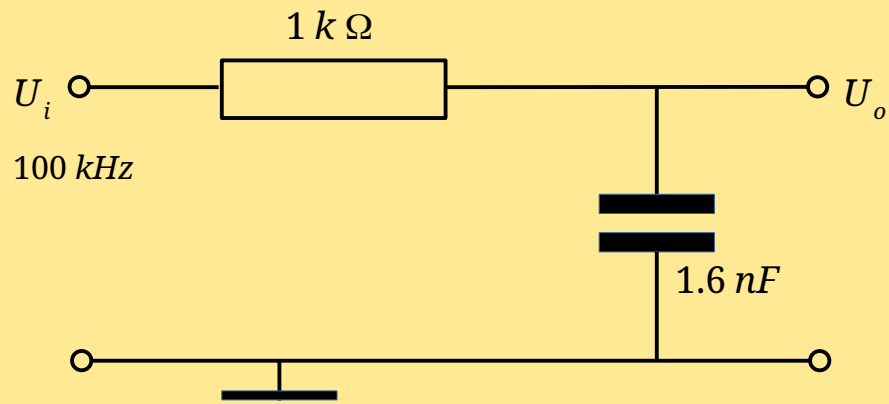




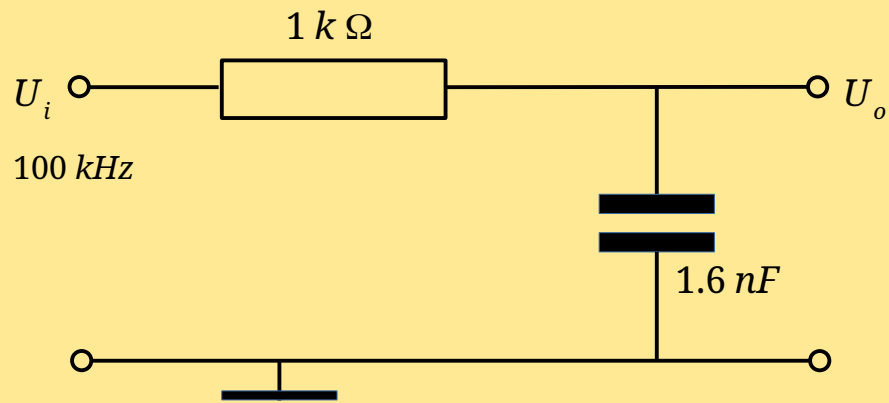
$$U_o = \frac{Z_C}{Z_R + Z_C} U_i$$



$$U_o = \frac{Z_C}{Z_R + Z_C} U_i = \frac{1}{R + \frac{1}{j2\pi f C}} U_i$$

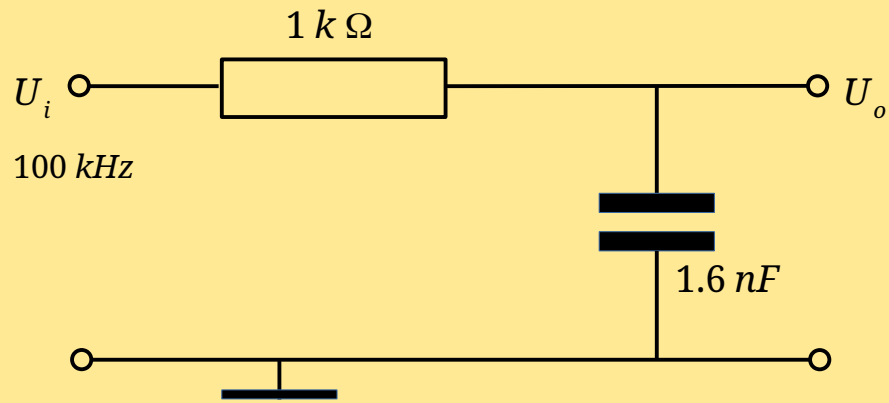


$$U_o = \frac{Z_C}{Z_R + Z_C} U_i = \frac{\frac{1}{j2\pi f C}}{R + \frac{1}{j2\pi f C}} U_i = \frac{1}{j2\pi f RC + 1} U_i$$



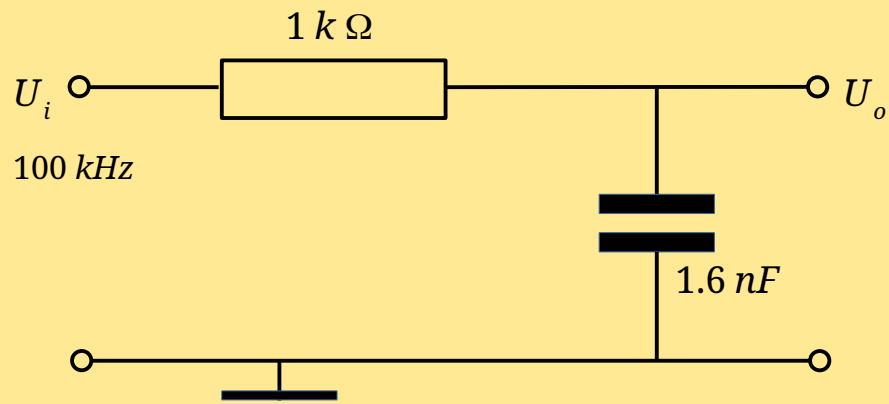
$$U_o = \frac{Z_C}{Z_R + Z_C} U_i = \frac{1}{R + \frac{1}{j2\pi f C}} U_i = \frac{1}{j2\pi f RC + 1} U_i = a U_i$$





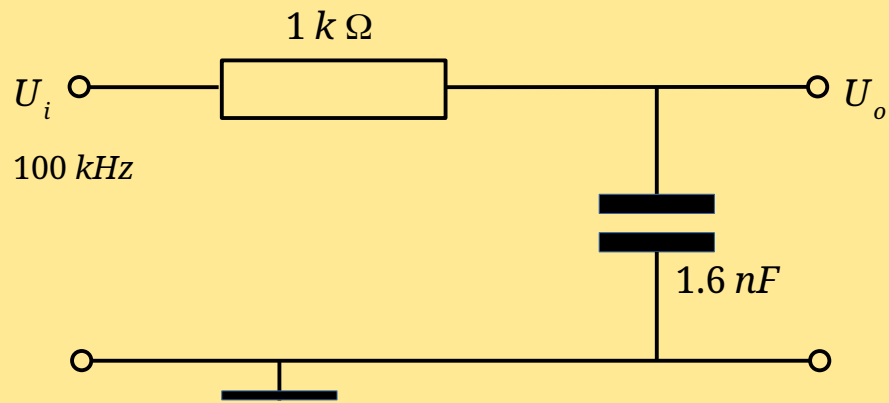
$$U_o = \frac{Z_C}{Z_R + Z_C} U_i = \frac{1}{R + \frac{1}{j 2 \pi f C}} U_i = \frac{1}{j 2 \pi f R C + 1} U_i = a U_i$$

$$a = \frac{1}{j 2 \times 3.14 \times 100000 \times 1000 \times 0.0000000016 + 1}$$



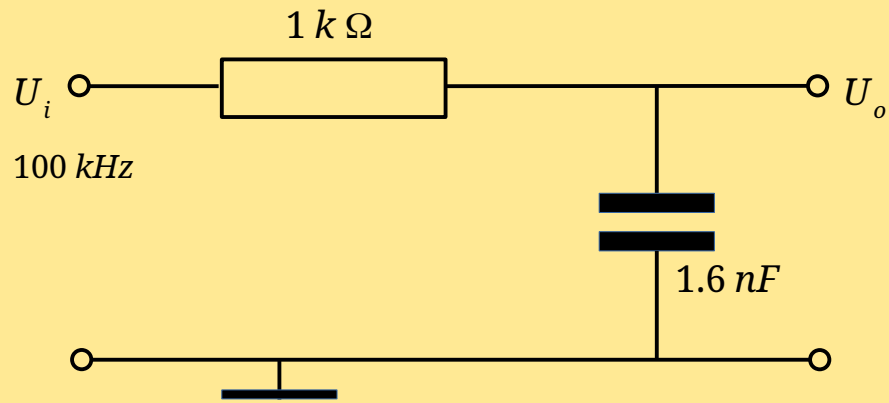
$$U_o = \frac{Z_C}{Z_R + Z_C} U_i = \frac{1}{R + \frac{1}{j 2 \pi f C}} U_i = \frac{1}{j 2 \pi f R C + 1} U_i = a U_i$$

$$a = \frac{1}{j 2 \times 3.14 \times 100000 \times 1000 \times 0.0000000016 + 1} \approx \frac{1}{1 + j}$$



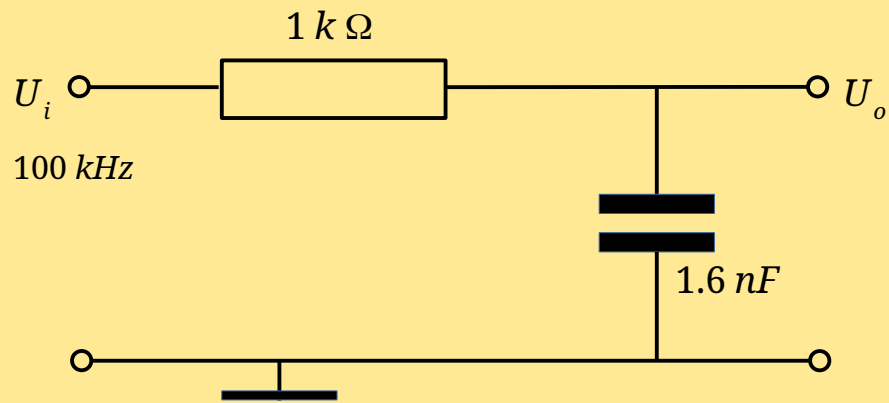
$$U_o = \frac{Z_C}{Z_R + Z_C} U_i = \frac{1}{R + \frac{1}{j 2 \pi f C}} U_i = \frac{1}{j 2 \pi f R C + 1} U_i = a U_i$$

$$a = \frac{1}{j 2 \times 3.14 \times 100000 \times 1000 \times 0.0000000016 + 1} \approx \frac{1}{1 + j} = \frac{(1 - j)}{(1 + j)(1 - j)}$$



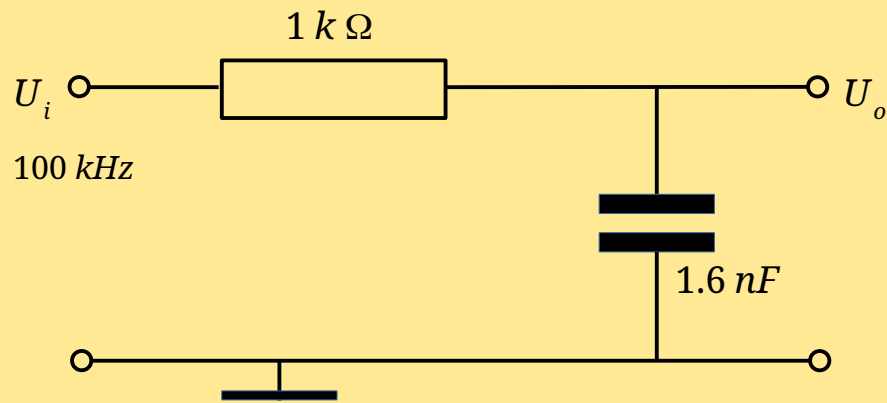
$$U_o = \frac{Z_c}{Z_R + Z_c} U_i = \frac{1}{R + \frac{1}{j 2 \pi f C}} U_i = \frac{1}{j 2 \pi f R C + 1} U_i = a U_i$$

$$a = \frac{1}{j 2 \times 3.14 \times 100000 \times 1000 \times 0.0000000016 + 1} \approx \frac{1}{1 + j} = \frac{(1 - j)}{(1 + j)(1 - j)} = \frac{(1 - j)}{1 + -j + j + 1}$$



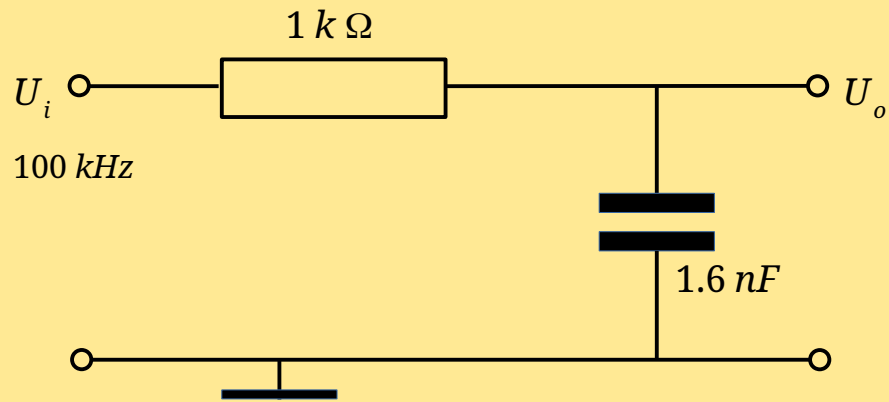
$$U_o = \frac{Z_C}{Z_R + Z_C} U_i = \frac{1}{R + \frac{1}{j2\pi f C}} U_i = \frac{1}{j2\pi f RC + 1} U_i = a U_i$$

$$a = \frac{1}{j2 \times 3.14 \times 100000 \times 1000 \times 0.0000000016 + 1} \approx \frac{1}{1 + j} = \frac{(1 - j)}{(1 + j)(1 - j)} = \frac{(1 - j)}{1 + -j + j + 1} = \frac{(1 - j)}{2}$$



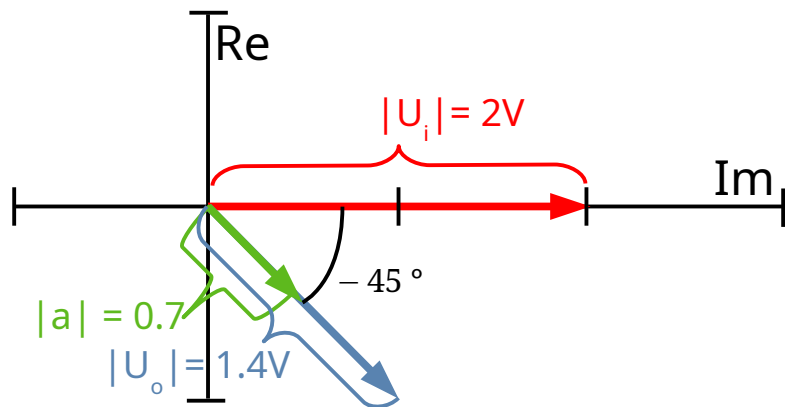
$$U_o = \frac{Z_C}{Z_R + Z_C} U_i = \frac{1}{R + \frac{1}{j2\pi f C}} U_i = \frac{1}{j2\pi f RC + 1} U_i = a U_i$$

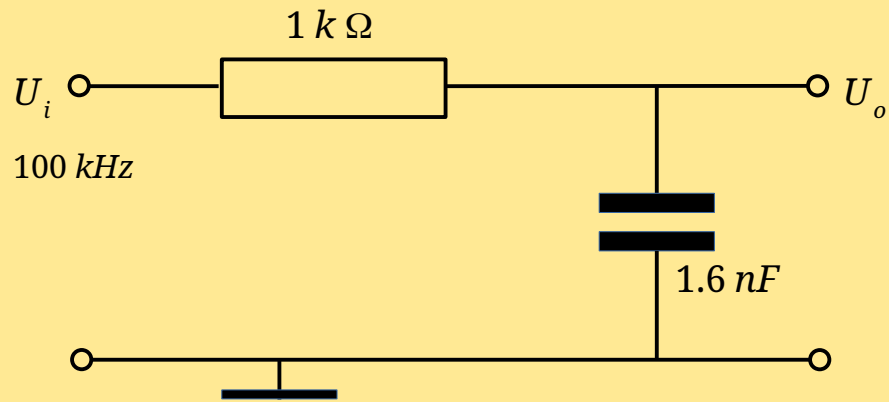
$$a = \frac{1}{j2 \times 3.14 \times 100000 \times 1000 \times 0.0000000016 + 1} \approx \frac{1}{1 + j} = \frac{(1 - j)}{(1 + j)(1 - j)} = \frac{(1 - j)}{1 + j} = \frac{(1 - j)}{2} = 0.5 - 0.5j$$



$$U_o = \frac{Z_C}{Z_R + Z_C} U_i = \frac{1}{R + \frac{1}{j2\pi f C}} U_i = \frac{1}{j2\pi f RC + 1} U_i = a U_i$$

$$a = \frac{1}{j2 \times 3.14 \times 100000 \times 1000 \times 0.0000000016 + 1} \approx \frac{1}{1 + j} = \frac{(1 - j)}{(1 + j)(1 - j)} = \frac{(1 - j)}{1 - j + j + 1} = \frac{(1 - j)}{2} = 0.5 - 0.5j$$





$$U_o = \frac{Z_C}{Z_R + Z_C} U_i = \frac{1}{R + \frac{1}{j2\pi f C}} U_i = \frac{1}{j2\pi f RC + 1} U_i = a U_i$$

$$a = \frac{1}{j2 \times 3.14 \times 100000 \times 1000 \times 0.0000000016 + 1} \approx \frac{1}{1 + j} = \frac{(1 - j)}{(1 + j)(1 - j)} = \frac{(1 - j)}{1 - j + j + 1} = \frac{(1 - j)}{2} = 0.5 - 0.5j$$

