Complexe getallen

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Simpel en elegant...

Vector optelling:

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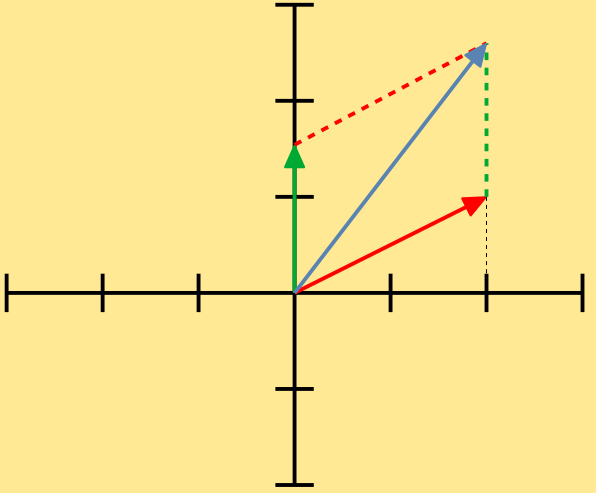

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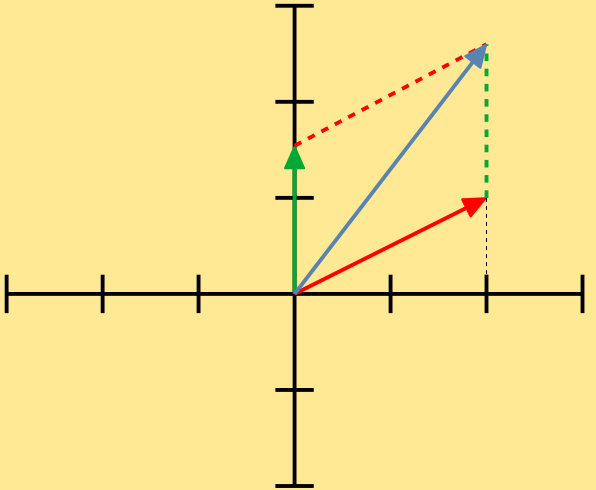

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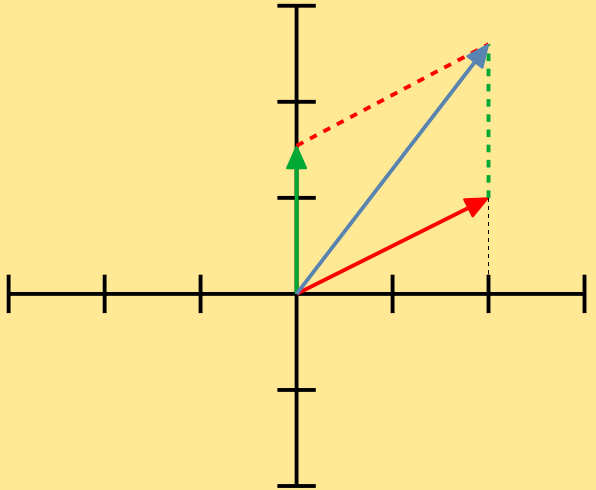

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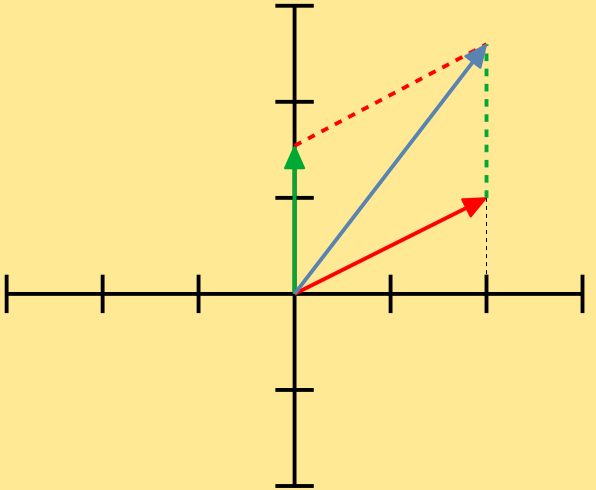

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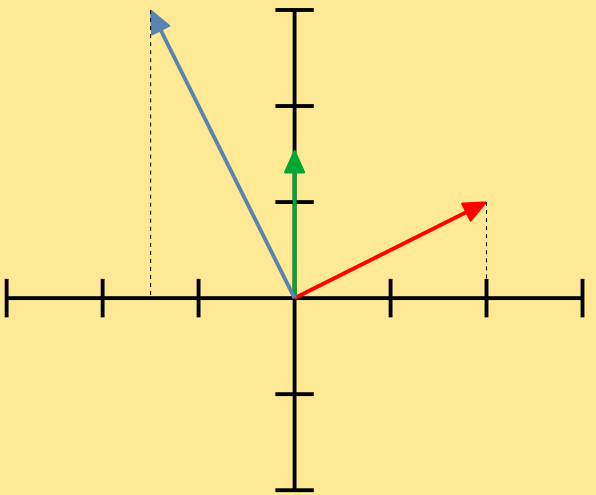

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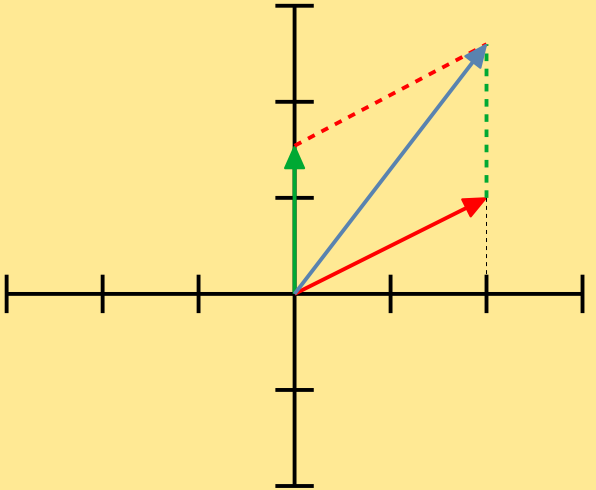

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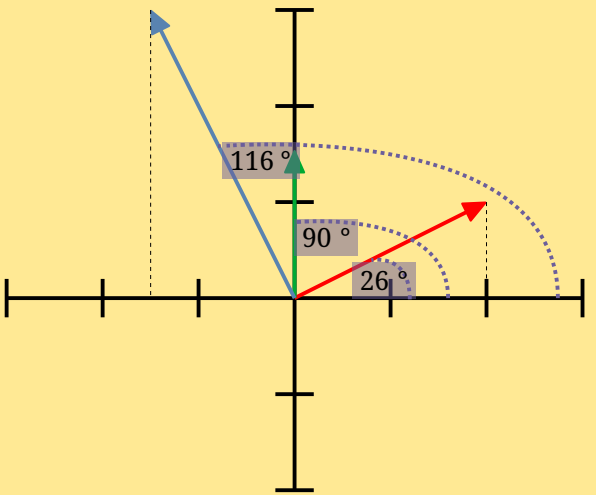

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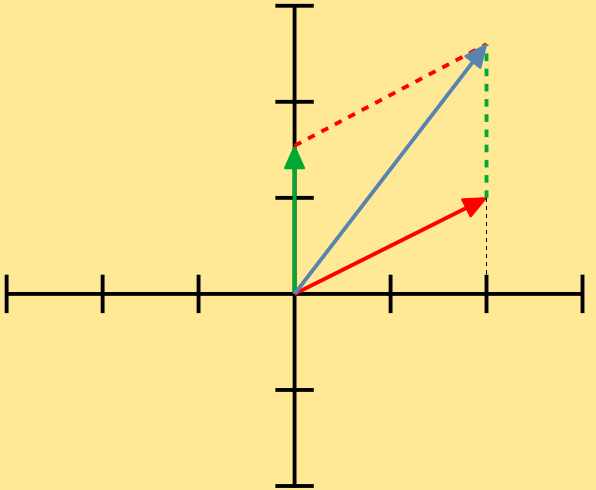

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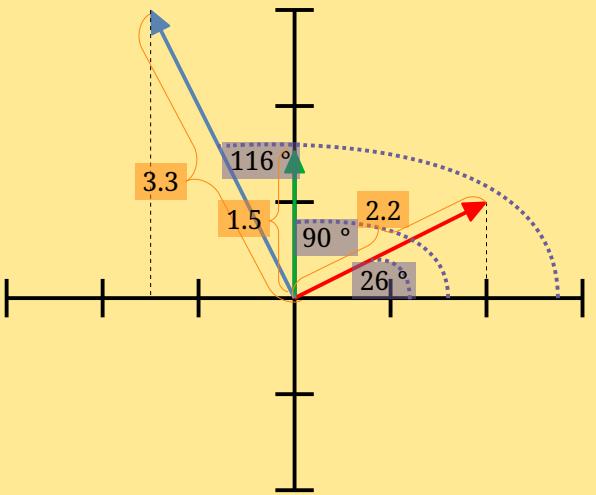

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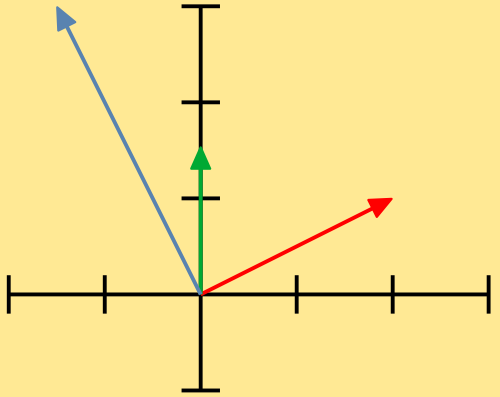

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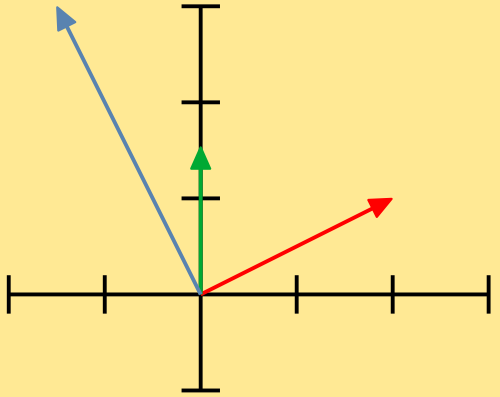

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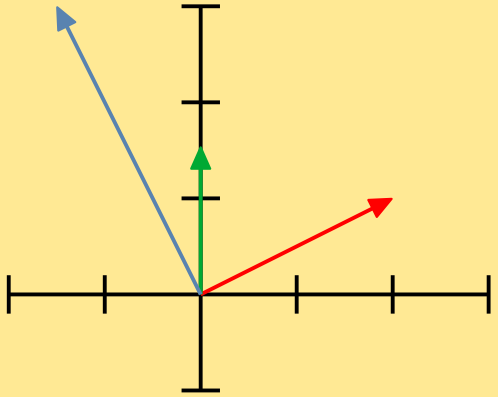

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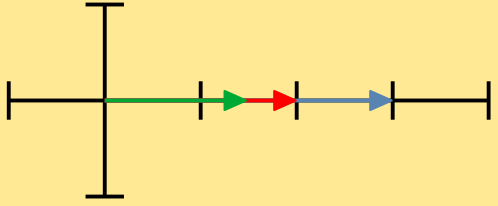

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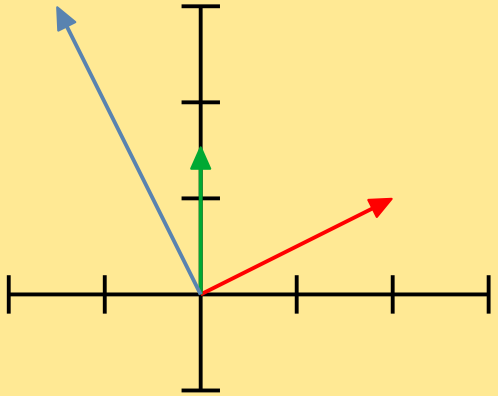

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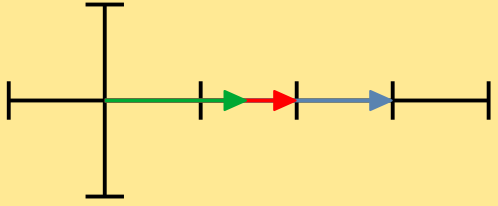

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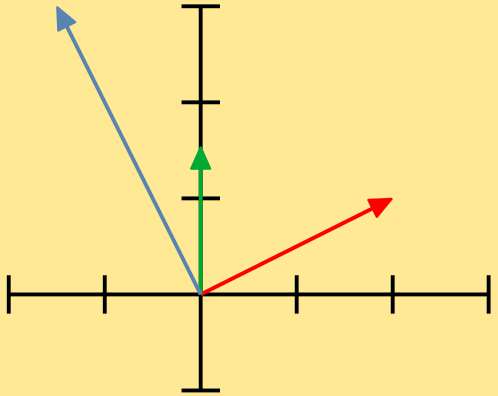

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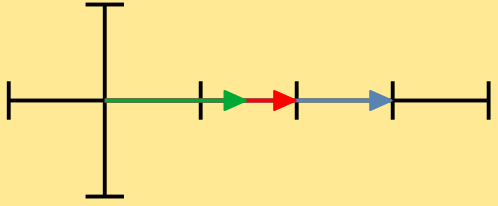

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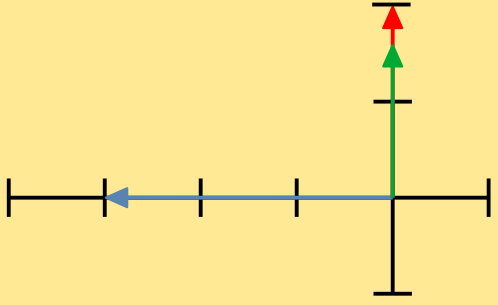

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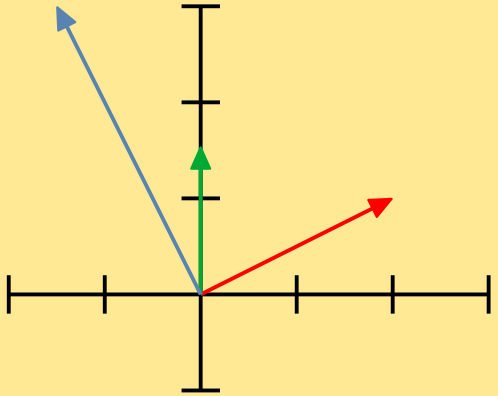

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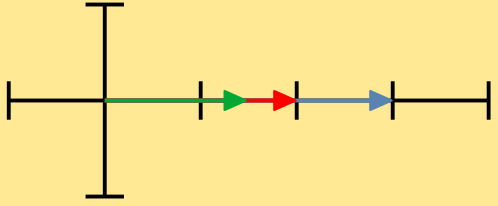

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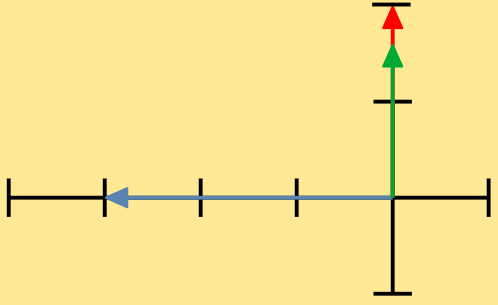

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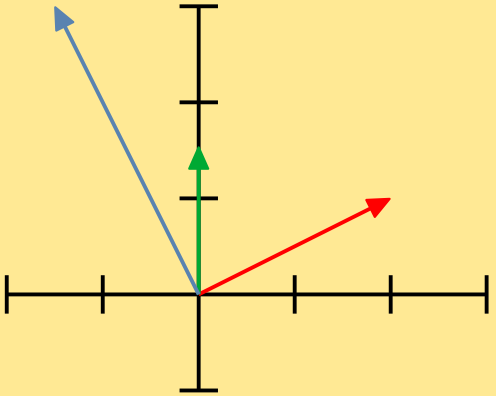

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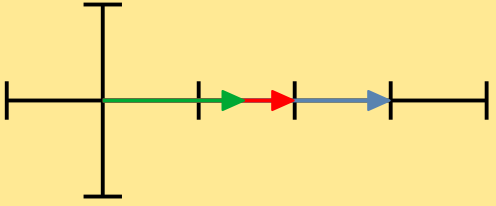

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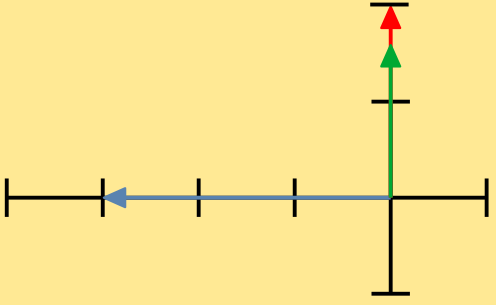

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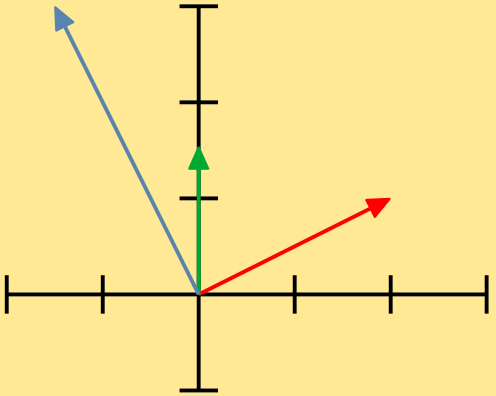

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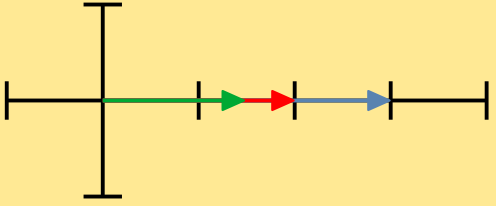

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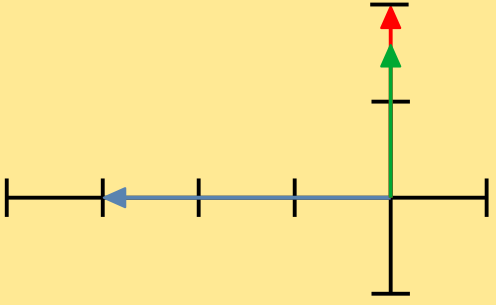

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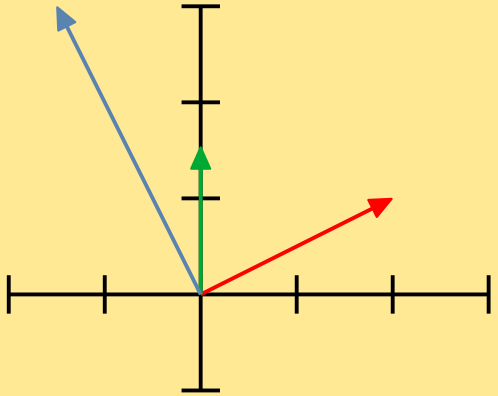

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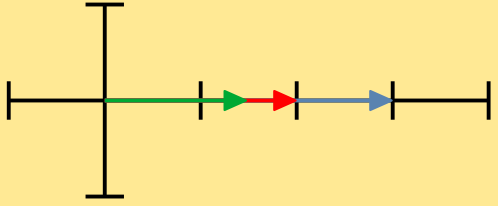

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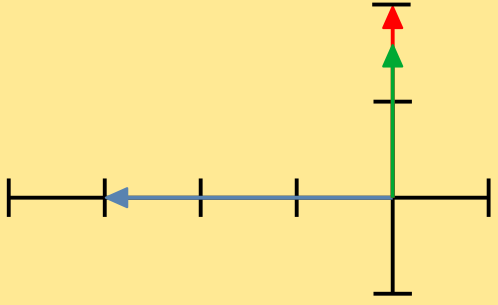

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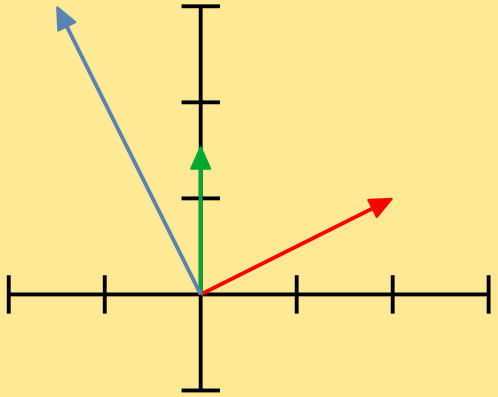

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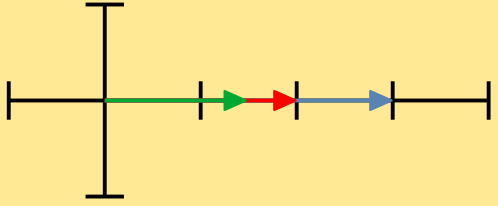
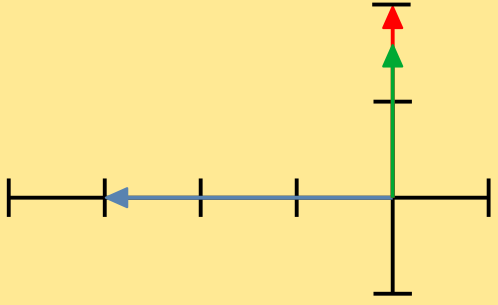
$$-1.5 + 3\,j$$

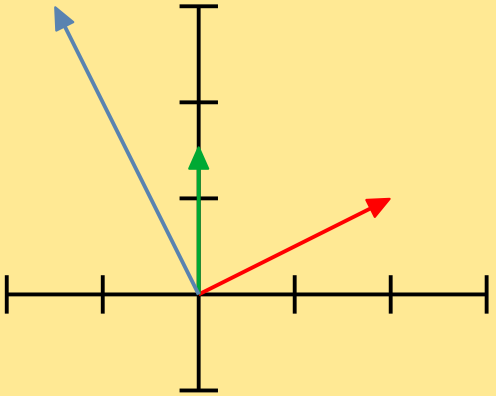
$$\begin{pmatrix}2\\0\end{pmatrix} \$ \begin{pmatrix}1.5\\0\end{pmatrix} = \begin{pmatrix}2\times 1.5 - 0\times 0\\2\times 0 + 0\times 1.5\end{pmatrix} = \begin{pmatrix}3\\0\end{pmatrix}$$



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



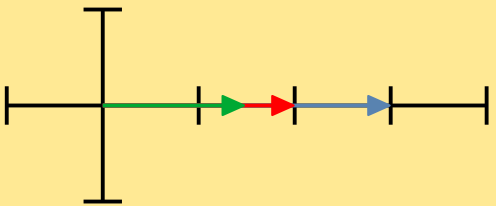
$$\begin{pmatrix}2\\1\end{pmatrix} \$ \begin{pmatrix}0\\1.5\end{pmatrix} = \begin{pmatrix}2\times 0 - 1\times 1.5\\2\times 1.5 + 1\times 0\end{pmatrix} = \begin{pmatrix}-1.5\\3\end{pmatrix}$$



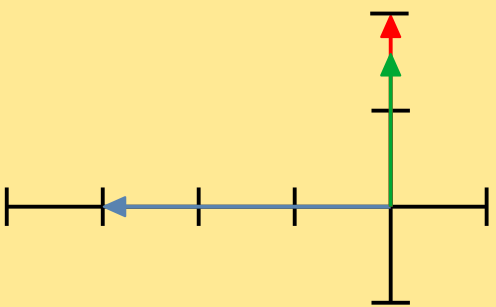
$$(2+1\,j)\times(0+1.5\,j) =$$
$$2\times 0 + 2\times 1.5\,j + 1\,j\times 0 + 1\,j\times 1.5\,j =$$
$$0 + 3\,j + 0\,j + 1.5\,j^2 =$$
$$3\,j + 1.5\,j^2 =$$
$$-1.5 + 3\,j$$

$$\boldsymbol{j^2 \stackrel{\text{def}}{=} -1 \Leftrightarrow j = \sqrt{-1}}$$

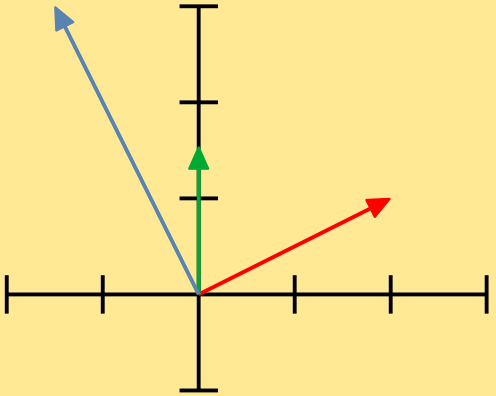
$$\begin{pmatrix}2\\0\end{pmatrix} \$ \begin{pmatrix}1.5\\0\end{pmatrix} = \begin{pmatrix}2\times 1.5 - 0\times 0\\2\times 0 + 0\times 1.5\end{pmatrix} = \begin{pmatrix}3\\0\end{pmatrix}$$



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



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



$$(2+1\,j)\times(0+1.5\,j) =$$
$$2\times 0 + 2\times 1.5\,j + 1\,j\times 0 + 1\,j\times 1.5\,j =$$
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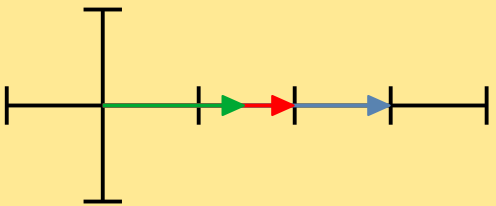
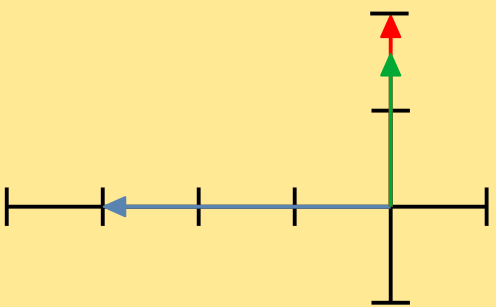
$$\begin{pmatrix}2\\0\end{pmatrix} \$ \begin{pmatrix}1.5\\0\end{pmatrix} = \begin{pmatrix}2\times 1.5 - 0\times 0\\2\times 0 + 0\times 1.5\end{pmatrix} = \begin{pmatrix}3\\0\end{pmatrix}$$

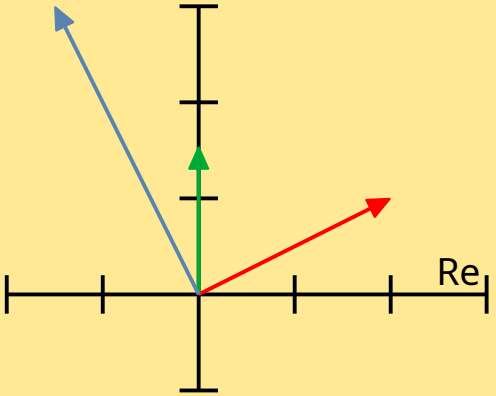


$$2\times 1.5 = 3$$

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



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



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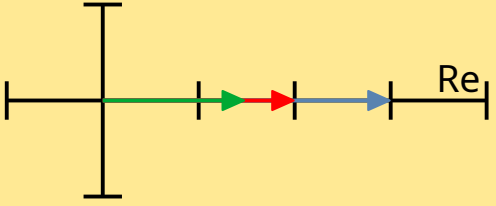

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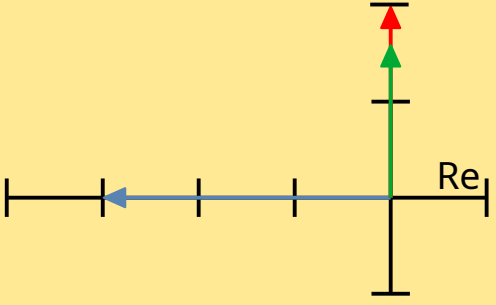
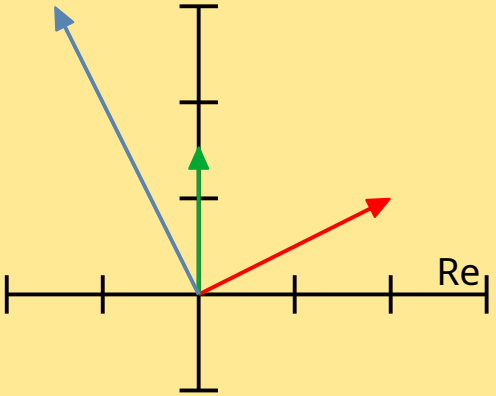
$$\begin{pmatrix}0\\2\end{pmatrix} \$ \begin{pmatrix}0\\1.5\end{pmatrix} = \begin{pmatrix}0\times 0 - 2\times 1.5\\0\times 1.5 + 2\times 0\end{pmatrix} = \begin{pmatrix}-3\\0\end{pmatrix}$$



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



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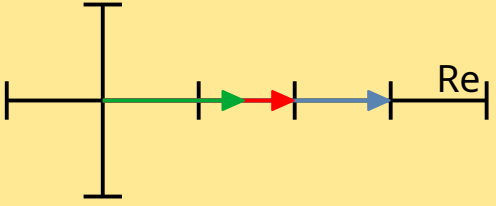

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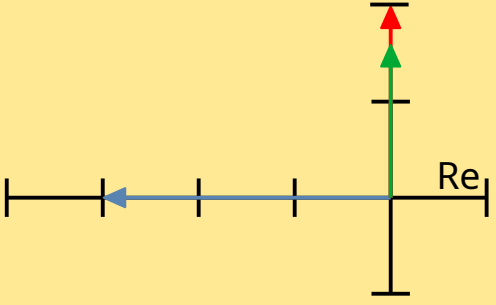
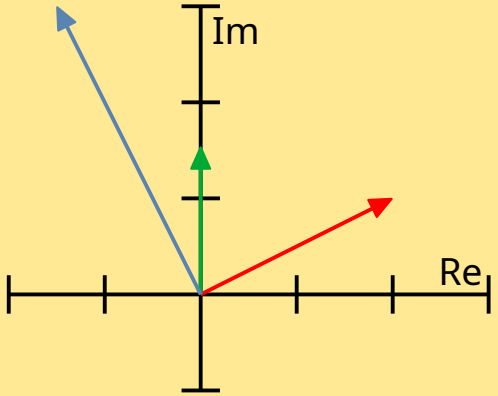


$$2\,j\times 1.5\,j = 3\,j^2 = -3$$

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



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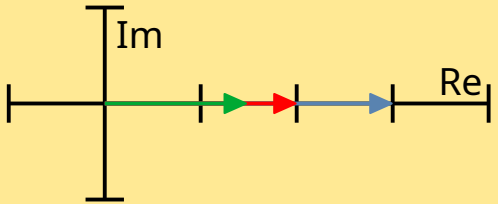

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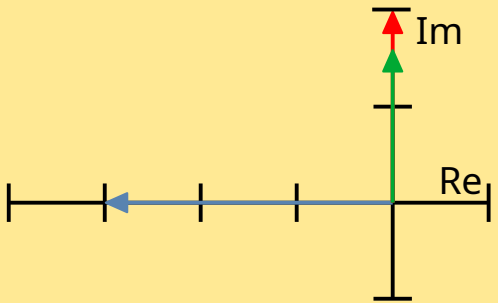
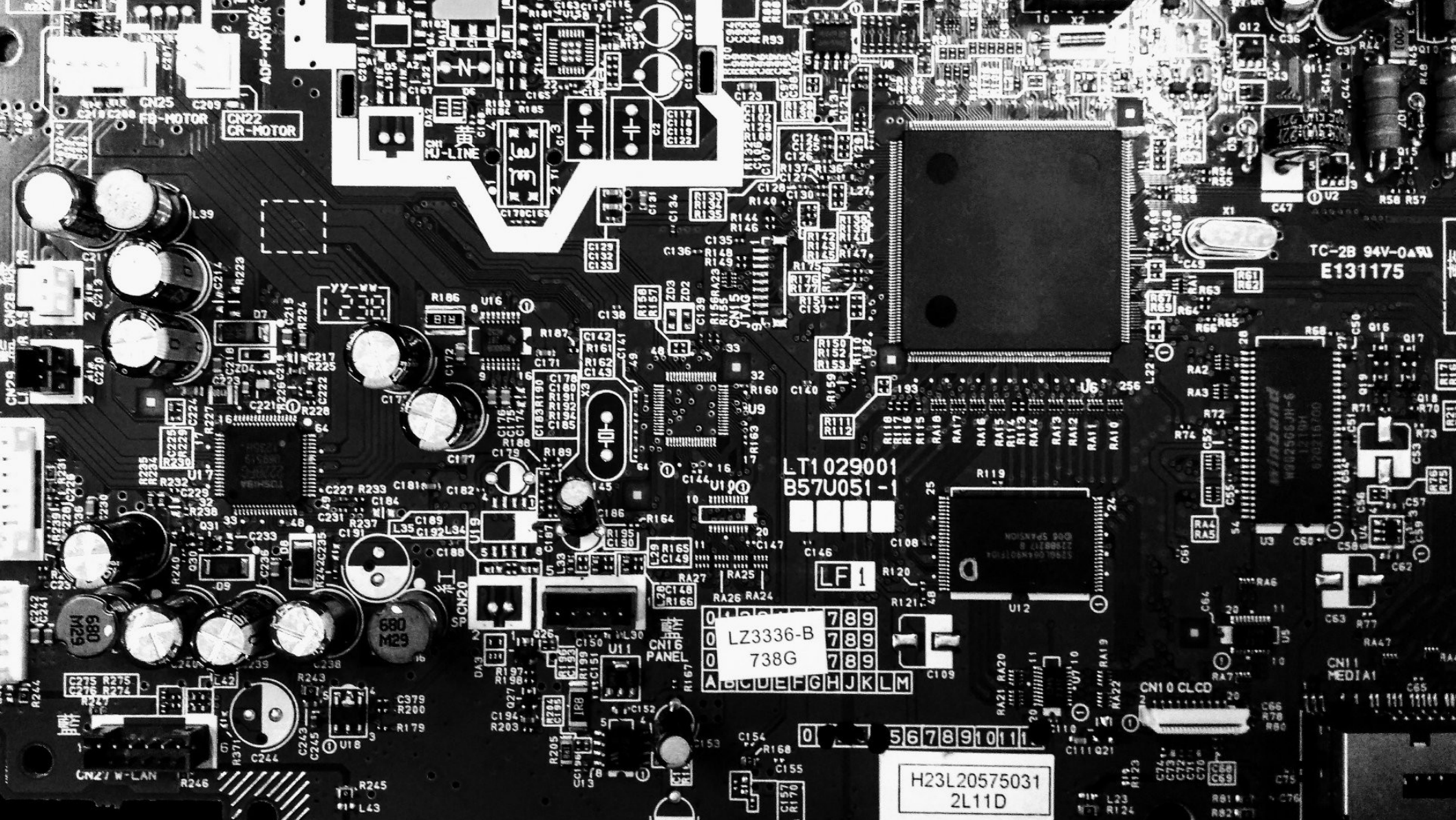


$$2\,j\times 1.5\,j = 3\,j^2 = -3$$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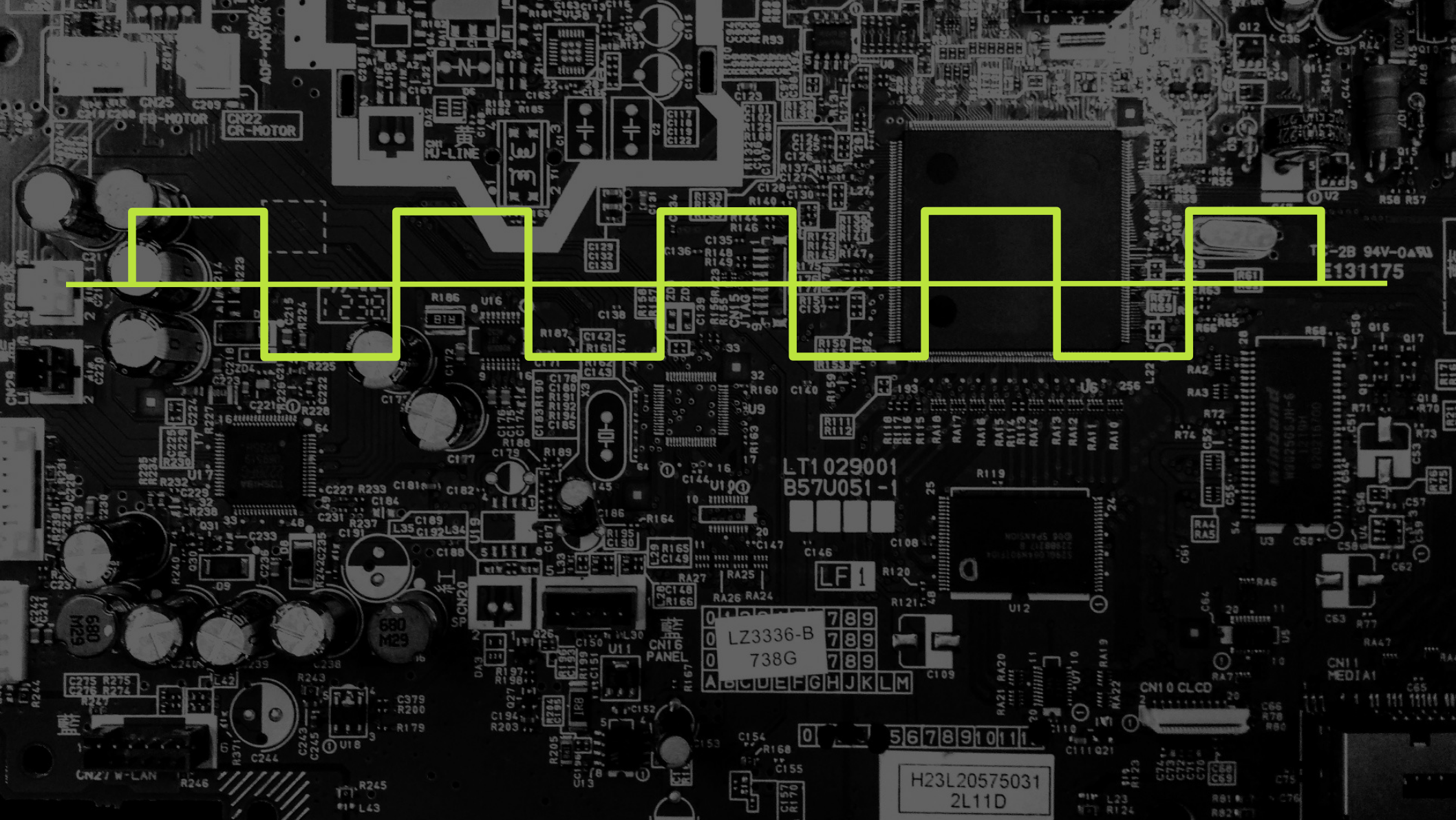
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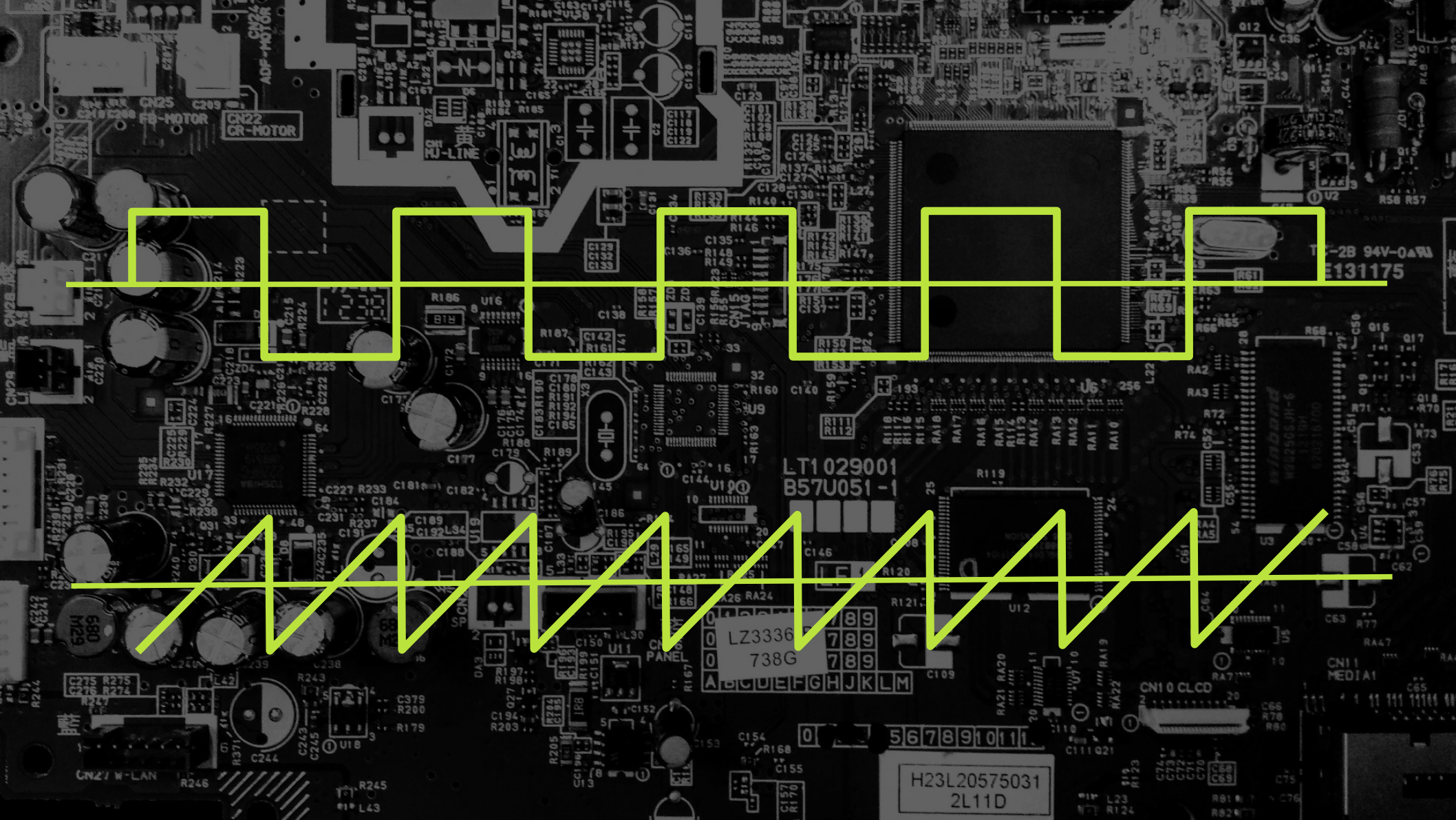
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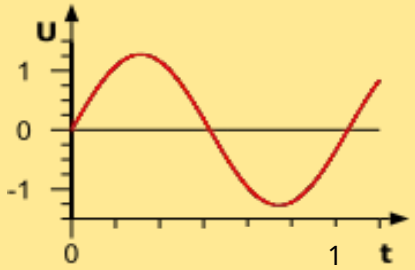
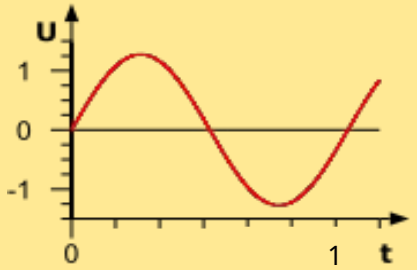
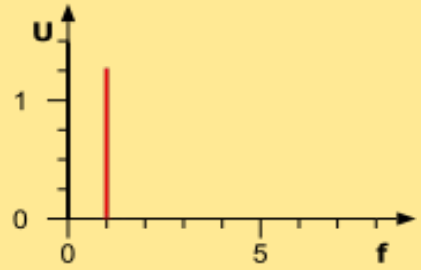
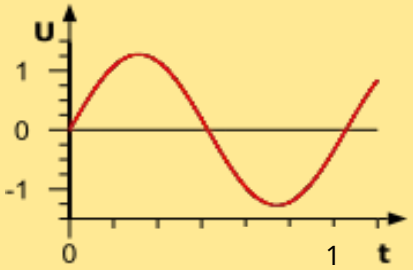
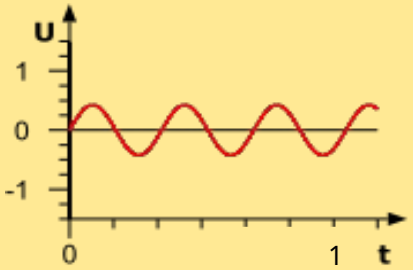
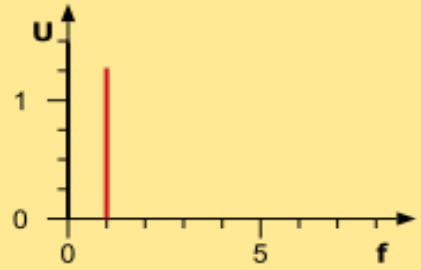


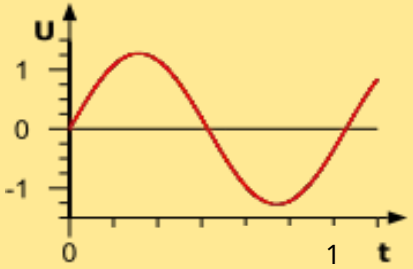


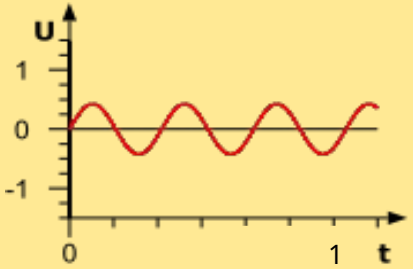


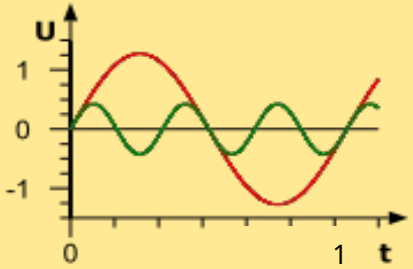


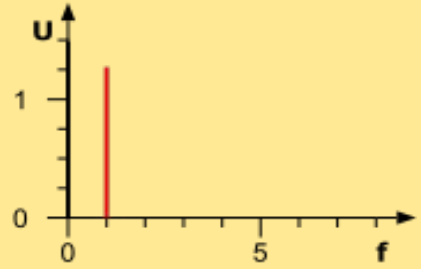


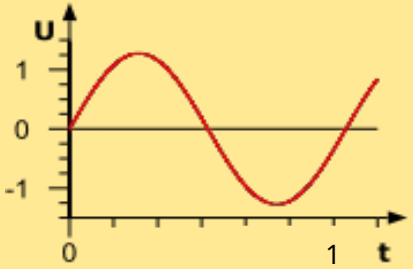


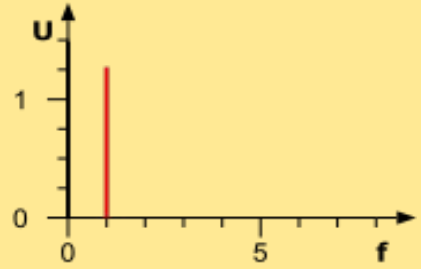


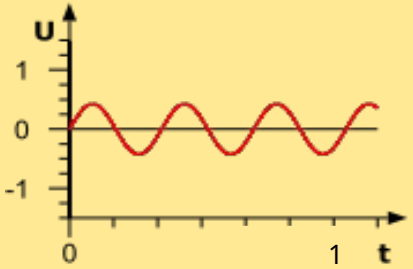


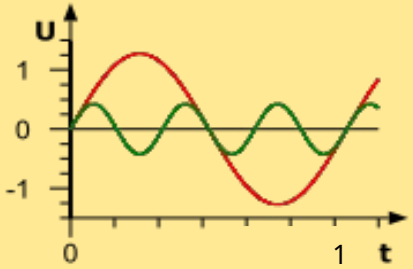


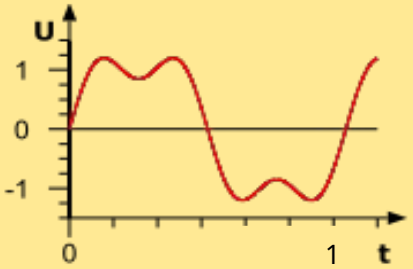


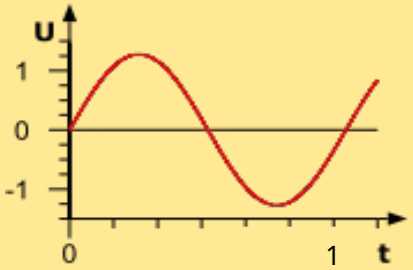


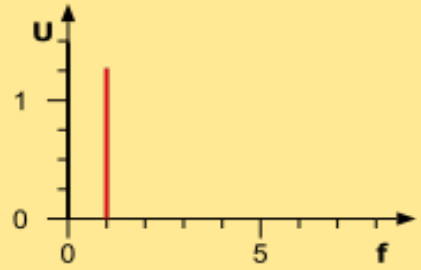


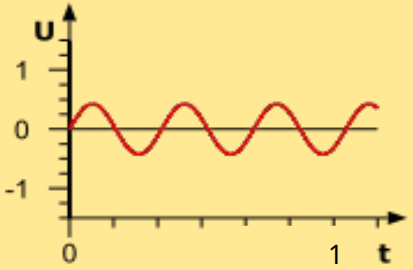


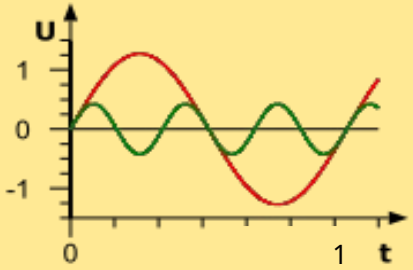


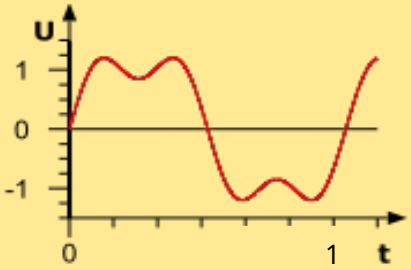


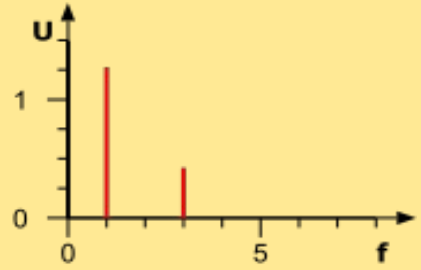


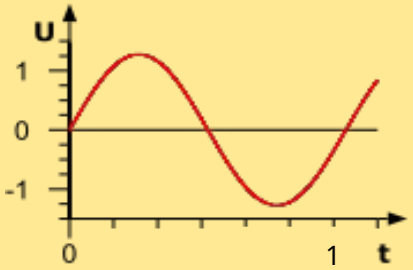


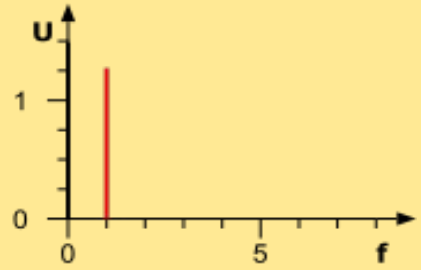


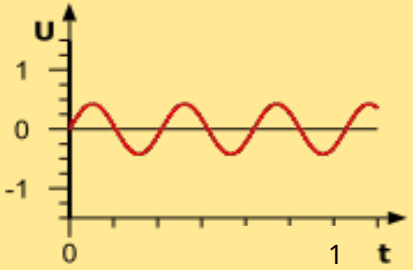


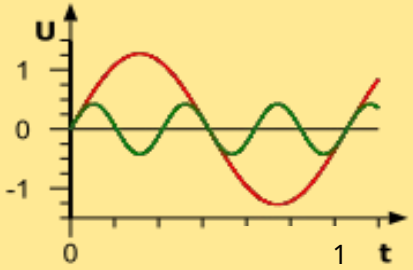


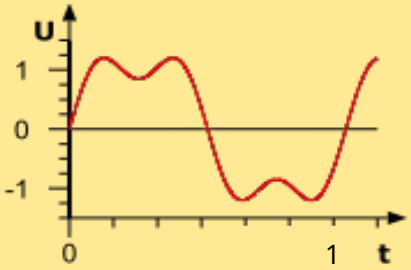


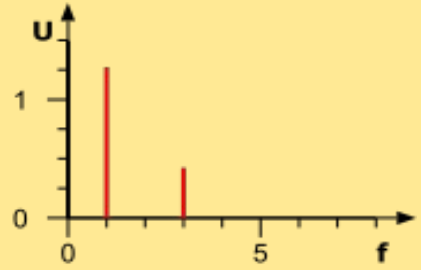


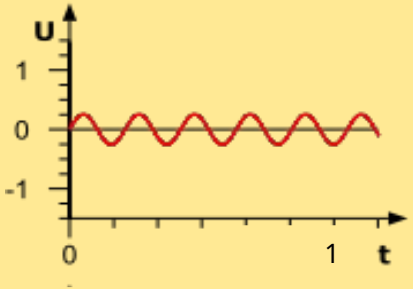


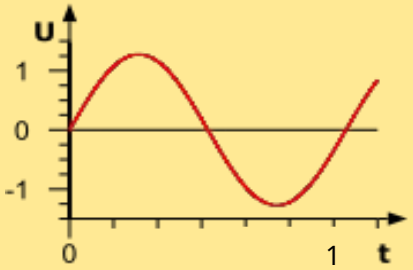


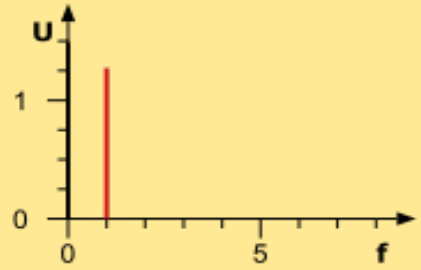


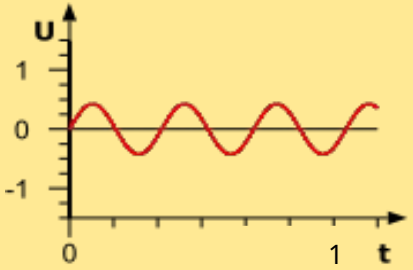


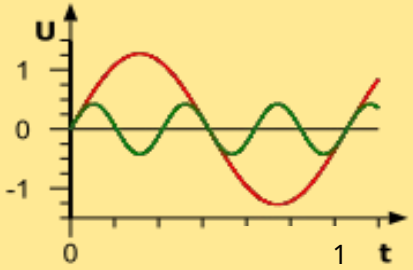


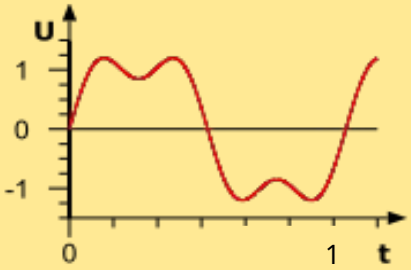


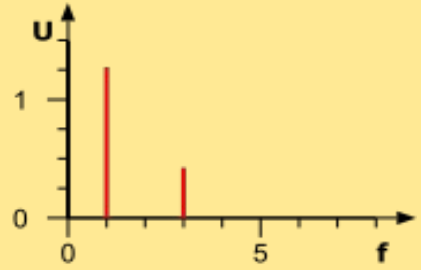


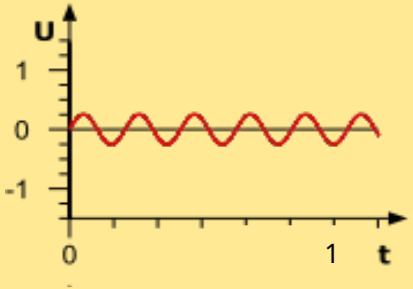


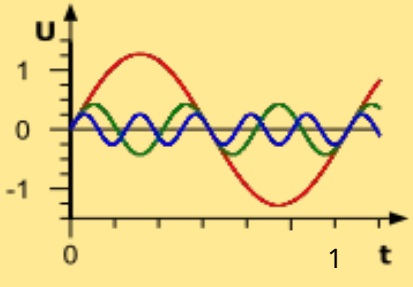


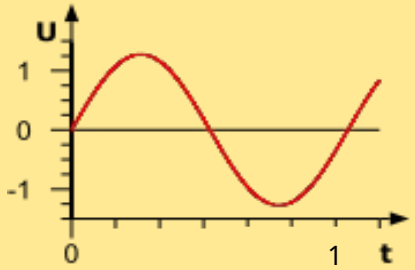


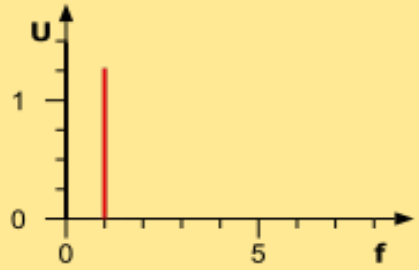


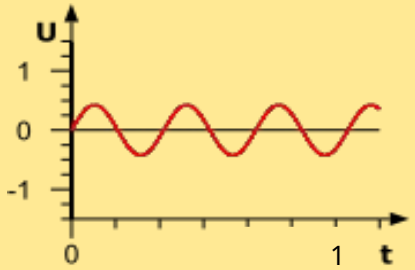


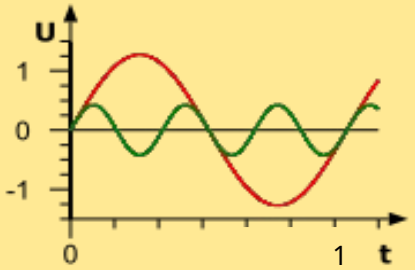


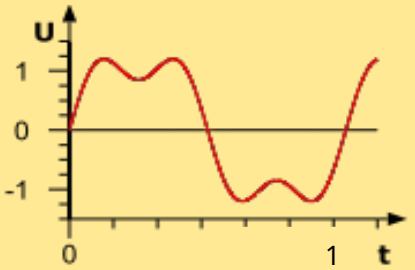


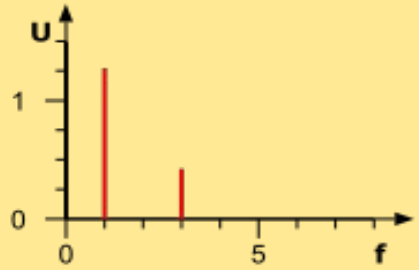


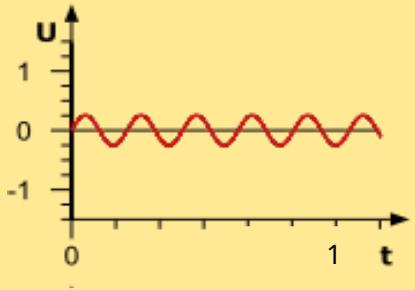


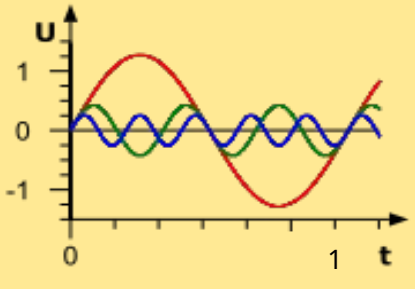


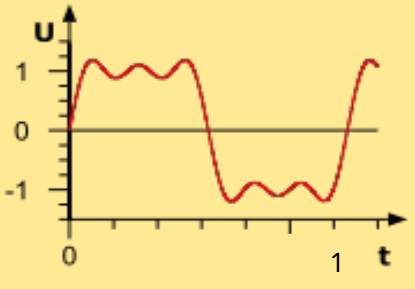


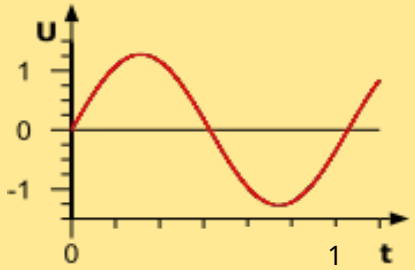


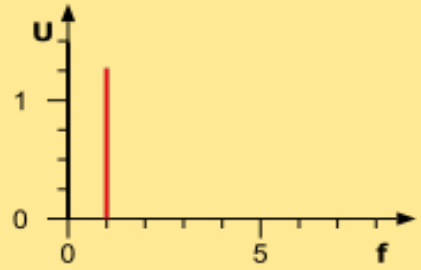


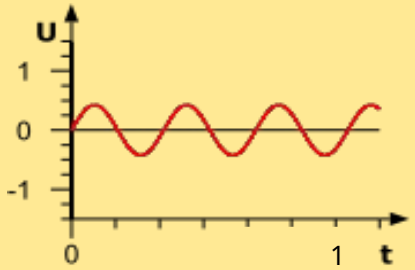


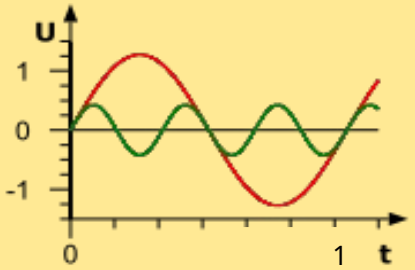


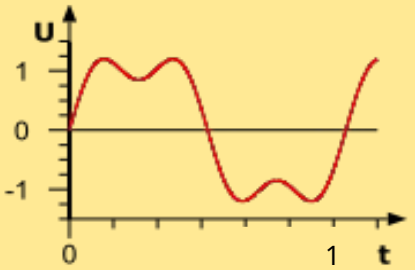


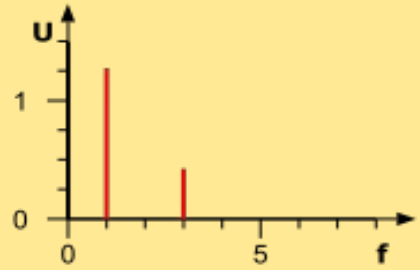


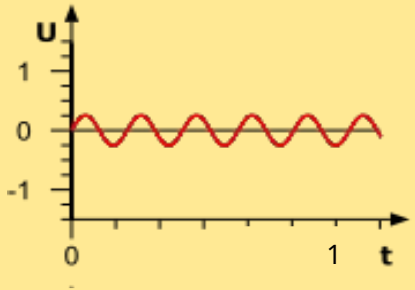


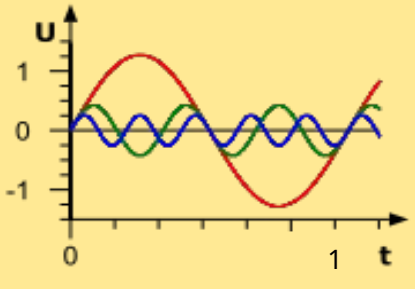


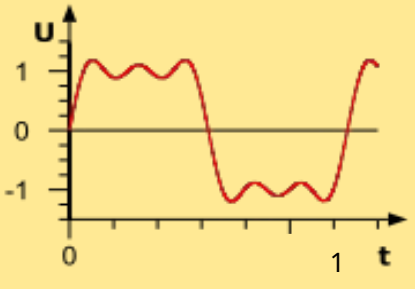


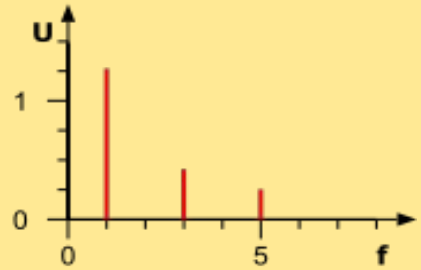


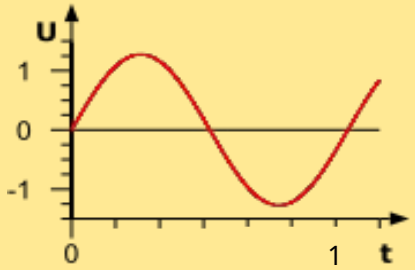


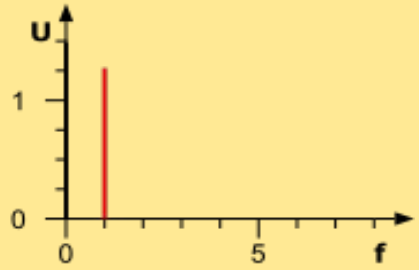


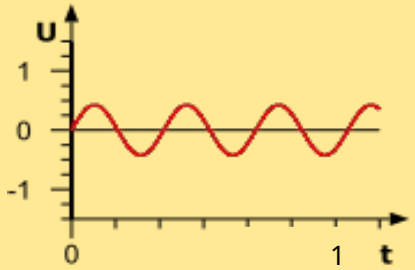


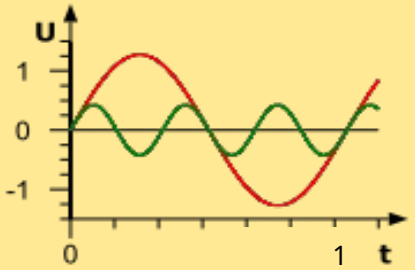


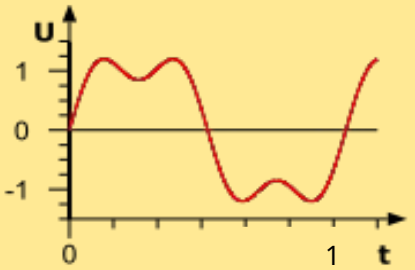


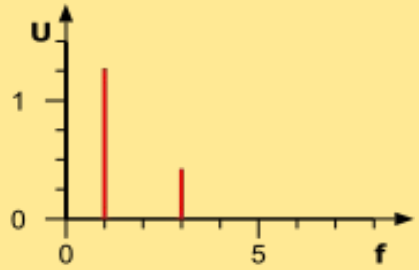


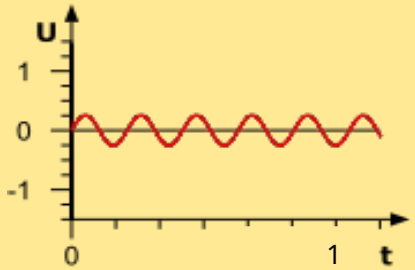


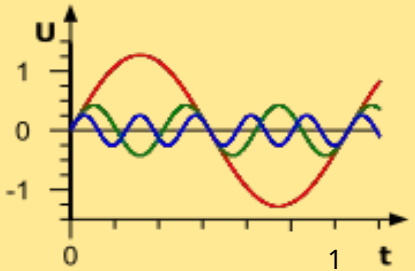


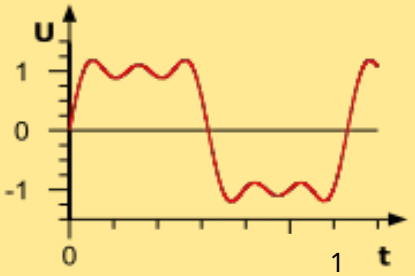


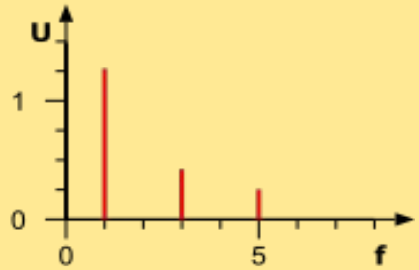


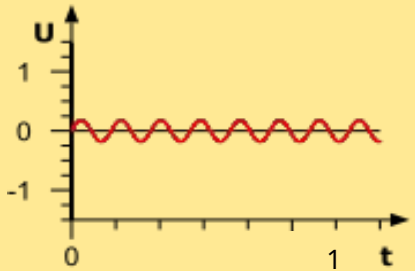


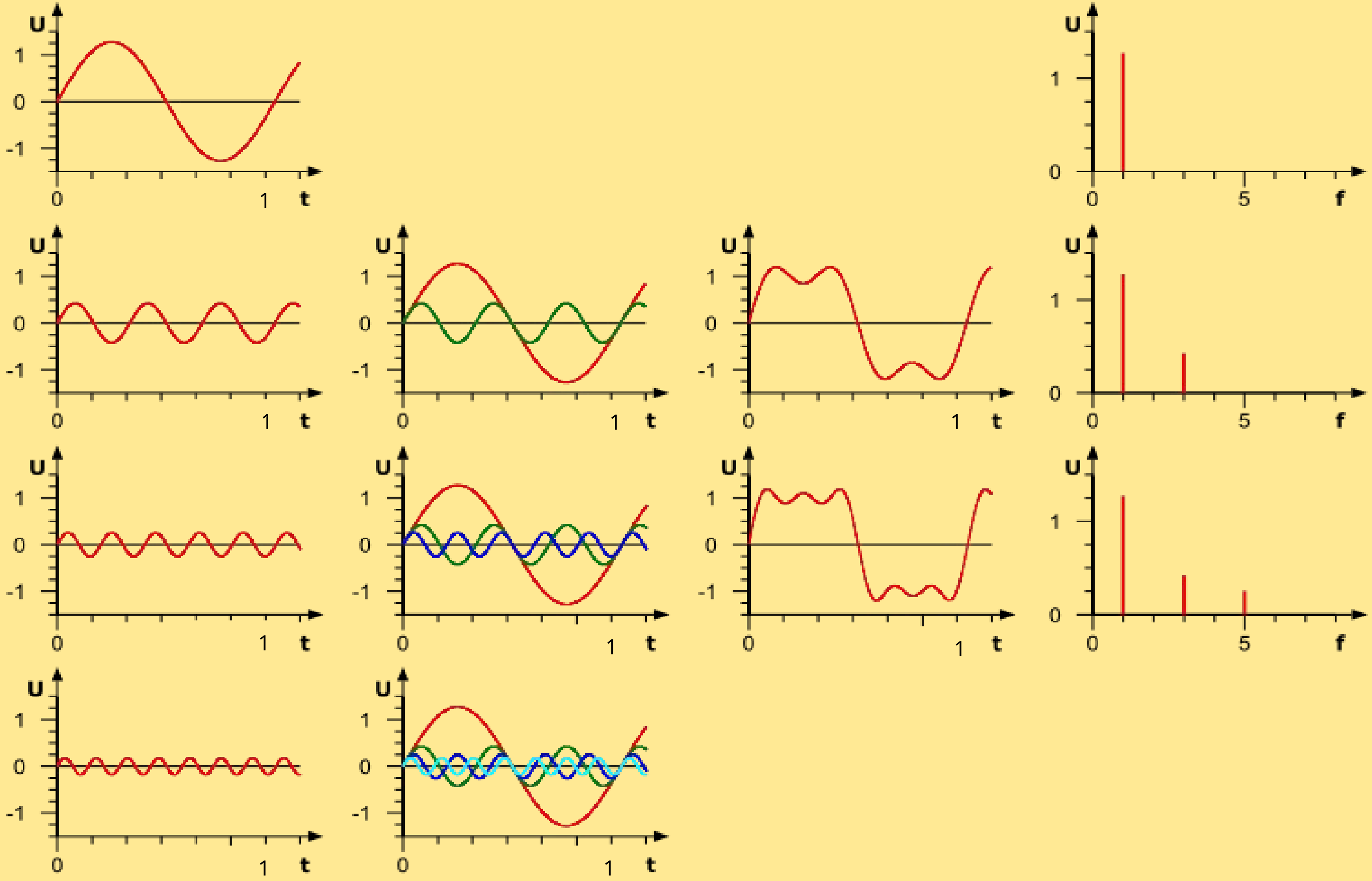


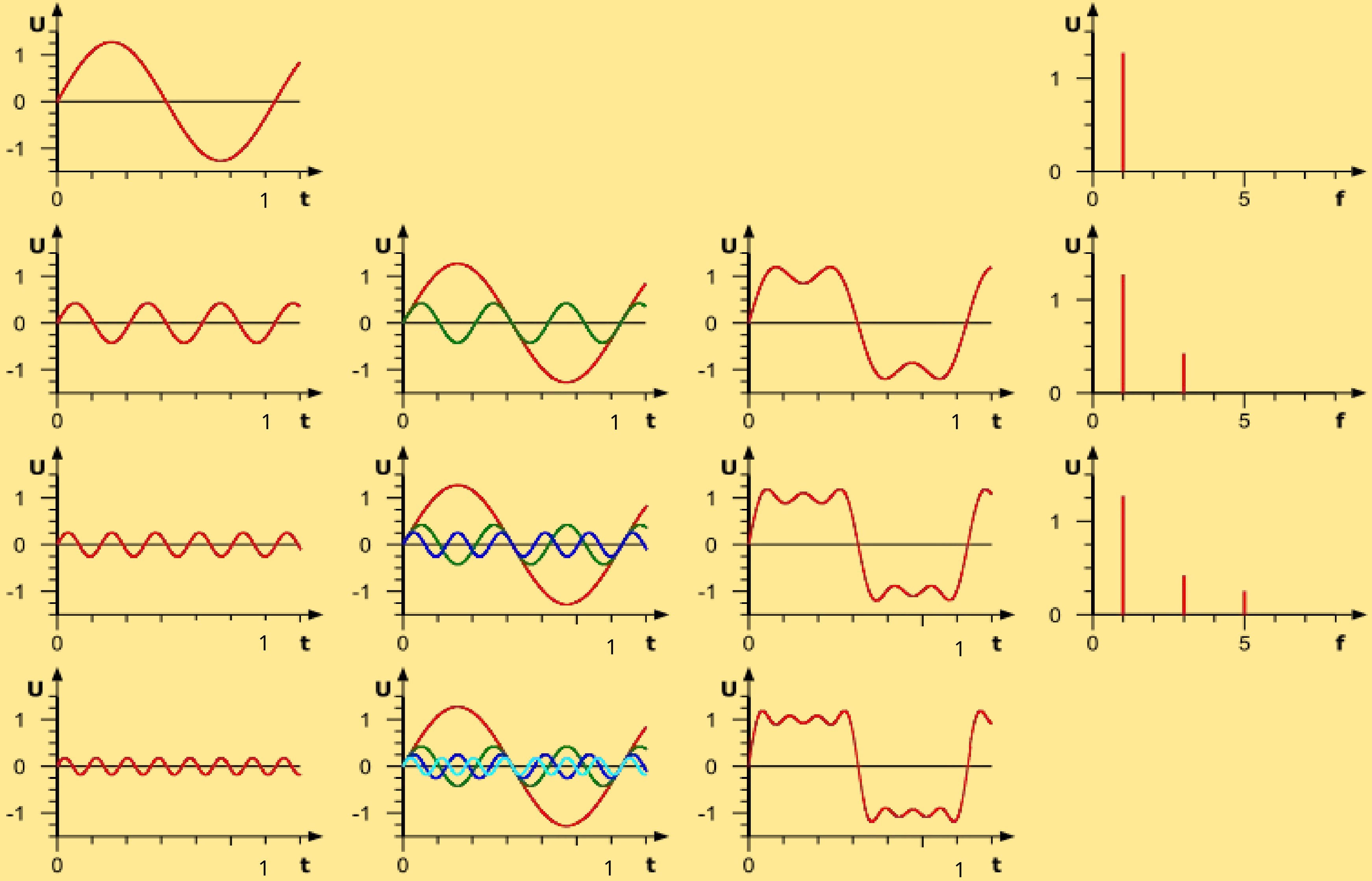


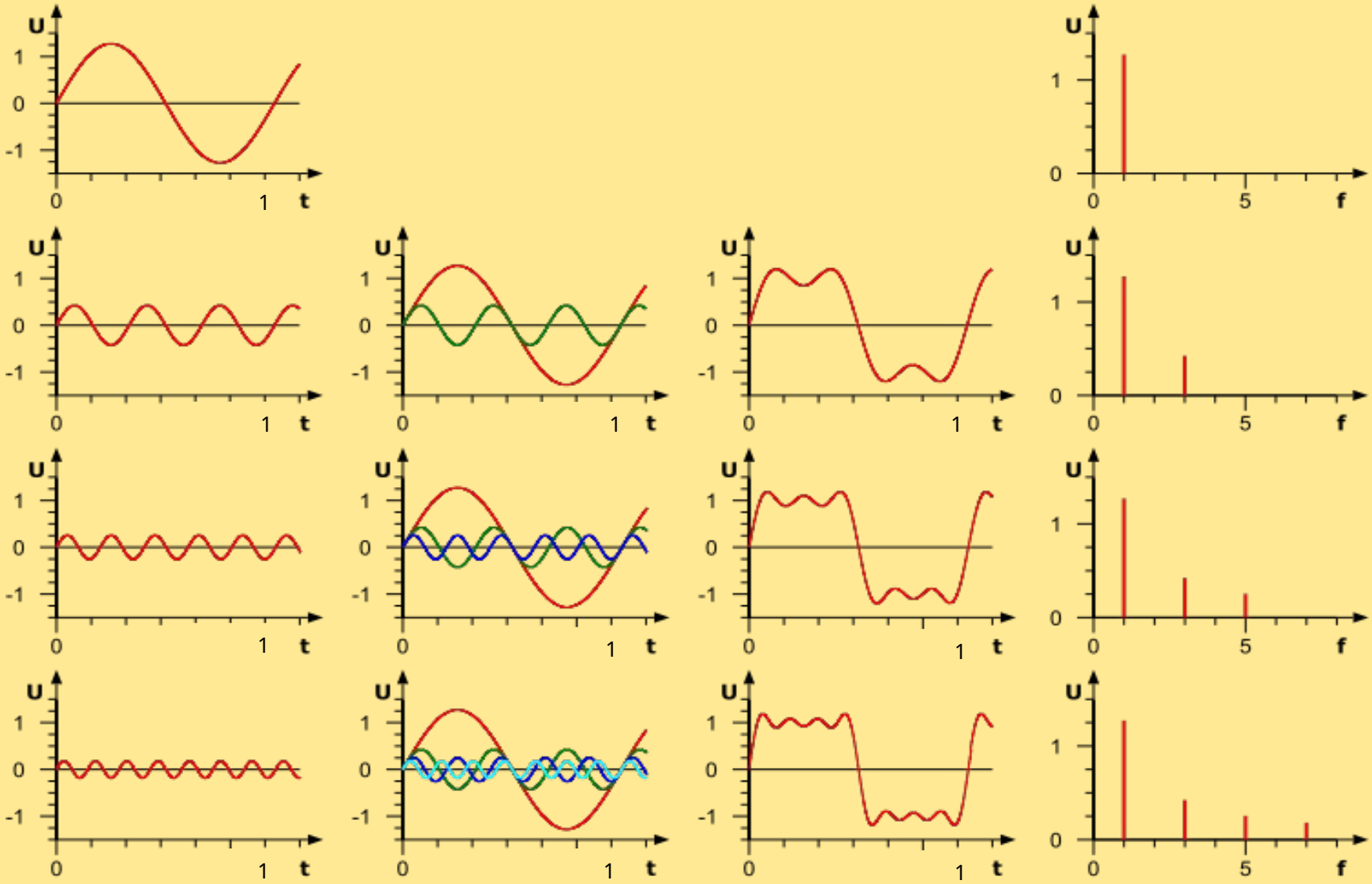


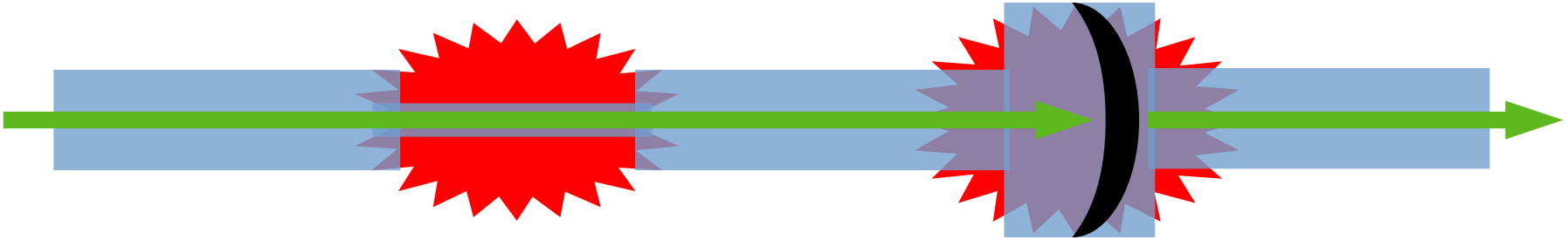


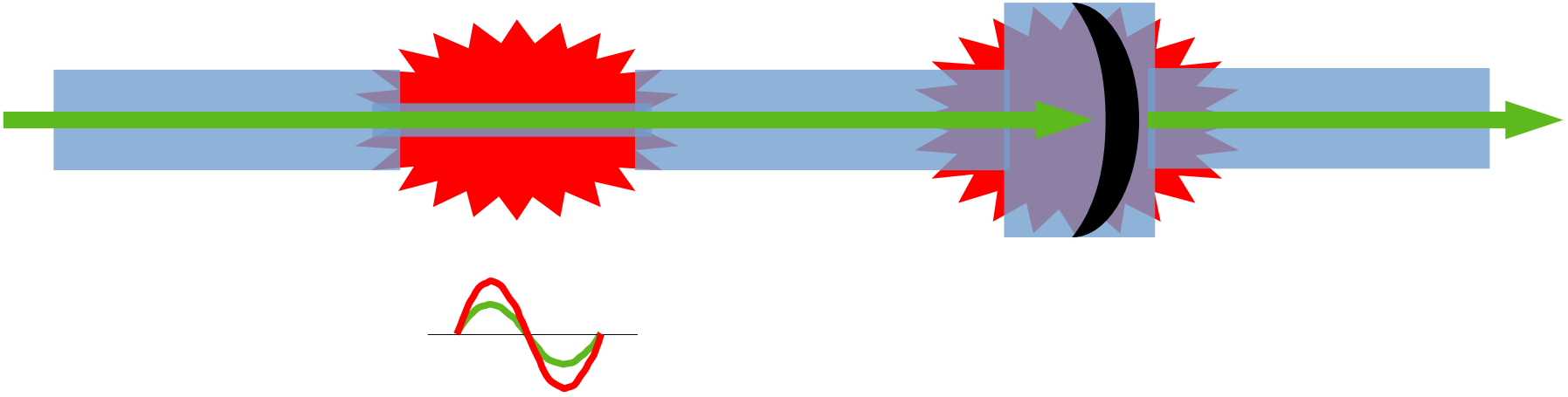


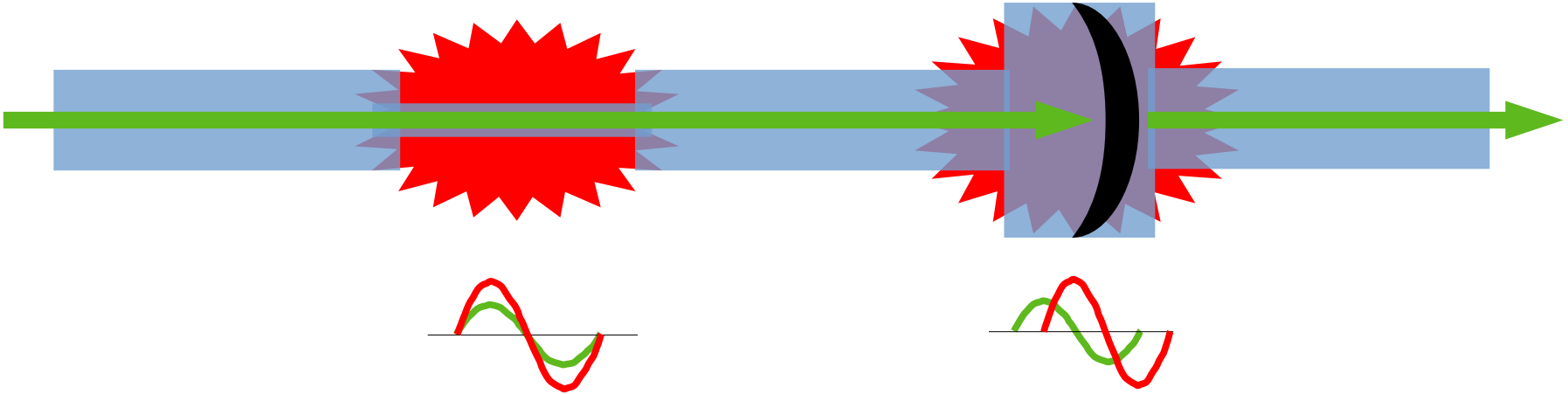


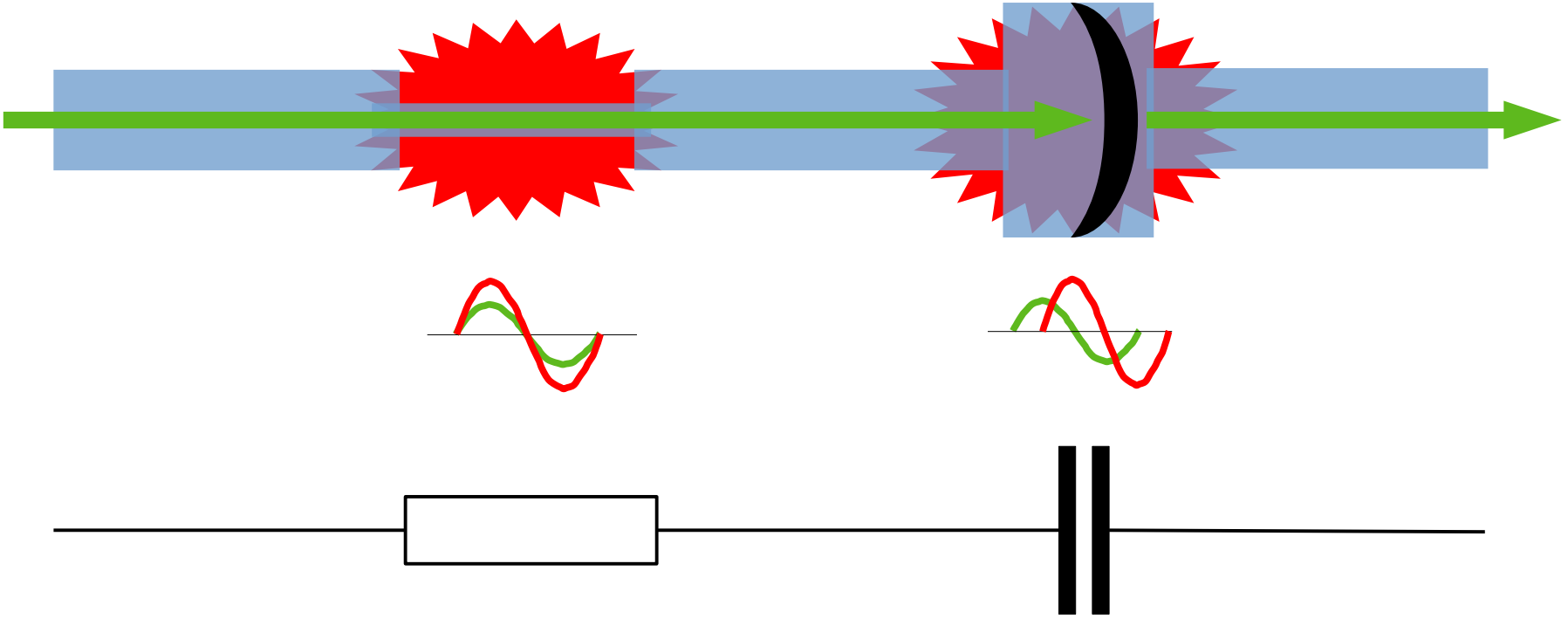


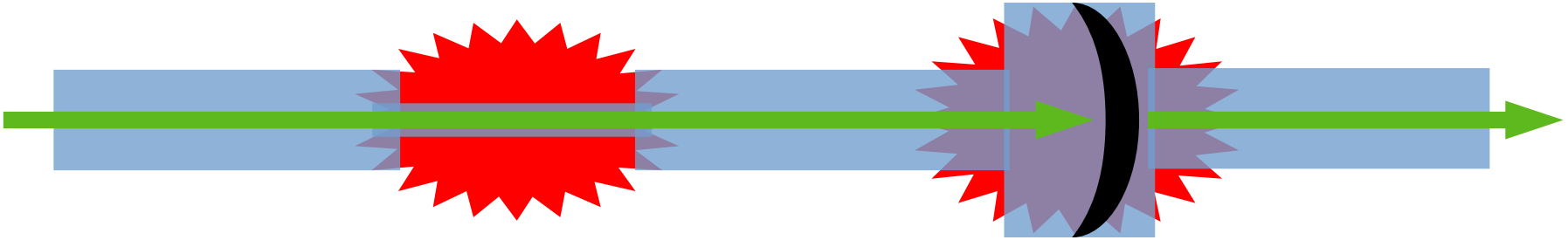


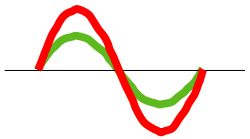


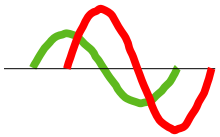


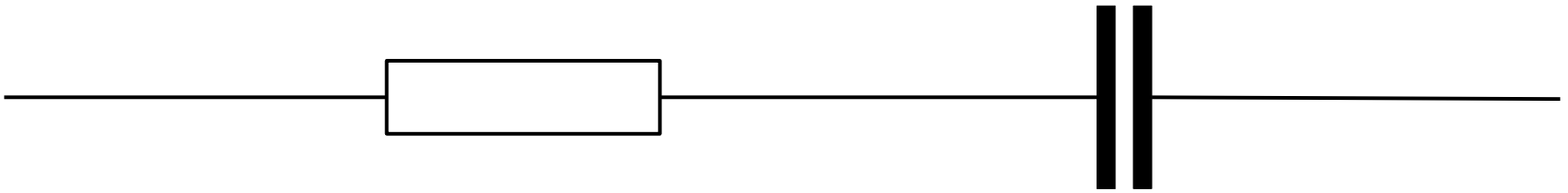




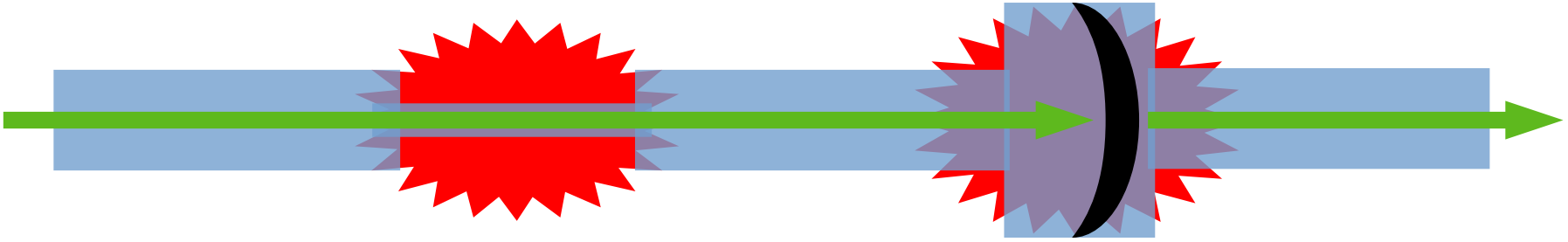


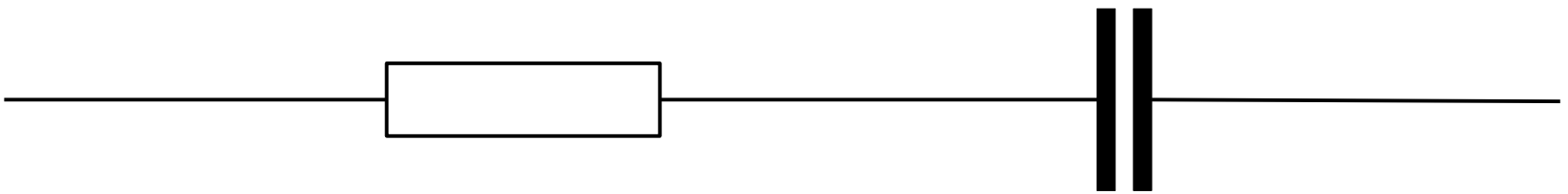






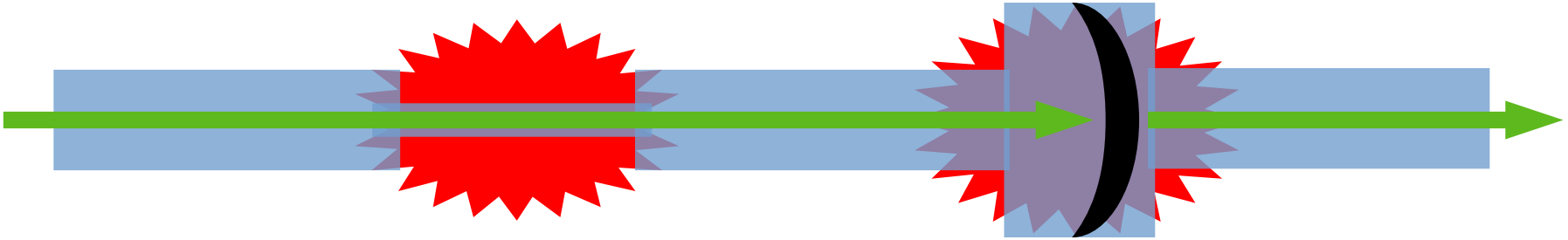
$$U_R = RI$$





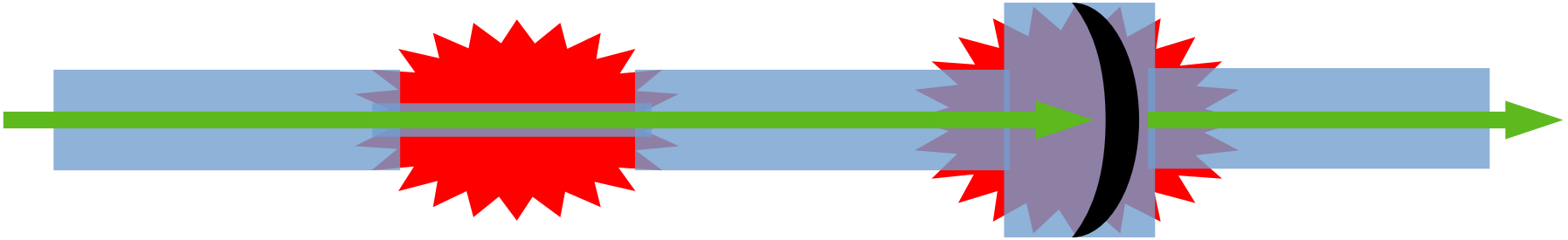
$$U_R = RI$$

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



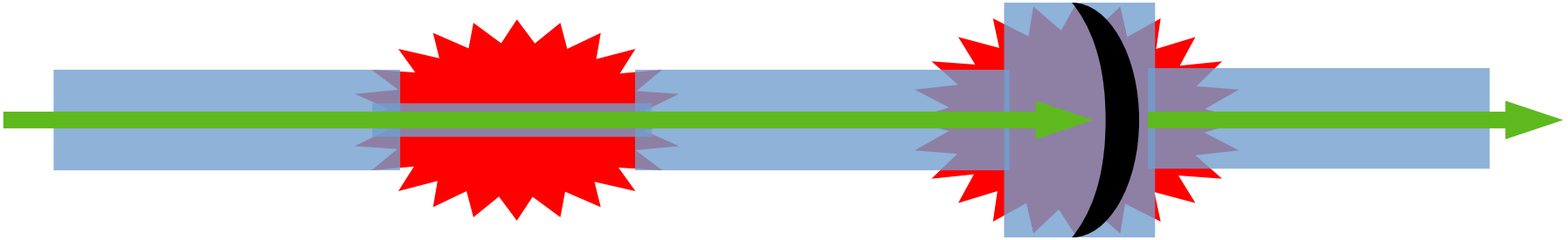
$$U_R = RI$$

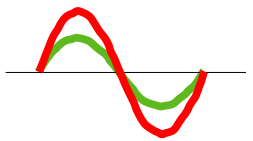
$$U_C = \frac{1}{2\,\pi\,f\,C}\,I$$

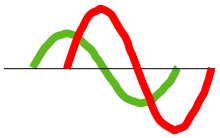


$$U_R = RI \qquad U_C = \frac{1}{2\,\pi\,f\,C}\,I$$

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



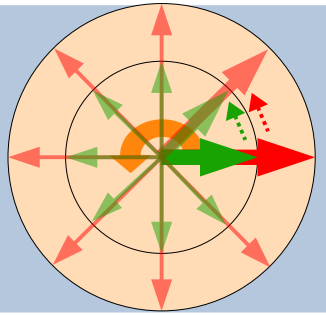


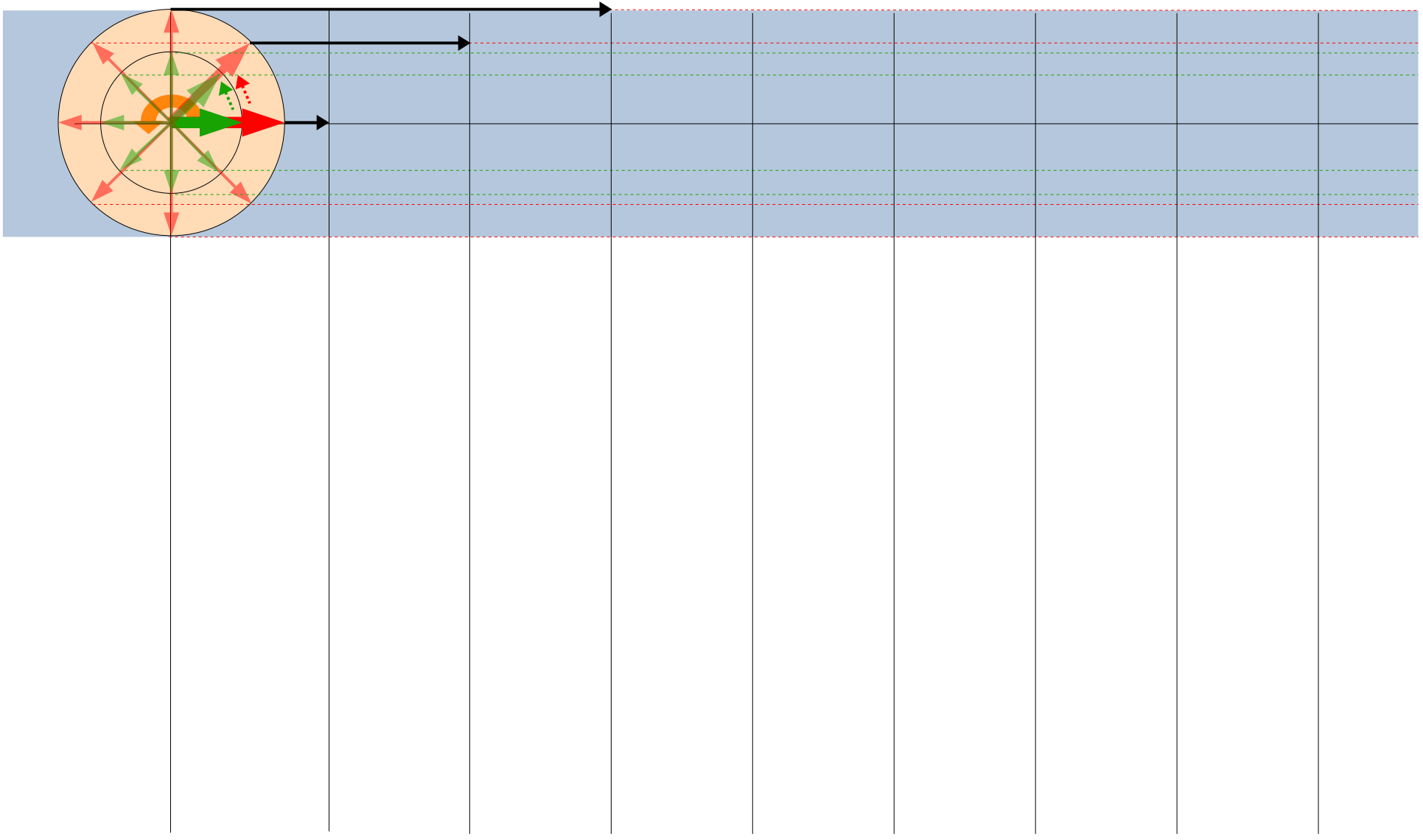


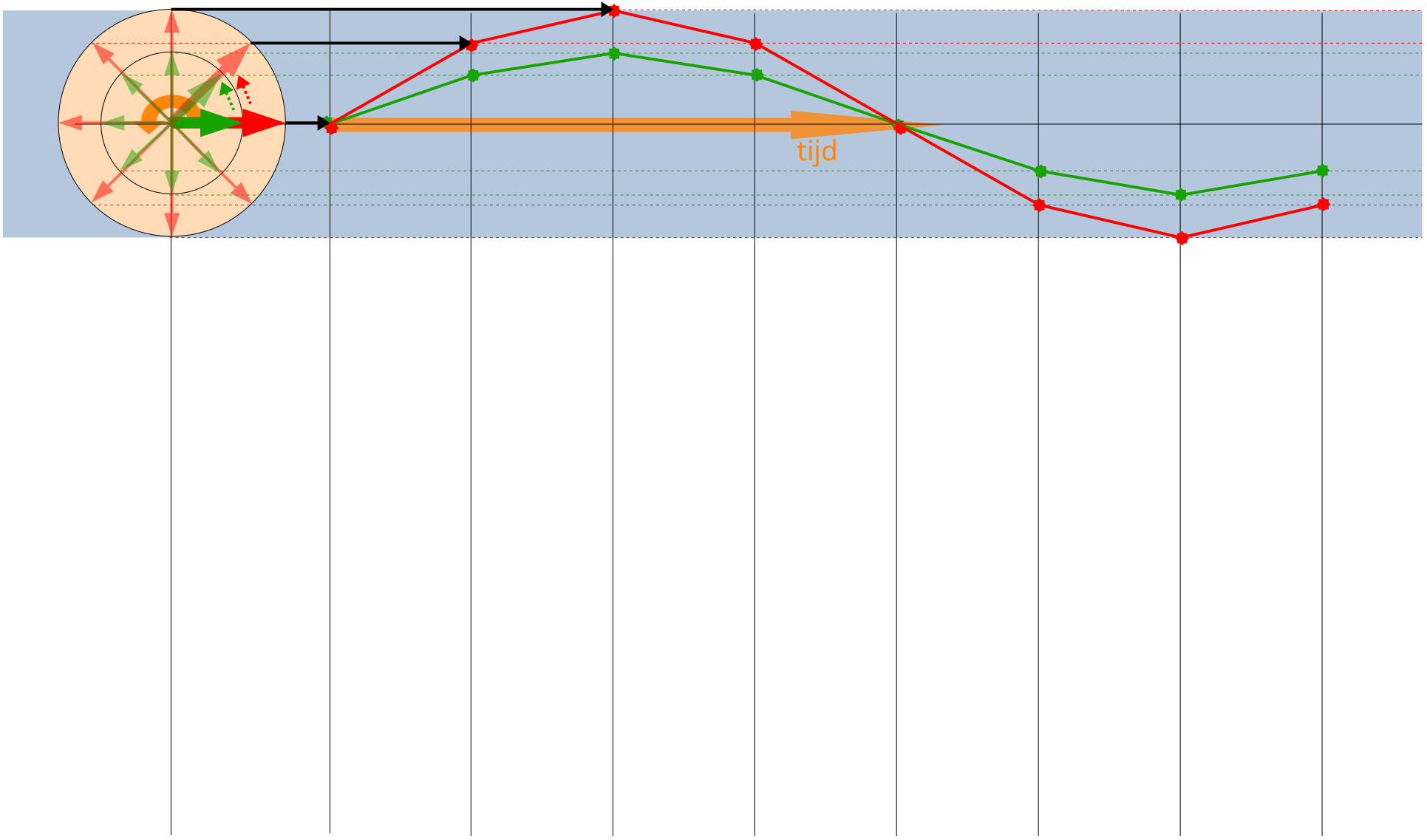
$$U_R = RI$$

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

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



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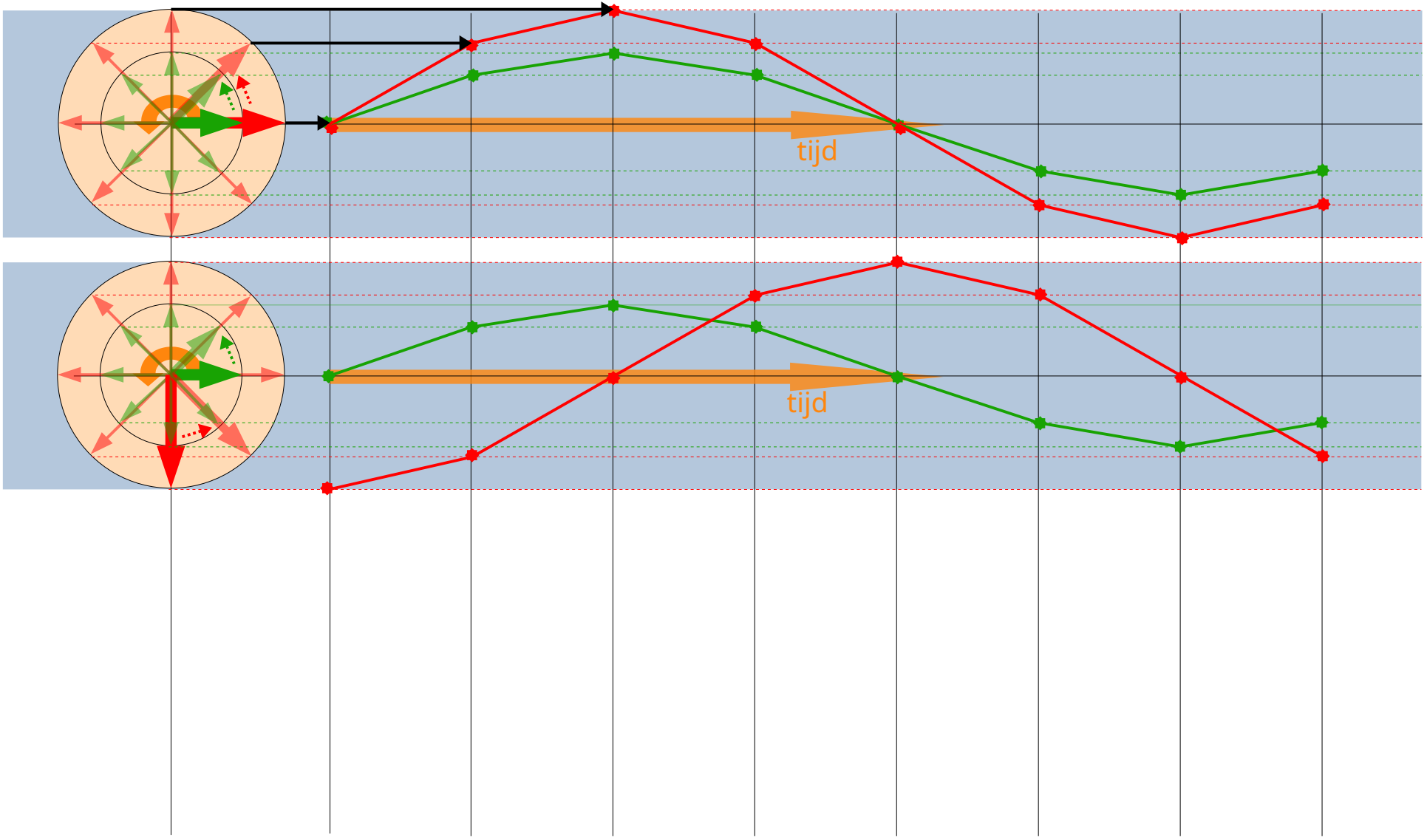
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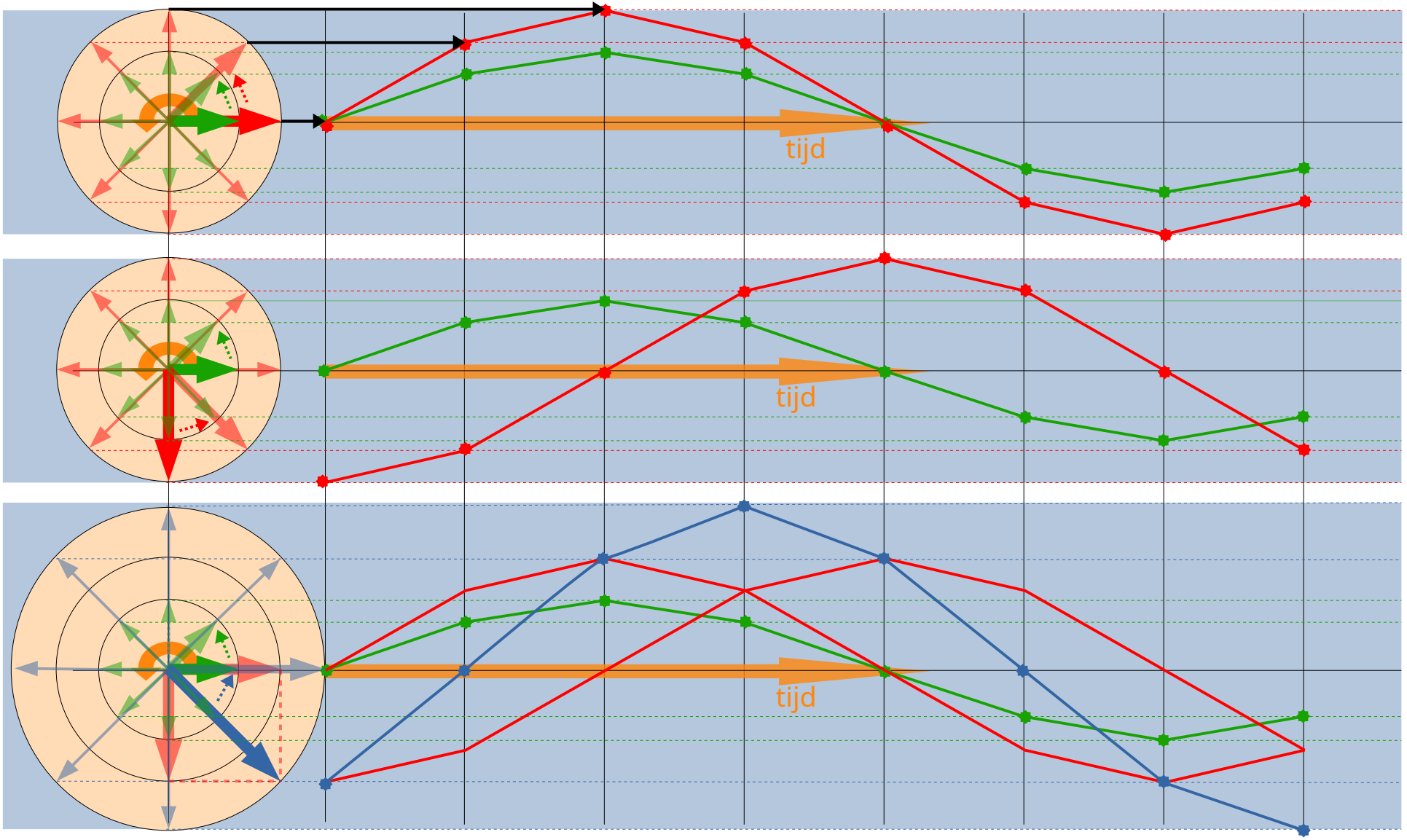
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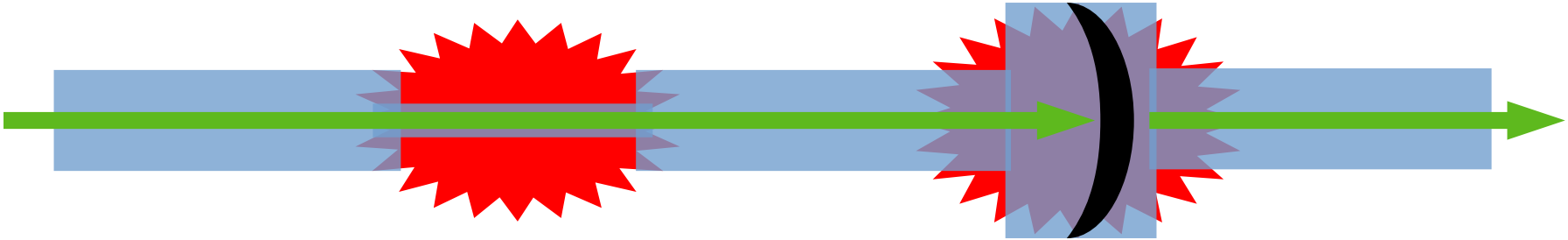
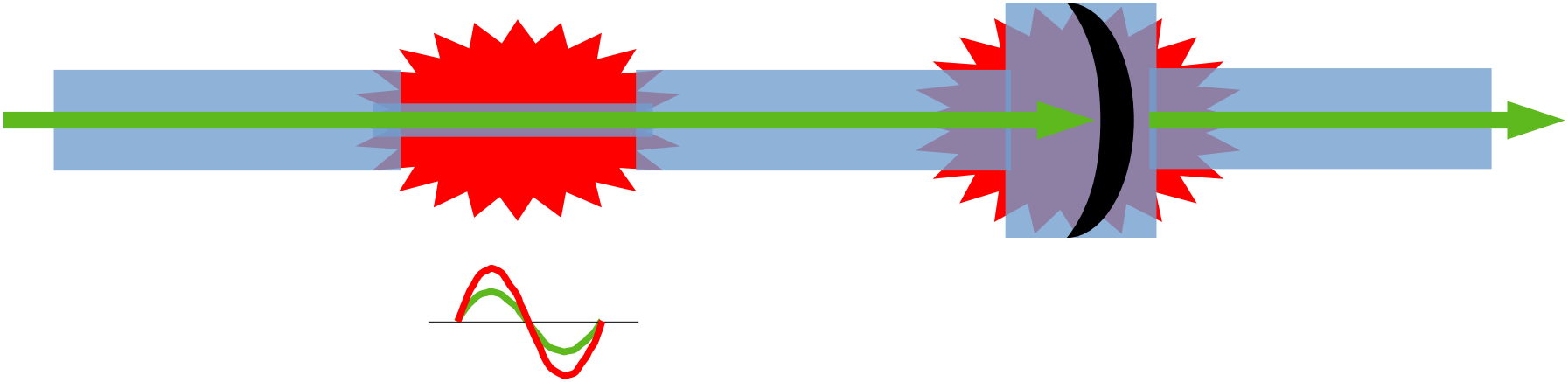
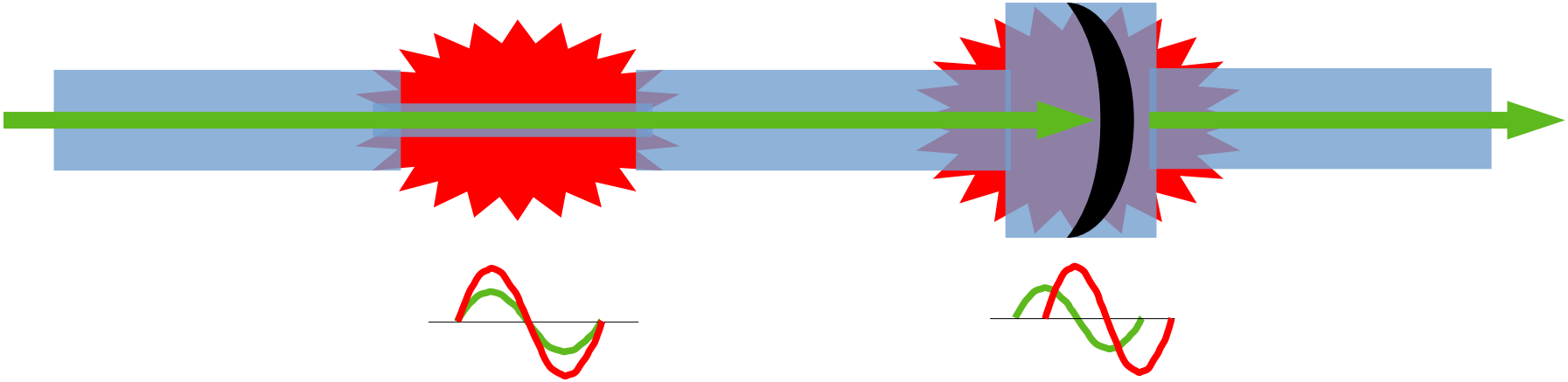
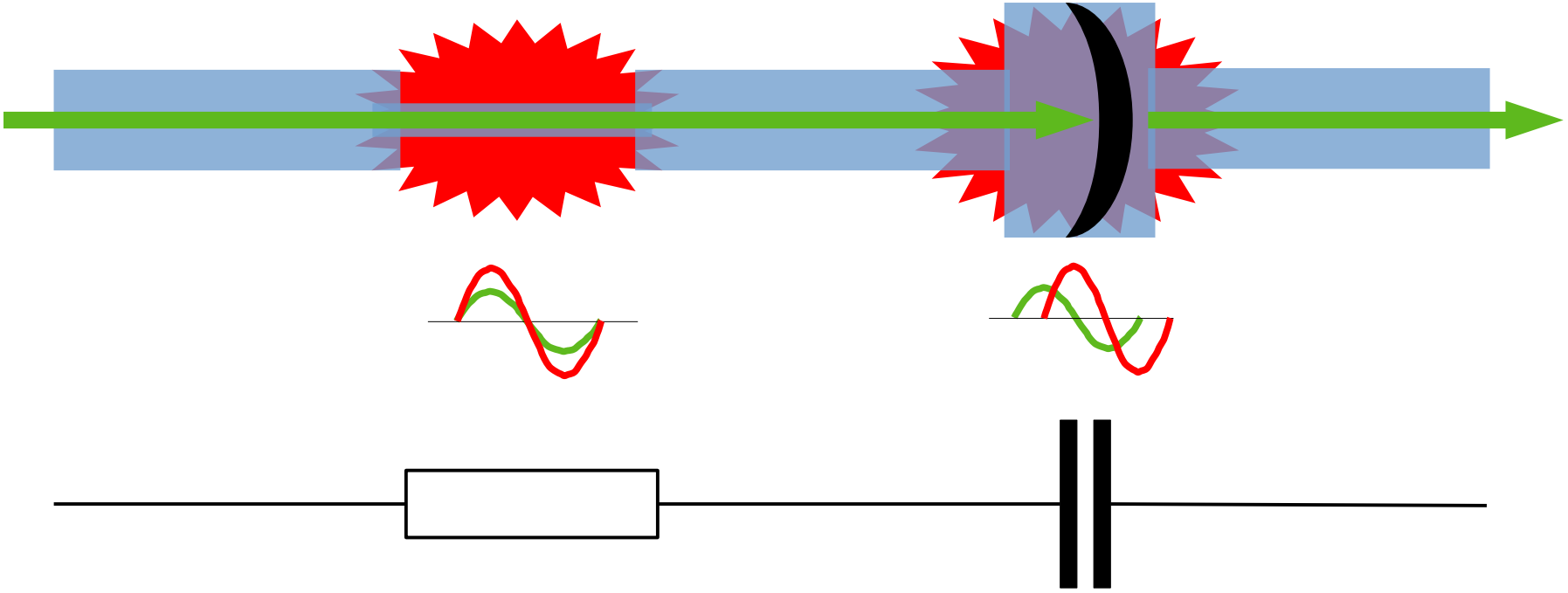
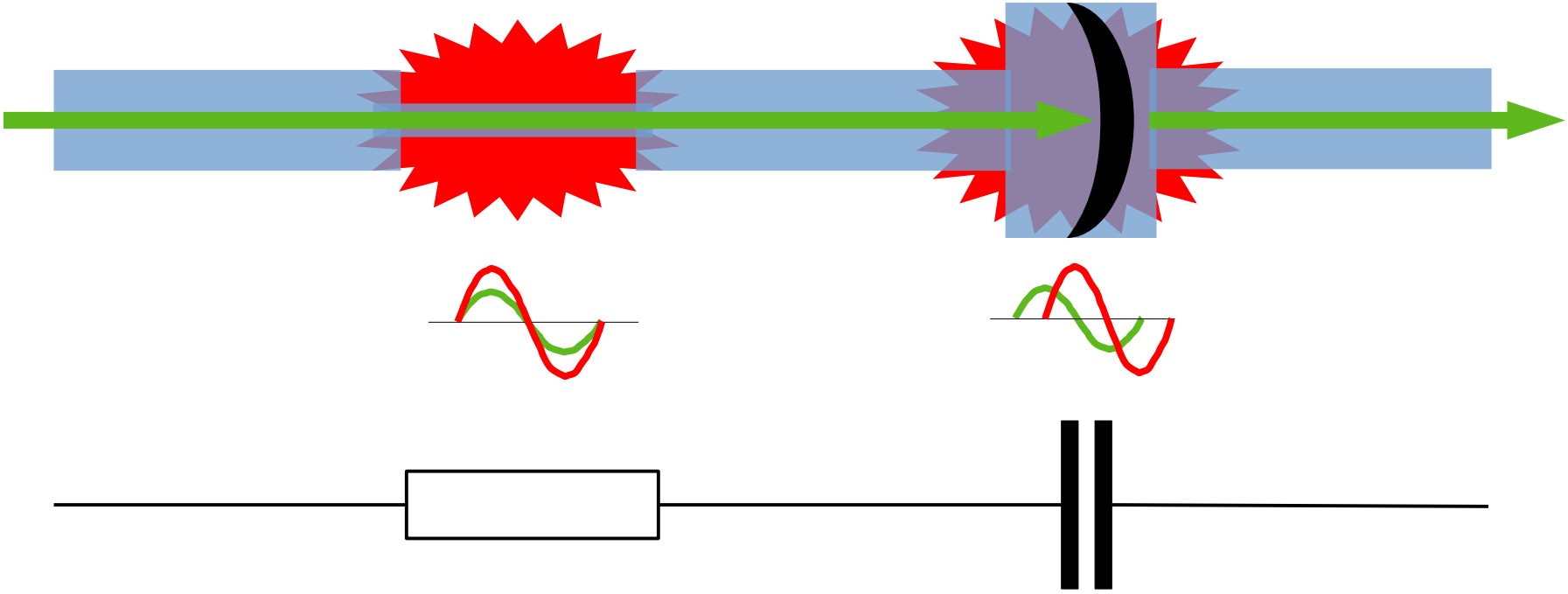


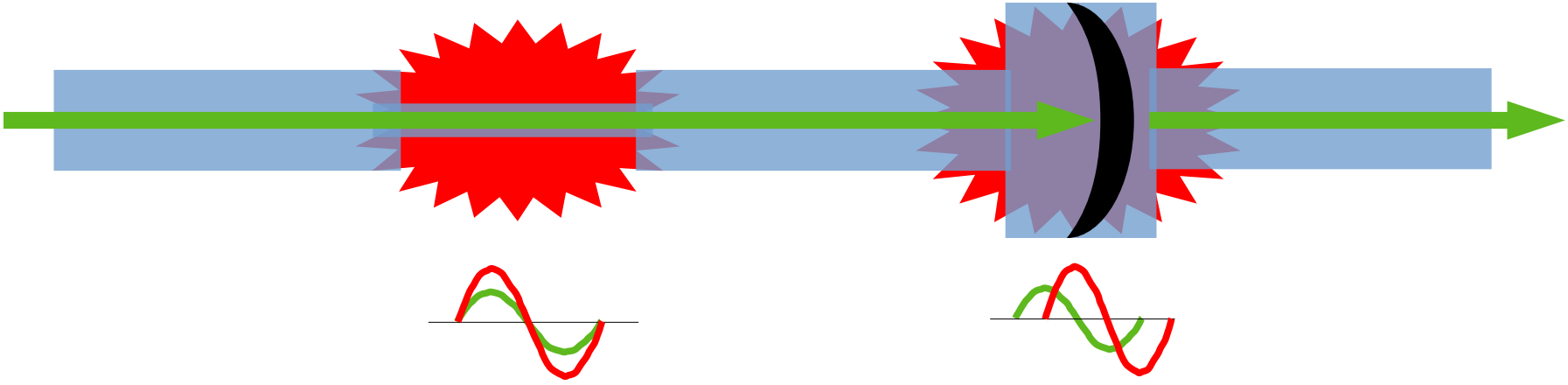


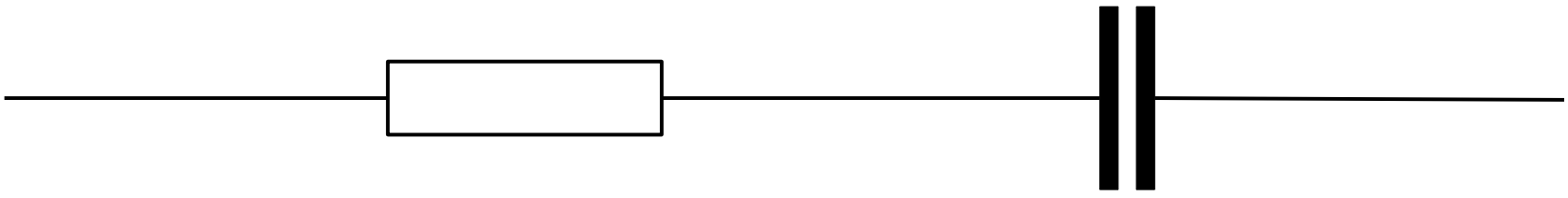






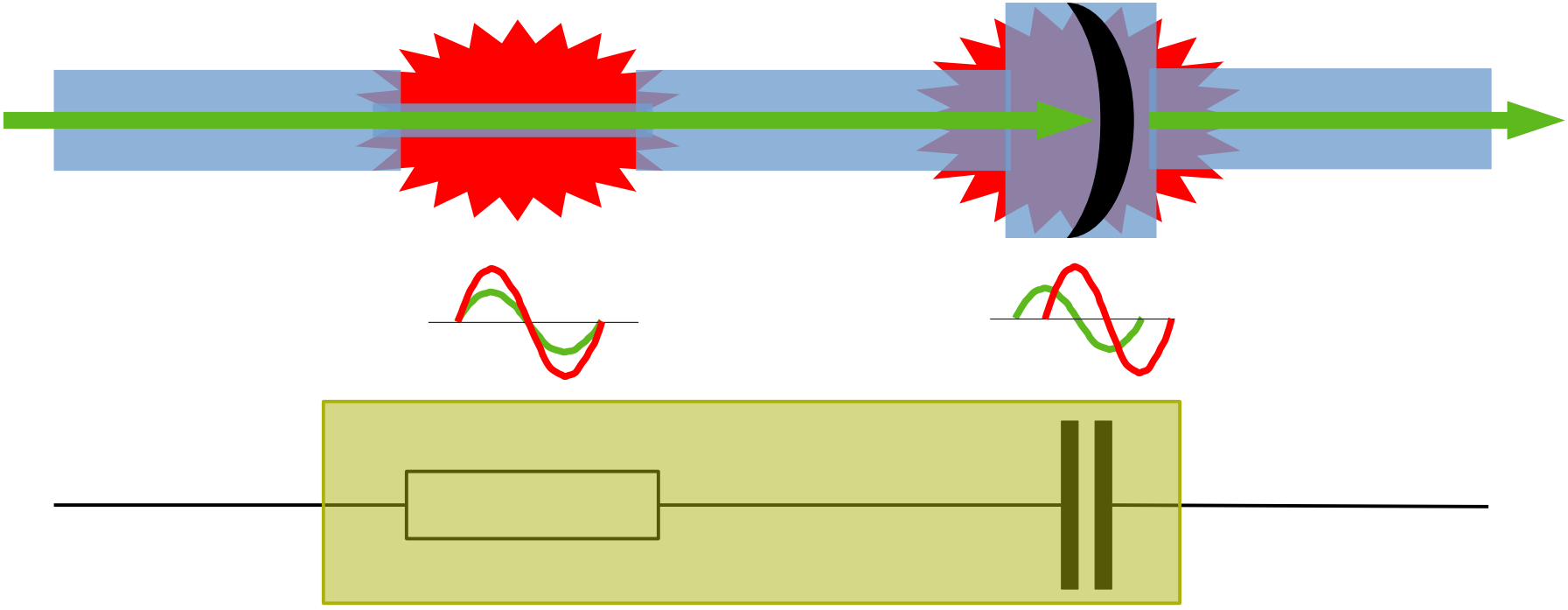
$$U_R = RI$$





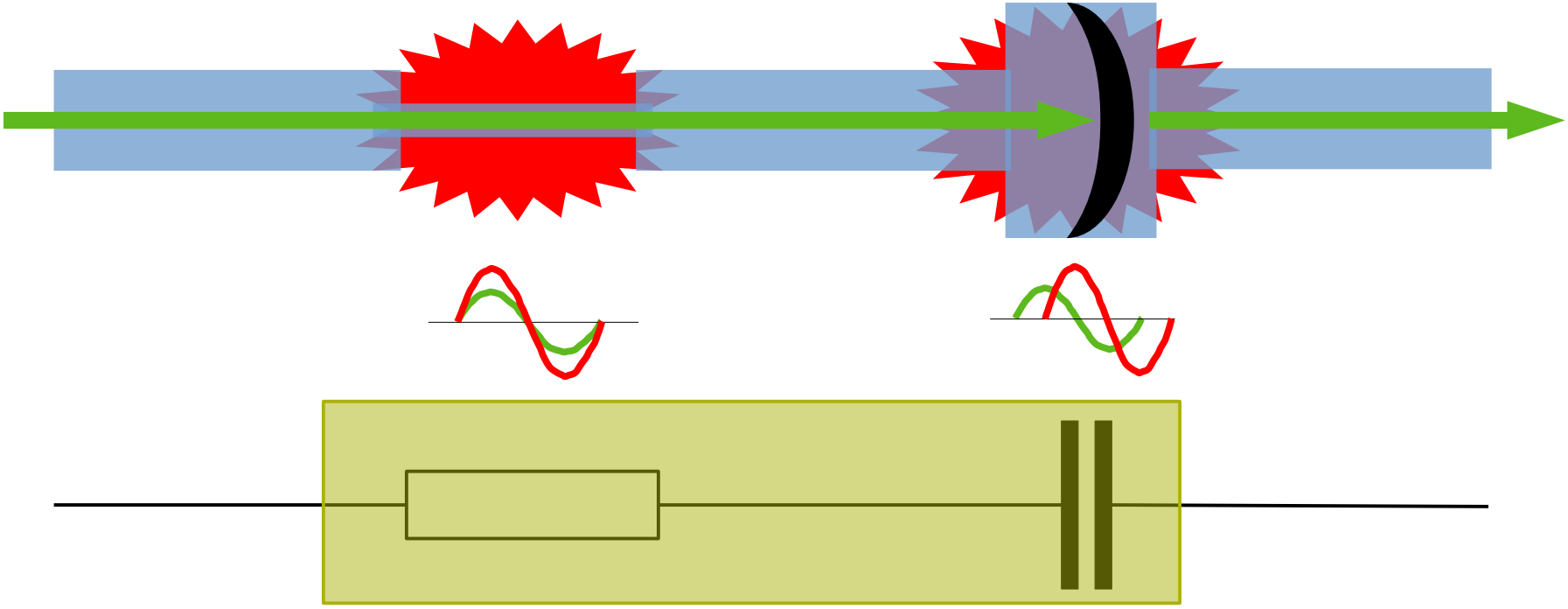
$$U_R = RI$$

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



$$U_R = RI$$

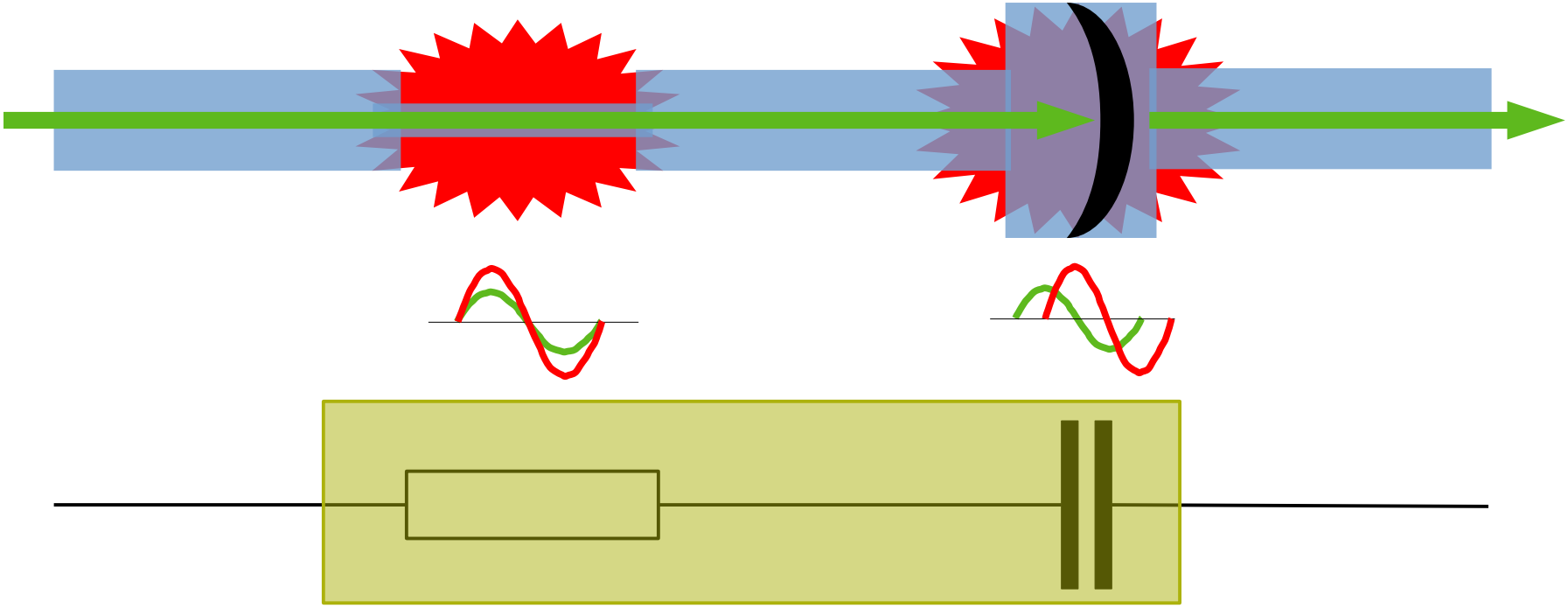
$$U_C = \frac{-1}{2\,\pi\,f\,C}\,j\,I = \frac{-j}{2\,\pi\,f\,C}\,I = \frac{1}{j\,2\,\pi\,f\,C}\,I$$



$$U_R = RI$$

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

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



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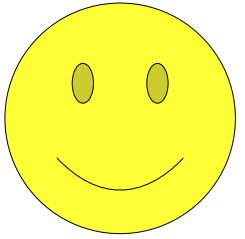
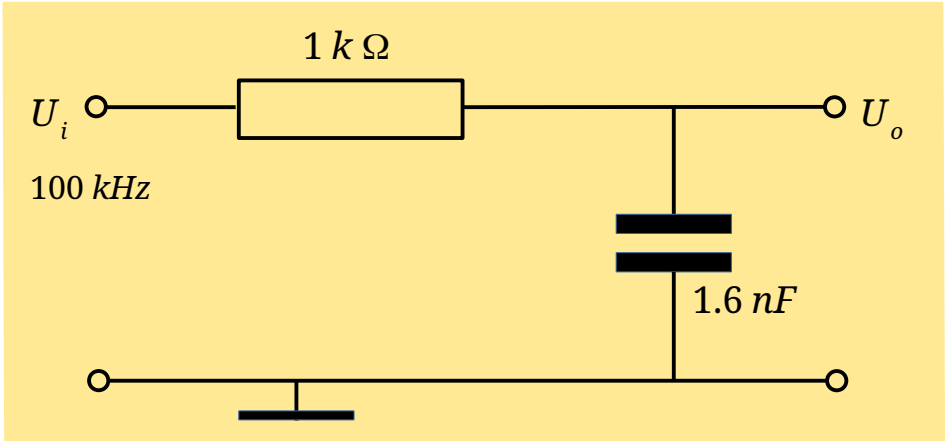
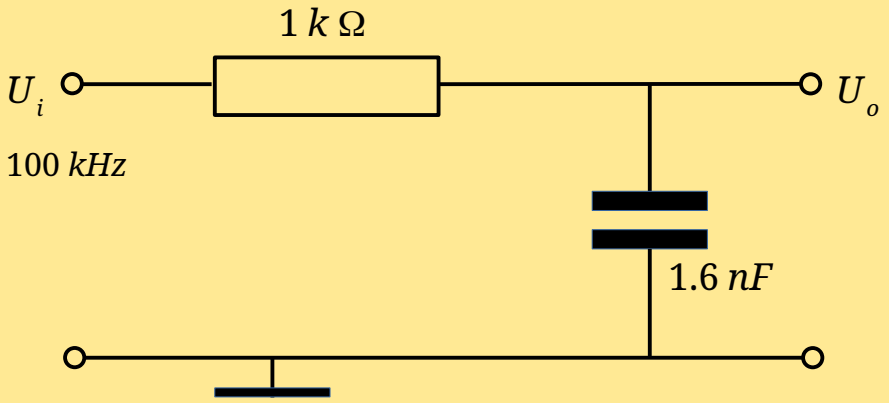
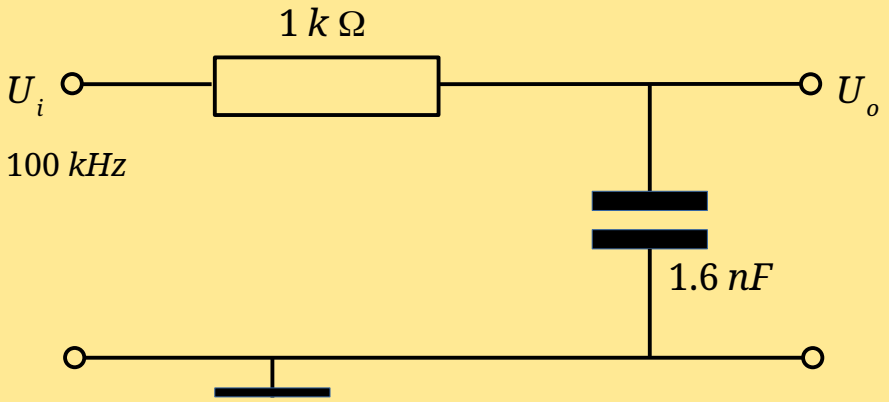
$$U_v = U_R + U_C = RI + \frac{1}{j\,2\,\pi\,f\,C}\,I = \left(R + \frac{1}{j\,2\,\pi\,f\,C}\right) I$$



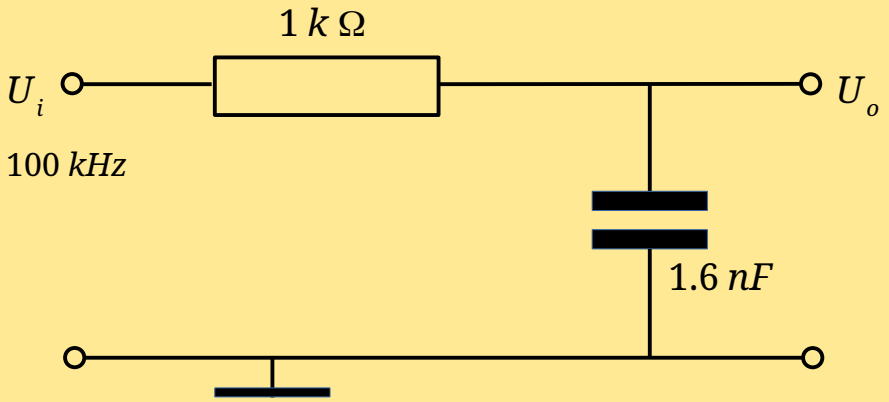

1 k Ω
U_i
U_o
100 kHz
1.6 nF



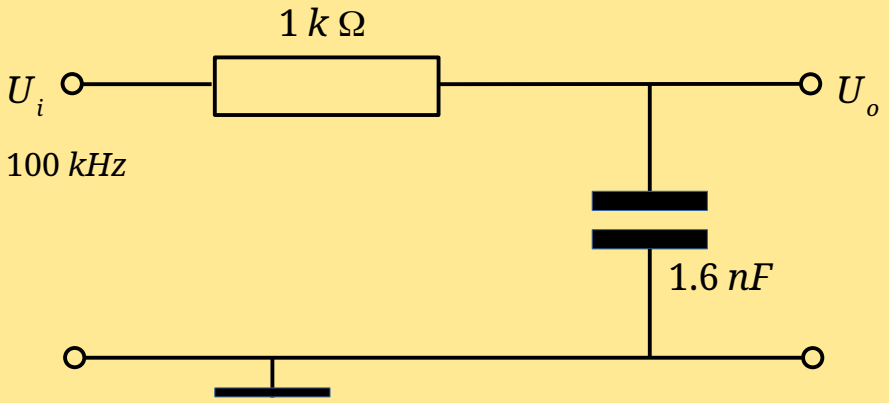
$$U_o = \frac{Z_C}{Z_R + Z_C} U_i$$



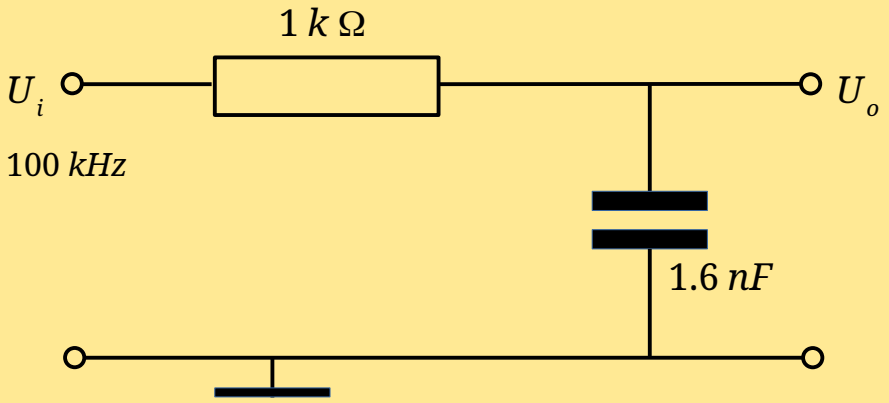
$$U_o = \frac{Z_C}{Z_R + Z_C} U_i = \frac{\frac{1}{j\,2\,\pi\,f\,C}}{R + \frac{1}{j\,2\,\pi\,f\,C}} U_i$$



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

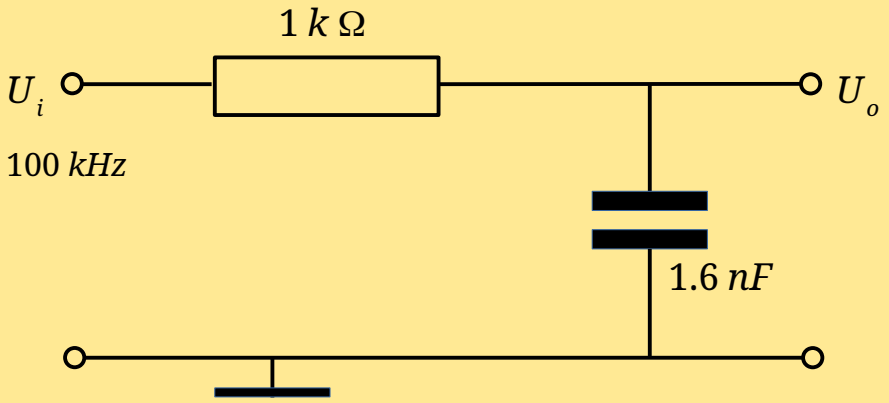


$$U_o = \frac{Z_C}{Z_R + Z_C} U_i = \frac{\frac{1}{j\,2\,\pi\,f\,C}}{R + \frac{1}{j\,2\,\pi\,f\,C}} U_i = \frac{1}{j\,2\,\pi\,f\,RC + 1} U_i = a\,U_i$$



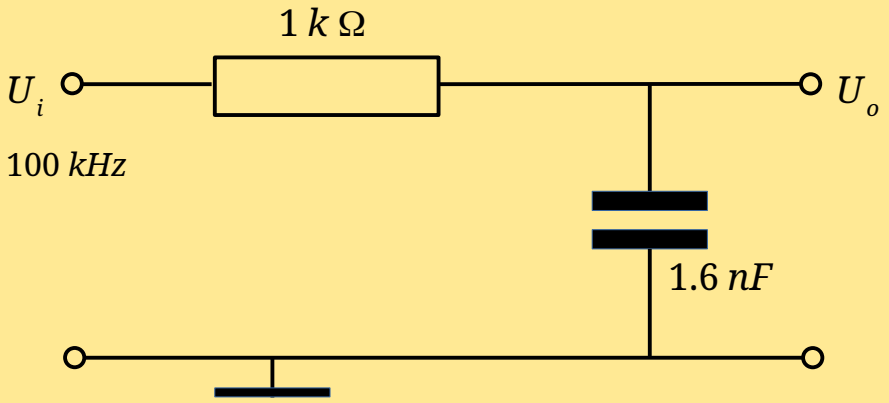
$$U_o = \frac{Z_C}{Z_R + Z_C} U_i = \frac{\frac{1}{j\,2\,\pi\,f\,C}}{R + \frac{1}{j\,2\,\pi\,f\,C}} U_i = \frac{1}{j\,2\,\pi\,f\,RC + 1} U_i = a\,U_i$$

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



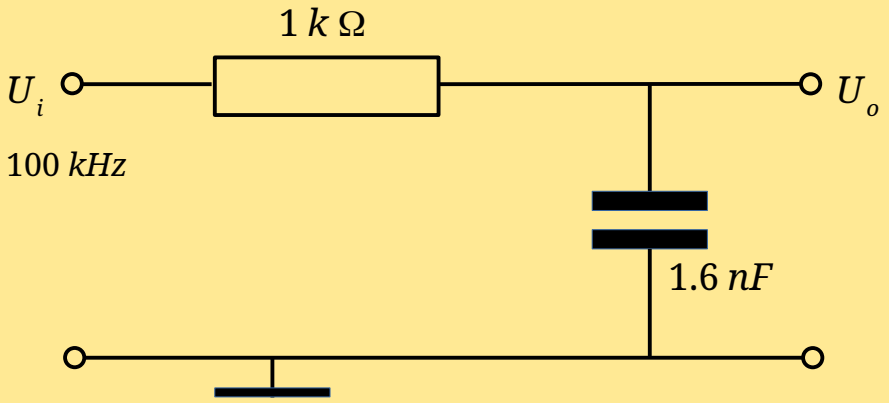
$$U_o = \frac{Z_C}{Z_R + Z_C} U_i = \frac{\frac{1}{j\,2\,\pi\,f\,C}}{R + \frac{1}{j\,2\,\pi\,f\,C}} U_i = \frac{1}{j\,2\,\pi\,f\,RC + 1} U_i = a\,U_i$$

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



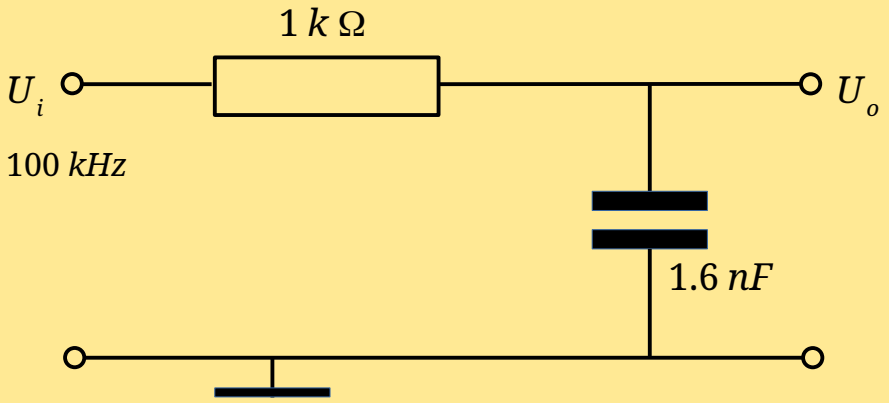
$$U_o = \frac{Z_C}{Z_R + Z_C} U_i = \frac{\frac{1}{j\,2\,\pi\,f\,C}}{R + \frac{1}{j\,2\,\pi\,f\,C}} U_i = \frac{1}{j\,2\,\pi\,f\,RC + 1} U_i = a\,U_i$$

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



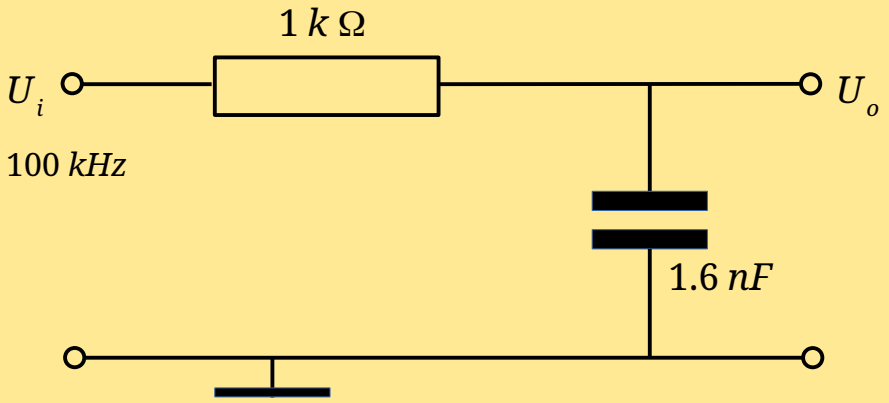
$$U_o = \frac{Z_C}{Z_R + Z_C} U_i = \frac{\frac{1}{j\,2\,\pi\,f\,C}}{R + \frac{1}{j\,2\,\pi\,f\,C}} U_i = \frac{1}{j\,2\,\pi\,f\,RC + 1} U_i = a\,U_i$$

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



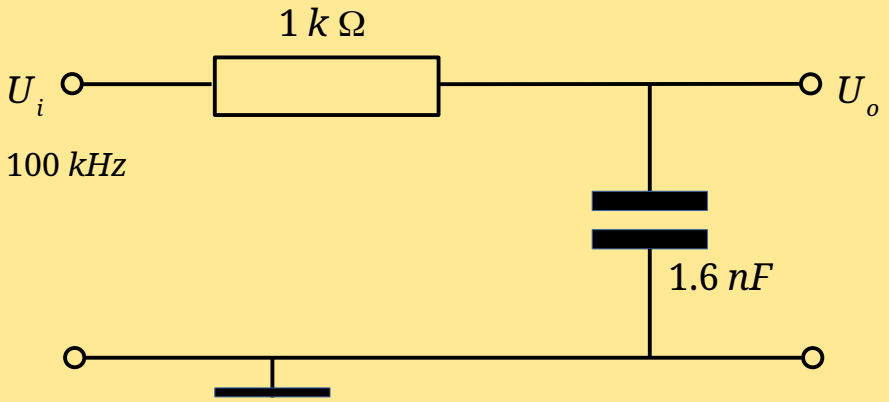
$$U_o = \frac{Z_C}{Z_R + Z_C} U_i = \frac{\frac{1}{j\,2\,\pi\,f\,C}}{R + \frac{1}{j\,2\,\pi\,f\,C}} U_i = \frac{1}{j\,2\,\pi\,f\,RC + 1} U_i = a\,U_i$$

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



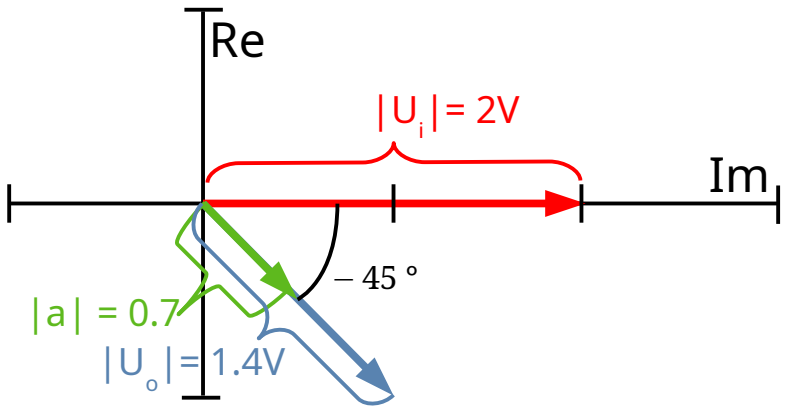
$$U_o = \frac{Z_C}{Z_R + Z_C} U_i = \frac{\frac{1}{j\,2\,\pi\,f\,C}}{R + \frac{1}{j\,2\,\pi\,f\,C}} U_i = \frac{1}{j\,2\,\pi\,f\,RC + 1} U_i = a\,U_i$$

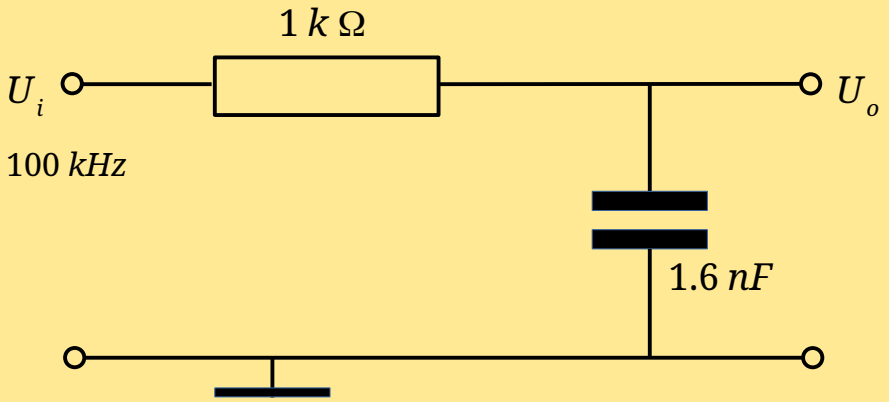
$$a = \frac{1}{j\,2 \times 3.14 \times 100000 \times 1000 \times 0.0000000016 + 1} \approx \frac{1}{1+j} = \frac{(1-j)}{(1+j)(1-j)} = \frac{(1-j)}{1+-j+j+1} = \frac{(1-j)}{2} = 0.5 - 0.5\,j$$



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

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





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