Corso di Laurea in Ingegneria Informatica, Biomedica e delle Telecomunicazioni

Corso di Campi Elettromagnetici
a.a. 2021-2022

Maxwell equations
Time domain & Phasors

Phasors

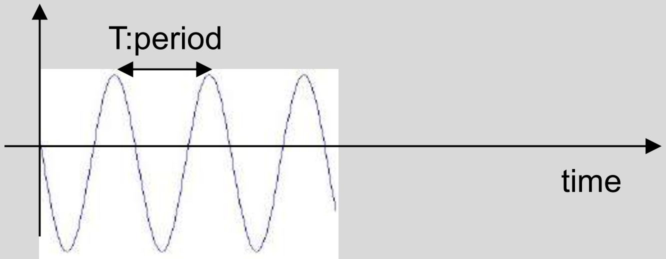
Time domain

$$f(t) = A\cos(\omega_0 t + \alpha)$$

Phasor domain

$$F = Ae^{j\alpha}$$

Signals usually adopted in ICT applications



$$f(t) = A\cos(2\pi f_0 t + \alpha)$$

$$f_0 : frequency = \frac{1}{T}$$

$$\omega_0 : angular\ frequency = 2\pi f_0$$

Phasors

Time domain

$$f(t) = A\cos\left(\omega_0 t + \alpha\right)$$

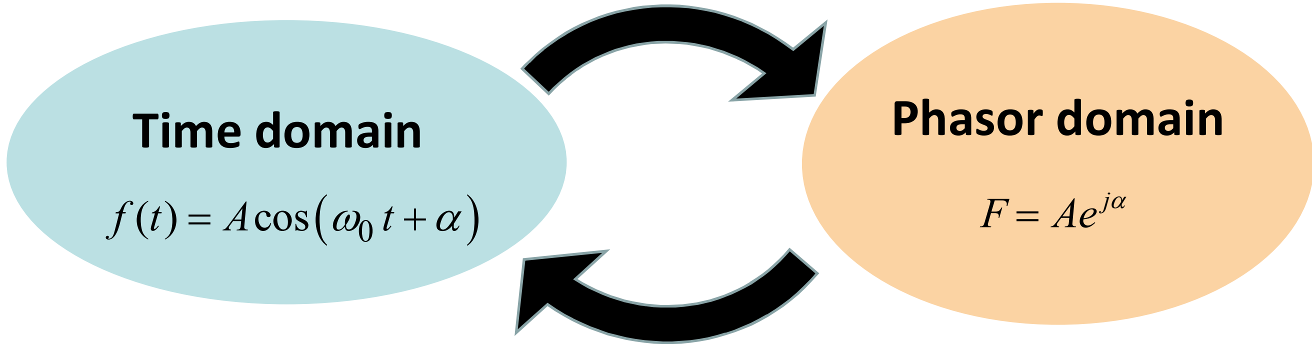
Phasor domain

$$F = Ae^{j\alpha}$$

1) How to jump back from the Phasor domain to the Time domain

2) Time domain derivative and Phasors

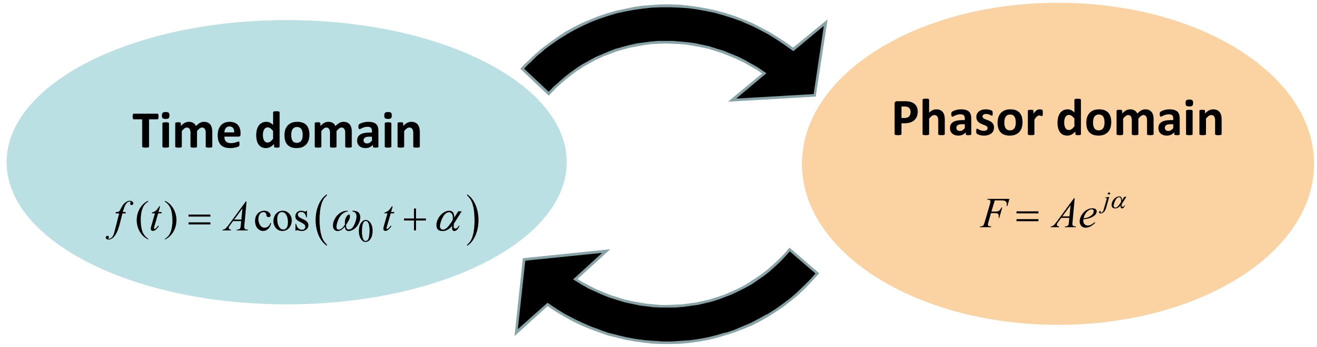
Phasors



$f(t) = A\cos(\omega_0 t + \alpha)$ → **T-to-P** → $F = Ae^{j\alpha}$

$F = Ae^{j\alpha}$ → **P-to-T** → $f(t) = \mathrm{Re}\left\{Fe^{j\omega_0 t}\right\} = A\cos(\omega_0 t + \alpha)$

Phasors



... memo ...

$f(t) \rightarrow$ **FT** $\rightarrow F(\omega)$

$\frac{df}{dt} \rightarrow$ **FT** $\rightarrow j\omega F(\omega)$

2) Time domain derivative and Phasors

$f(t) \rightarrow$ **T-to-P** $\rightarrow F$

$\frac{df(t)}{dt} \rightarrow$ **T-to-P** $\rightarrow j\omega_0 F$

ω_0 now is fixed!

Phasors

- **Phasors and functions of *n* variables**
- **Phasors and vector functions**
- **Phasors and vector functions of *n* variables**

1) How to jump back from the Phasor domain to the Time domain

2) Time domain derivative and Phasors

Phasors

- Phasors and functions of n variables
- Phasors and vector functions
- **Phasors and vector functions of *n* variables**

1) How to jump back from the Phasor domain to the Time domain

2) Time domain derivative and Phasors

Phasors and vector functions of *n* variables

Time domain

$$\vec{\mathbf{f}}(t,x,y,z) = f_x(t,x,y,z)\hat{i}_x + f_y(t,x,y,z)\hat{i}_y + f_z(t,x,y,z)\,\hat{i}_z$$

Phasor domain

$$\vec{\mathbf{F}}(x,y,z) = F_x(x,y,z)\hat{i}_x + F_y(x,y,z)\hat{i}_y + F_z(x,y,z)\hat{i}_z$$

$$f_x(t,x,y,z) = A_x(x,y,z)\cos\left(\omega_0 t + \alpha_x(x,y,z)\right) \;\rightarrow\; \text{T-to-P} \;\rightarrow\; F_x(x,y,z) = A_x(x,y,z)e^{j\alpha_x(x,y,z)}$$

$$f_y(t,x,y,z) = A_y(x,y,z)\cos\left(\omega_0 t + \alpha_y(x,y,z)\right) \;\rightarrow\; \text{T-to-P} \;\rightarrow\; F_y(x,y,z) = A_y(x,y,z)e^{j\alpha_y(x,y,z)}$$

$$f_z(t,x,y,z) = A_z(x,y,z)\cos\left(\omega_0 t + \alpha_z(x,y,z)\right) \;\rightarrow\; \text{T-to-P} \;\rightarrow\; F_z(x,y,z) = A_z(x,y,z)e^{j\alpha_z(x,y,z)}$$

Phasors and vector functions of *n* variables

Time domain

$$\vec{\mathbf{f}}(t,x,y,z) = f_x(t,x,y,z)\hat{i}_x + f_y(t,x,y,z)\hat{i}_y + f_z(t,x,y,z)\,\hat{i}_z$$

Phasor domain

$$\vec{\mathbf{F}}(x,y,z) = F_x(x,y,z)\hat{i}_x + F_y(x,y,z)\hat{i}_y + F_z(x,y,z)\hat{i}_z$$

$\vec{\mathbf{f}}(t,x,y,z)$ → **T-to-P** → $\vec{\mathbf{F}}(x,y,z)$

$$\begin{aligned}\vec{\mathbf{f}}(t,x,y,z) &= f_x(t,x,y,z)\hat{i}_x + f_y(t,x,y,z)\hat{i}_y + f_z(t,x,y,z)\hat{i}_z = \\ &= A_x(x,y,z)\cos\left(\omega_0 t + \alpha_x(x,y,z)\right)\hat{i}_x + \\ &\quad A_y(x,y,z)\cos\left(\omega_0 t + \alpha_y(x,y,z)\right)\hat{i}_y + \\ &\quad A_z(x,y,z)\cos\left(\omega_0 t + \alpha_z(x,y,z)\right)\hat{i}_z\end{aligned}$$

$$\begin{aligned}\vec{\mathbf{F}}(x,y,z) &= F_x(x,y,z)\hat{i}_x + F_y(x,y,z)\hat{i}_y + F_z(x,y,z)\hat{i}_z = \\ &= A_x(x,y,z)e^{j\alpha_x(x,y,z)}\hat{i}_x + A_y(x,y,z)e^{j\alpha_y(x,y,z)}\hat{i}_y + A_z(x,y,z)e^{j\alpha_z(x,y,z)}\hat{i}_z\end{aligned}$$

Phasors and vector functions of *n* variables

Time domain

$$\vec{\mathbf{f}}(t,x,y,z) = f_x(t,x,y,z)\hat{i}_x + f_y(t,x,y,z)\hat{i}_y + f_z(t,x,y,z)\,\hat{i}_z$$

Phasor domain

$$\vec{\mathbf{F}}(x,y,z) = F_x(x,y,z)\hat{i}_x + F_y(x,y,z)\hat{i}_y + F_z(x,y,z)\hat{i}_z$$

1) How to jump back from the Phasor domain to the Time domain

$$F_x(x,y,z) = A_x(x,y,z)e^{j\alpha_x(x,y,z)} \longrightarrow \boxed{\text{P-to-T}} \longrightarrow f_x(t,x,y,z) = \mathrm{Re}\left\{F_x(x,y,z)e^{j\omega_0 t}\right\}$$

$$F_y(x,y,z) = A_y(x,y,z)e^{j\alpha_y(x,y,z)} \longrightarrow \boxed{\text{P-to-T}} \longrightarrow f_y(t,x,y,z) = \mathrm{Re}\left\{F_y(x,y,z)e^{j\omega_0 t}\right\}$$

$$F_z(x,y,z) = A_z(x,y,z)e^{j\alpha_z(x,y,z)} \longrightarrow \boxed{\text{P-to-T}} \longrightarrow f_z(t,x,y,z) = \mathrm{Re}\left\{F_z(x,y,z)e^{j\omega_0 t}\right\}$$

Phasors and vector functions of *n* variables

Time domain

$$\vec{\mathbf{f}}(t,x,y,z) = f_x(t,x,y,z)\hat{i}_x + f_y(t,x,y,z)\hat{i}_y + f_z(t,x,y,z)\hat{i}_z$$

Phasor domain

$$\vec{\mathbf{F}}(x,y,z) = F_x(x,y,z)\hat{i}_x + F_y(x,y,z)\hat{i}_y + F_z(x,y,z)\hat{i}_z$$

1) How to jump back from the Phasor domain to the Time domain

$$F_x(x,y,z) = A_x(x,y,z)e^{j\alpha_x(x,y,z)} \rightarrow \boxed{\text{P-to-T}} \rightarrow f_x(t,x,y,z) = \mathrm{Re}\left\{F_x(x,y,z)e^{j\omega_0 t}\right\}$$

$$F_y(x,y,z) = A_y(x,y,z)e^{j\alpha_y(x,y,z)} \rightarrow \boxed{\text{P-to-T}} \rightarrow f_y(t,x,y,z) = \mathrm{Re}\left\{F_y(x,y,z)e^{j\omega_0 t}\right\}$$

$$F_z(x,y,z) = A_z(x,y,z)e^{j\alpha_z(x,y,z)} \rightarrow \boxed{\text{P-to-T}} \rightarrow f_z(t,x,y,z) = \mathrm{Re}\left\{F_z(x,y,z)e^{j\omega_0 t}\right\}$$

Phasors and vector functions of *n* variables

Time domain

$$\vec{\mathbf{f}}(t,x,y,z) = f_x(t,x,y,z)\hat{i}_x + f_y(t,x,y,z)\hat{i}_y + f_z(t,x,y,z)\,\hat{i}_z$$

Phasor domain

$$\vec{\mathbf{F}}(x,y,z) = F_x(x,y,z)\hat{i}_x + F_y(x,y,z)\hat{i}_y + F_z(x,y,z)\hat{i}_z$$

2) Time domain derivative and Phasors

$\vec{\mathbf{f}}(t,x,y,z)$ → **T-to-P** → $\vec{\mathbf{F}}(x,y,z)$

$\dfrac{\partial \vec{\mathbf{f}}}{\partial t}$ → **T-to-P** → $j\omega_0\vec{\mathbf{F}}(x,y,z) = j\omega_0 F_x(x,y,z)\hat{i}_x + j\omega_0 F_y(x,y,z)\hat{i}_y + j\omega_0 F_z(x,y,z)\hat{i}_z$

$$\frac{\partial \vec{\mathbf{f}}(t,\vec{\mathbf{r}})}{\partial t} = \frac{\partial f_x}{\partial t}\hat{i}_x + \frac{\partial f_y}{\partial t}\hat{i}_y + \frac{\partial f_z}{\partial t}\hat{i}_z$$

$\dfrac{\partial f_x(t)}{\partial t}$ → T-to-P → $j\omega_0 F_x(x,y,z)$

$\dfrac{\partial f_y(t)}{\partial t}$ → T-to-P → $j\omega_0 F_y(x,y,z)$

$\dfrac{\partial f_z(t)}{\partial t}$ → T-to-P → $j\omega_0 F_z(x,y,z)$

Phasors and vector functions of *n* variables

Time domain

$$\vec{\mathbf{f}}(t,x,y,z) = f_x(t,x,y,z)\hat{i}_x + f_y(t,x,y,z)\hat{i}_y + f_z(t,x,y,z)\,\hat{i}_z$$

Phasor domain

$$\vec{\mathbf{F}}(x,y,z) = F_x(x,y,z)\hat{i}_x + F_y(x,y,z)\hat{i}_y + F_z(x,y,z)\hat{i}_z$$

2) Time domain derivative and Phasors

$\vec{\mathbf{f}}(t,x,y,z)$ → **T-to-P** → $\vec{\mathbf{F}}(x,y,z)$

$\nabla\cdot\vec{\mathbf{f}}$ → **T-to-P** → $\nabla\cdot\vec{\mathbf{F}}(x,y,z)$

$$\nabla\cdot\vec{\mathbf{f}}(t,\vec{\mathbf{r}}) = \frac{\partial f_x}{\partial x} + \frac{\partial f_y}{\partial y} + \frac{\partial f_z}{\partial z}$$

$\dfrac{\partial f_x}{\partial x}$ → **T-to-P** → $\dfrac{\partial F_x(x,y,z)}{\partial x}$

$\dfrac{\partial f_y}{\partial y}$ → **T-to-P** → $\dfrac{\partial F_y(x,y,z)}{\partial y}$

$\dfrac{\partial f_z}{\partial z}$ → **T-to-P** → $\dfrac{\partial F_z(x,y,z)}{\partial z}$

Phasors and vector functions of *n* variables

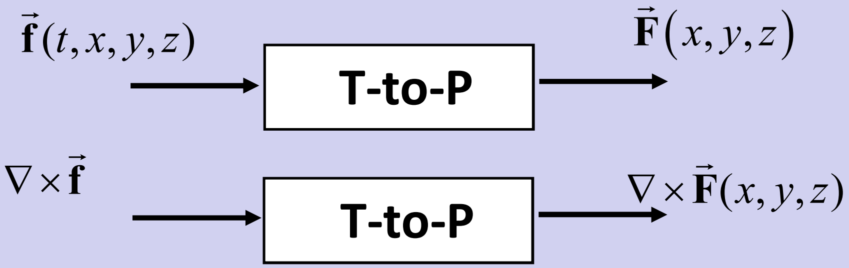
Time domain

$$\vec{\mathbf{f}}(t,x,y,z) = f_x(t,x,y,z)\hat{i}_x + f_y(t,x,y,z)\hat{i}_y + f_z(t,x,y,z)\,\hat{i}_z$$

Phasor domain

$$\vec{\mathbf{F}}(x,y,z) = F_x(x,y,z)\hat{i}_x + F_y(x,y,z)\hat{i}_y + F_z(x,y,z)\hat{i}_z$$

2) Time domain derivative and Phasors



$$\nabla\times\vec{\mathbf{f}}(t,\vec{\mathbf{r}}) = \left(\frac{\partial f_z}{\partial y} - \frac{\partial f_y}{\partial z}\right)\hat{i}_x + \left(\frac{\partial f_x}{\partial z} - \frac{\partial f_z}{\partial x}\right)\hat{i}_y + \left(\frac{\partial f_y}{\partial x} - \frac{\partial f_x}{\partial y}\right)\hat{i}_z$$

Phasors and vector functions of *n* variables

Time domain

$$\vec{\mathbf{f}}(t,x,y,z) = f_x(t,x,y,z)\hat{i}_x + f_y(t,x,y,z)\hat{i}_y + f_z(t,x,y,z)\,\hat{i}_z$$

Phasor domain

$$\vec{\mathbf{F}}(x,y,z) = F_x(x,y,z)\hat{i}_x + F_y(x,y,z)\hat{i}_y + F_z(x,y,z)\hat{i}_z$$

2) Time domain derivative and Phasors

$$\vec{\mathbf{f}}(t,x,y,z) \longrightarrow \boxed{\text{T-to-P}} \longrightarrow \vec{\mathbf{F}}(x,y,z)$$

$$\frac{\partial \vec{\mathbf{f}}}{\partial t} \longrightarrow \boxed{\text{T-to-P}} \longrightarrow j\omega_0\vec{\mathbf{F}}(x,y,z)$$

$$\nabla \cdot \vec{\mathbf{f}} \longrightarrow \boxed{\text{T-to-P}} \longrightarrow \nabla \cdot \vec{\mathbf{F}}(x,y,z)$$

$$\nabla \times \vec{\mathbf{f}} \longrightarrow \boxed{\text{T-to-P}} \longrightarrow \nabla \times \vec{\mathbf{F}}(x,y,z)$$

Phasors and vector functions of *n* variables

Time domain

$$\vec{\mathbf{f}}(x,y,z,t) = f_x(x,y,z,t)\hat{i}_x + f_y(x,y,z,t)\hat{i}_y + f_z(x,y,z,t)\,\hat{i}_z$$

Phasor domain

$$\vec{\mathbf{F}}(x,y,z) = F_x(x,y,z)\hat{i}_x + F_y(x,y,z)\hat{i}_y + F_z(x,y,z)\hat{i}_z$$

2) Time domain derivative and Phasors

$$\vec{\mathbf{f}}(x,y,z,t) \longrightarrow \boxed{\text{T-to-P}} \longrightarrow \vec{\mathbf{F}}(x,y,z)$$

$$\frac{\partial \vec{\mathbf{f}}}{\partial t} \longrightarrow \boxed{\text{T-to-P}} \longrightarrow j\omega_0 \vec{\mathbf{F}}(x,y,z)$$

$$\nabla \cdot \vec{\mathbf{f}} \longrightarrow \boxed{\text{T-to-P}} \longrightarrow \nabla \cdot \vec{\mathbf{F}}(x,y,z)$$

$$\nabla \times \vec{\mathbf{f}} \longrightarrow \boxed{\text{T-to-P}} \longrightarrow \nabla \times \vec{\mathbf{F}}(x,y,z)$$

Maxwell equations
Time domain & Phasor domain

Time domain

$$
\begin{cases}
\nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\
\nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\
\nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\
\nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0
\end{cases}
$$

Maxwell equations
Time domain & Phasor domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

Phasor domain

Maxwell equations
Time domain & Phasor domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

Phasor domain

$$\begin{cases} \\ \\ \\ \end{cases}$$

$\vec{\mathbf{f}}(x,y,z,t)$ →	T-to-P	→ $\vec{\mathbf{F}}(x,y,z)$
$\dfrac{\partial \vec{\mathbf{f}}}{\partial t}$ →	T-to-P	→ $j\omega_0 \vec{\mathbf{F}}(x,y,z)$
$\nabla \cdot \vec{\mathbf{f}}$ →	T-to-P	→ $\nabla \cdot \vec{\mathbf{F}}(x,y,z)$
$\nabla \times \vec{\mathbf{f}}$ →	T-to-P	→ $\nabla \times \vec{\mathbf{F}}(x,y,z)$

Maxwell equations
Time domain & Phasor domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

Phasor domain

$$\begin{cases} \\ \\ \end{cases}$$

$\vec{\mathbf{f}}(x,y,z,t) \longrightarrow$ T-to-P $\longrightarrow \vec{\mathbf{F}}(x,y,z)$

$\dfrac{\partial \vec{\mathbf{f}}}{\partial t} \longrightarrow$ T-to-P $\longrightarrow j\omega_0 \vec{\mathbf{F}}(x,y,z)$

$\nabla \cdot \vec{\mathbf{f}} \longrightarrow$ T-to-P $\longrightarrow \nabla \cdot \vec{\mathbf{F}}(x,y,z)$

$\nabla \times \vec{\mathbf{f}} \longrightarrow$ T-to-P $\longrightarrow \nabla \times \vec{\mathbf{F}}(x,y,z)$

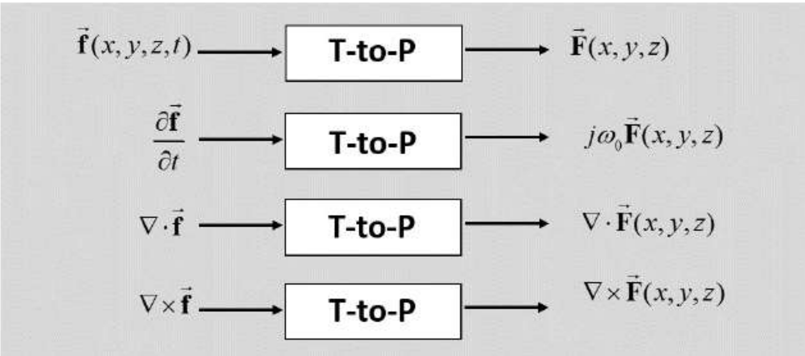
$\vec{\mathbf{e}}(\vec{\mathbf{r}},t) \longrightarrow$ T-to-P $\longrightarrow \vec{\mathbf{E}}(\vec{\mathbf{r}})$

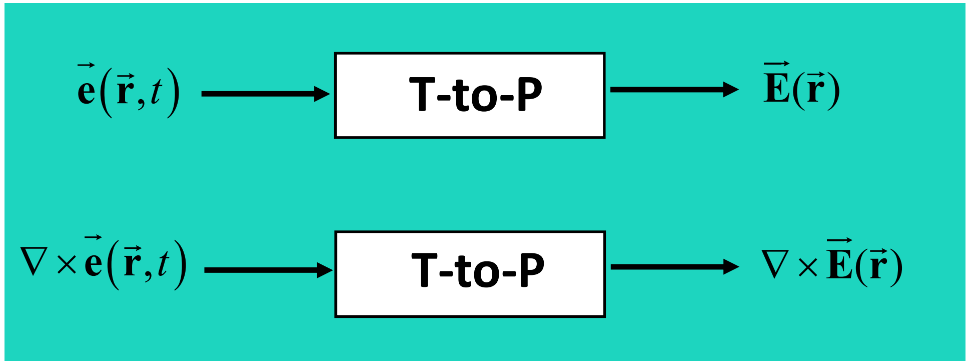
Maxwell equations
Time domain & Phasor domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

Phasor domain





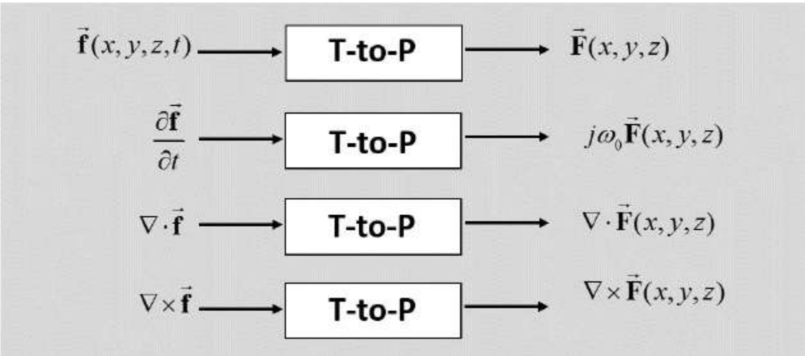
Maxwell equations
Time domain & Phasor domain

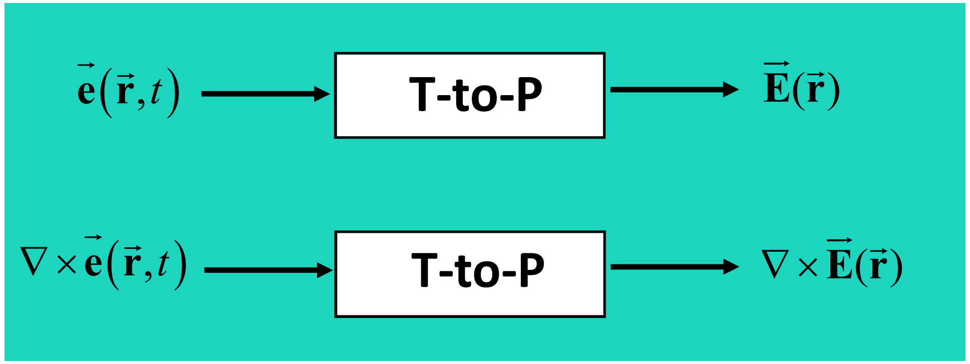
Time domain

$$\begin{cases}\nabla\times\vec{\mathbf{e}}(\vec{\mathbf{r}},t)=-\dfrac{\partial\vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t}\\ \nabla\times\vec{\mathbf{h}}(\vec{\mathbf{r}},t)=\dfrac{\partial\vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t}+\vec{\mathbf{j}}(\vec{\mathbf{r}},t)\\ \nabla\cdot\vec{\mathbf{d}}(\vec{\mathbf{r}},t)=\rho(\vec{\mathbf{r}},t)\\ \nabla\cdot\vec{\mathbf{b}}(\vec{\mathbf{r}},t)=0\end{cases}$$

Phasor domain

$$\begin{cases}\nabla\times\vec{\mathbf{E}}(\vec{\mathbf{r}})\end{cases}$$





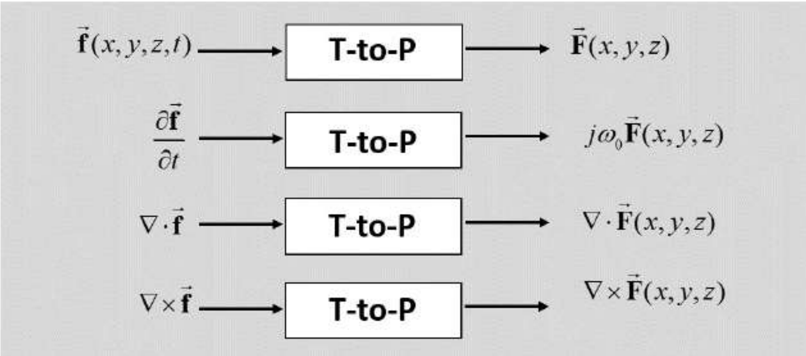
Maxwell equations
Time domain & Phasor domain

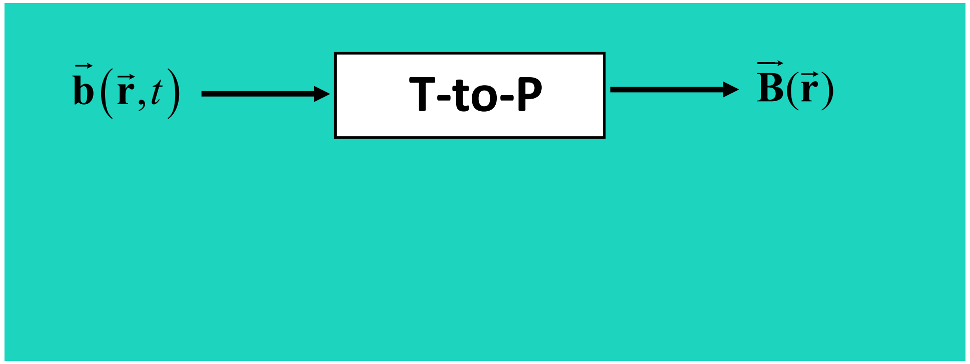
Time domain

$$
\begin{cases}
\nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\
\nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\
\nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\
\nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0
\end{cases}
$$

Phasor domain

$$
\begin{cases}
\nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}})
\end{cases}
$$





Maxwell equations
Time domain & Phasor domain

Time domain

$$
\begin{cases}
\nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\
\nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\
\nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\
\nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0
\end{cases}
$$

Phasor domain

$$
\begin{cases}
\nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}})
\end{cases}
$$

$\vec{\mathbf{f}}(x,y,z,t)$ → T-to-P → $\vec{\mathbf{F}}(x,y,z)$

$\dfrac{\partial \vec{\mathbf{f}}}{\partial t}$ → T-to-P → $j\omega_0 \vec{\mathbf{F}}(x,y,z)$

$\nabla \cdot \vec{\mathbf{f}}$ → T-to-P → $\nabla \cdot \vec{\mathbf{F}}(x,y,z)$

$\nabla \times \vec{\mathbf{f}}$ → T-to-P → $\nabla \times \vec{\mathbf{F}}(x,y,z)$

$\vec{\mathbf{b}}(\vec{\mathbf{r}},t)$ → T-to-P → $\vec{\mathbf{B}}(\vec{\mathbf{r}})$

$\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t}$ → T-to-P → $j\omega_0 \vec{\mathbf{B}}(\vec{\mathbf{r}})$

Maxwell equations
Time domain & Phasor domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

Phasor domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}}) = -j\omega_0 \vec{\mathbf{B}}(\vec{\mathbf{r}}) \end{cases}$$

$\vec{\mathbf{f}}(x,y,z,t)$ → T-to-P → $\vec{\mathbf{F}}(x,y,z)$

$\dfrac{\partial \vec{\mathbf{f}}}{\partial t}$ → T-to-P → $j\omega_0 \vec{\mathbf{F}}(x,y,z)$

$\nabla \cdot \vec{\mathbf{f}}$ → T-to-P → $\nabla \cdot \vec{\mathbf{F}}(x,y,z)$

$\nabla \times \vec{\mathbf{f}}$ → T-to-P → $\nabla \times \vec{\mathbf{F}}(x,y,z)$

$\vec{\mathbf{b}}(\vec{\mathbf{r}},t)$ → T-to-P → $\vec{\mathbf{B}}(\vec{\mathbf{r}})$

$\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t}$ → T-to-P → $j\omega_0 \vec{\mathbf{B}}(\vec{\mathbf{r}})$

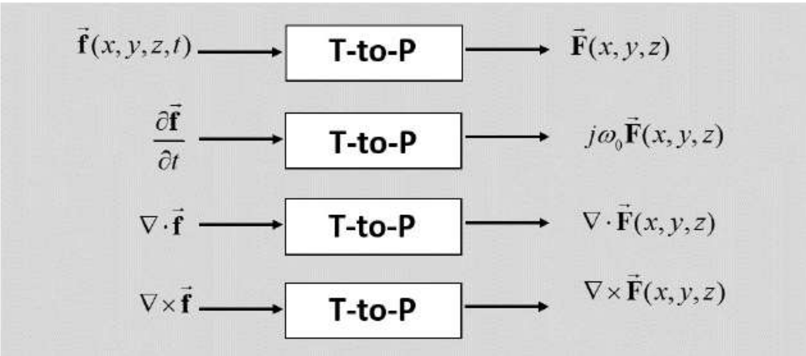
Maxwell equations
Time domain & Phasor domain

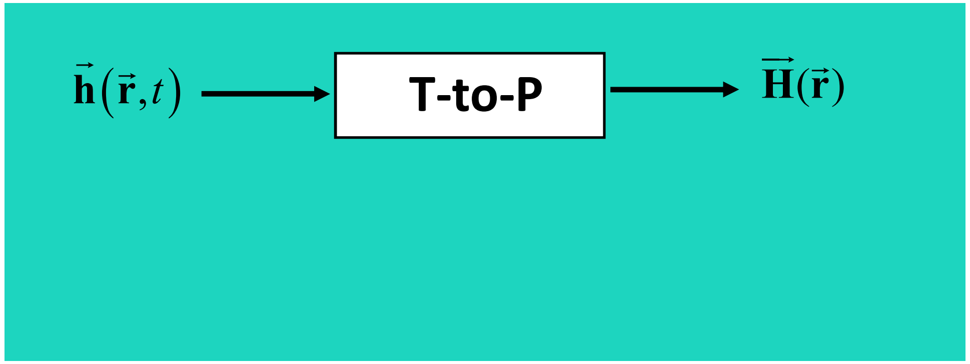
Time domain

$$
\begin{cases}
\nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\
\nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\
\nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\
\nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0
\end{cases}
$$

Phasor domain

$$
\begin{cases}
\nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}}) = -j\omega_0 \vec{\mathbf{B}}(\vec{\mathbf{r}})
\end{cases}
$$





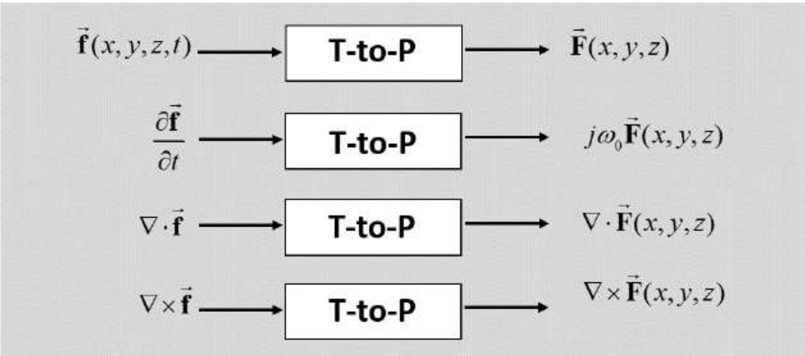
Maxwell equations
Time domain & Phasor domain

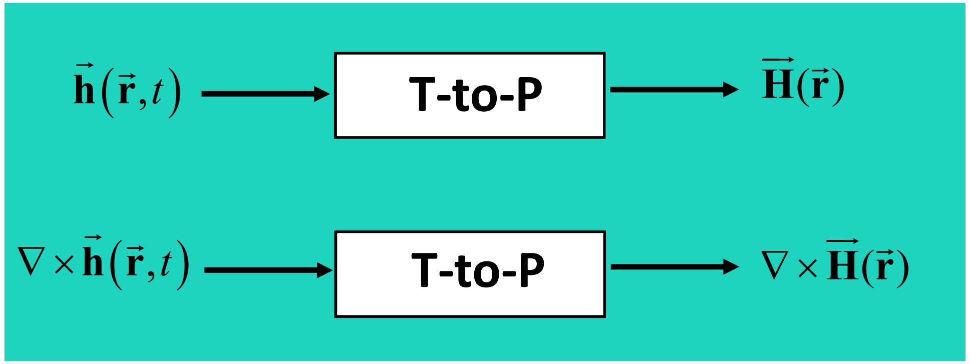
Time domain

$$
\begin{cases}
\nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\
\nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\
\nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\
\nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0
\end{cases}
$$

Phasor domain

$$
\begin{cases}
\nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}}) = -j\omega_0 \vec{\mathbf{B}}(\vec{\mathbf{r}})
\end{cases}
$$





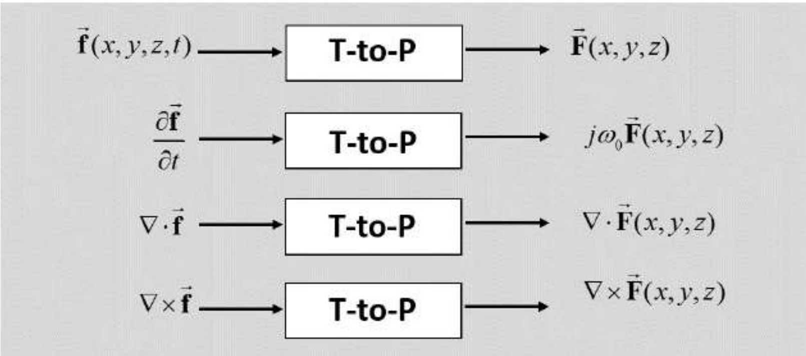
Maxwell equations
Time domain & Phasor domain

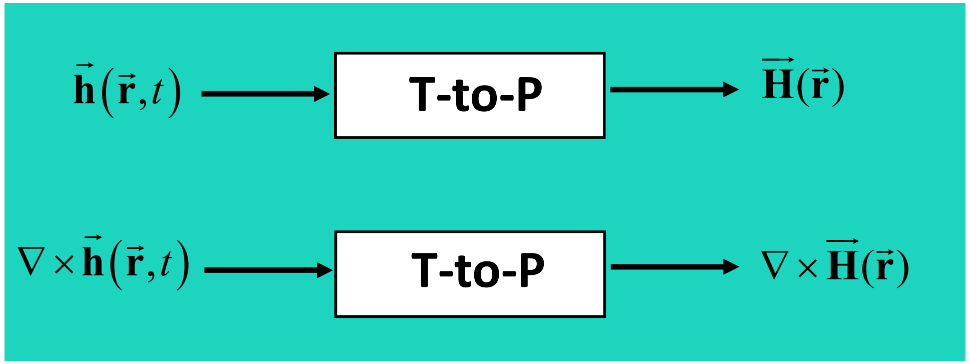
Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

Phasor domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}}) = -j\omega_0 \vec{\mathbf{B}}(\vec{\mathbf{r}}) \\ \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}}) \end{cases}$$





Maxwell equations
Time domain & Phasor domain

Time domain

$$
\begin{cases}
\nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\
\nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\
\nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\
\nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0
\end{cases}
$$

Phasor domain

$$
\begin{cases}
\nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}}) = -j\omega_0 \vec{\mathbf{B}}(\vec{\mathbf{r}}) \\
\nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}})
\end{cases}
$$

$\vec{\mathbf{f}}(x,y,z,t) \longrightarrow$ T-to-P $\longrightarrow \vec{\mathbf{F}}(x,y,z)$

$\dfrac{\partial \vec{\mathbf{f}}}{\partial t} \longrightarrow$ T-to-P $\longrightarrow j\omega_0 \vec{\mathbf{F}}(x,y,z)$

$\nabla \cdot \vec{\mathbf{f}} \longrightarrow$ T-to-P $\longrightarrow \nabla \cdot \vec{\mathbf{F}}(x,y,z)$

$\nabla \times \vec{\mathbf{f}} \longrightarrow$ T-to-P $\longrightarrow \nabla \times \vec{\mathbf{F}}(x,y,z)$

$\vec{\mathbf{d}}(\vec{\mathbf{r}},t) \longrightarrow$ T-to-P $\longrightarrow \vec{\mathbf{D}}(\vec{\mathbf{r}})$

Maxwell equations
Time domain & Phasor domain

Time domain

$$
\begin{cases}
\nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\
\nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\
\nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\
\nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0
\end{cases}
$$

Phasor domain

$$
\begin{cases}
\nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}}) = -j\omega_0 \vec{\mathbf{B}}(\vec{\mathbf{r}}) \\
\nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}})
\end{cases}
$$

$\vec{\mathbf{f}}(x,y,z,t)$ → T-to-P → $\vec{\mathbf{F}}(x,y,z)$

$\dfrac{\partial \vec{\mathbf{f}}}{\partial t}$ → T-to-P → $j\omega_0 \vec{\mathbf{F}}(x,y,z)$

$\nabla \cdot \vec{\mathbf{f}}$ → T-to-P → $\nabla \cdot \vec{\mathbf{F}}(x,y,z)$

$\nabla \times \vec{\mathbf{f}}$ → T-to-P → $\nabla \times \vec{\mathbf{F}}(x,y,z)$

$\vec{\mathbf{d}}(\vec{\mathbf{r}},t)$ → T-to-P → $\vec{\mathbf{D}}(\vec{\mathbf{r}})$

$\dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t}$ → T-to-P → $j\omega_0 \vec{\mathbf{D}}(\vec{\mathbf{r}})$

Maxwell equations
Time domain & Phasor domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

Phasor domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}}) = -j\omega_0 \vec{\mathbf{B}}(\vec{\mathbf{r}}) \\ \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}}) = j\omega_0 \vec{\mathbf{D}}(\vec{\mathbf{r}}) \end{cases}$$

$\vec{\mathbf{f}}(x,y,z,t)$ → T-to-P → $\vec{\mathbf{F}}(x,y,z)$

$\dfrac{\partial \vec{\mathbf{f}}}{\partial t}$ → T-to-P → $j\omega_0 \vec{\mathbf{F}}(x,y,z)$

$\nabla \cdot \vec{\mathbf{f}}$ → T-to-P → $\nabla \cdot \vec{\mathbf{F}}(x,y,z)$

$\nabla \times \vec{\mathbf{f}}$ → T-to-P → $\nabla \times \vec{\mathbf{F}}(x,y,z)$

$\vec{\mathbf{d}}(\vec{\mathbf{r}},t)$ → T-to-P → $\vec{\mathbf{D}}(\vec{\mathbf{r}})$

$\dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t}$ → T-to-P → $j\omega_0 \vec{\mathbf{D}}(\vec{\mathbf{r}})$

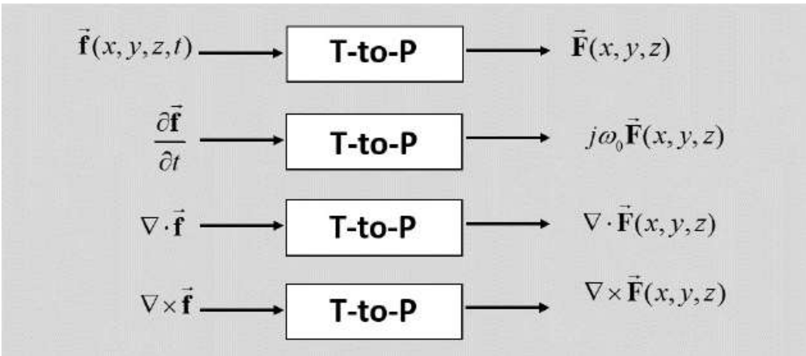
Maxwell equations
Time domain & Phasor domain

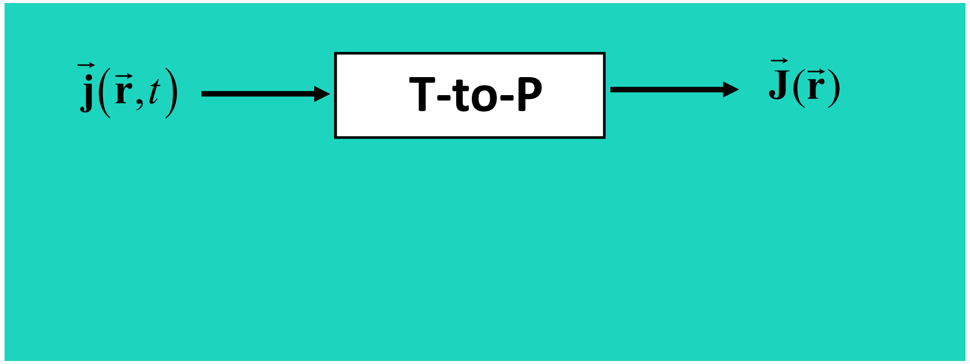
Time domain

$$
\begin{cases}
\nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\
\nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\
\nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\
\nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0
\end{cases}
$$

Phasor domain

$$
\begin{cases}
\nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}}) = -j\omega_0 \vec{\mathbf{B}}(\vec{\mathbf{r}}) \\
\nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}}) = j\omega_0 \vec{\mathbf{D}}(\vec{\mathbf{r}})
\end{cases}
$$





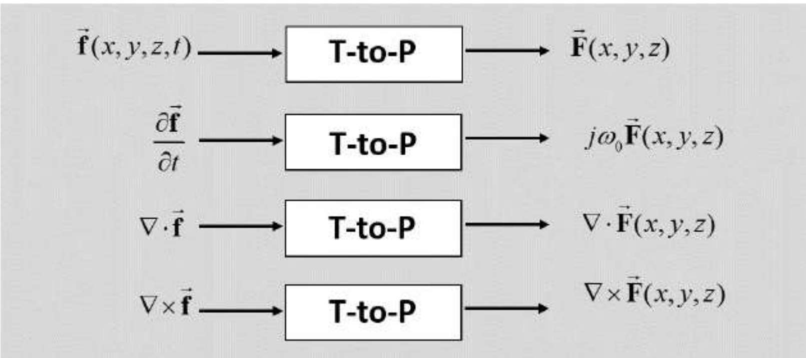
Maxwell equations
Time domain & Phasor domain

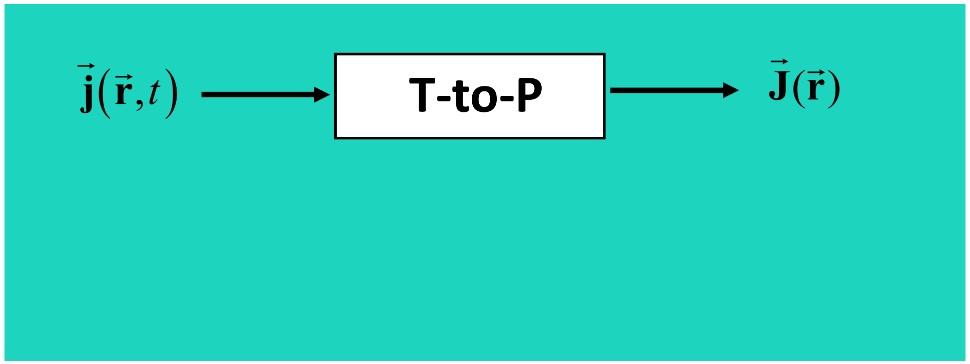
Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

Phasor domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}}) = -j\omega_0 \vec{\mathbf{B}}(\vec{\mathbf{r}}) \\ \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}}) = j\omega_0 \vec{\mathbf{D}}(\vec{\mathbf{r}}) + \vec{\mathbf{J}}(\vec{\mathbf{r}}) \end{cases}$$





Maxwell equations
Time domain & Phasor domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

Phasor domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}}) = -j\omega_0 \vec{\mathbf{B}}(\vec{\mathbf{r}}) \\ \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}}) = j\omega_0 \vec{\mathbf{D}}(\vec{\mathbf{r}}) + \vec{\mathbf{J}}(\vec{\mathbf{r}}) \end{cases}$$

$\vec{\mathbf{f}}(x,y,z,t) \longrightarrow$ T-to-P $\longrightarrow \vec{\mathbf{F}}(x,y,z)$

$\dfrac{\partial \vec{\mathbf{f}}}{\partial t} \longrightarrow$ T-to-P $\longrightarrow j\omega_0 \vec{\mathbf{F}}(x,y,z)$

$\nabla \cdot \vec{\mathbf{f}} \longrightarrow$ T-to-P $\longrightarrow \nabla \cdot \vec{\mathbf{F}}(x,y,z)$

$\nabla \times \vec{\mathbf{f}} \longrightarrow$ T-to-P $\longrightarrow \nabla \times \vec{\mathbf{F}}(x,y,z)$

$\vec{\mathbf{d}}(\vec{\mathbf{r}},t) \longrightarrow$ T-to-P $\longrightarrow \vec{\mathbf{D}}(\vec{\mathbf{r}})$

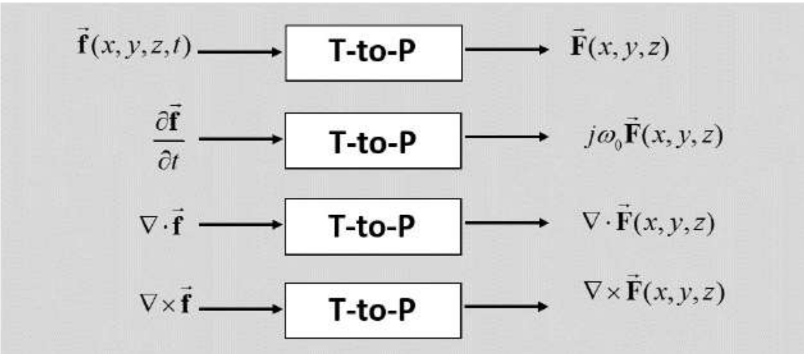
Maxwell equations
Time domain & Phasor domain

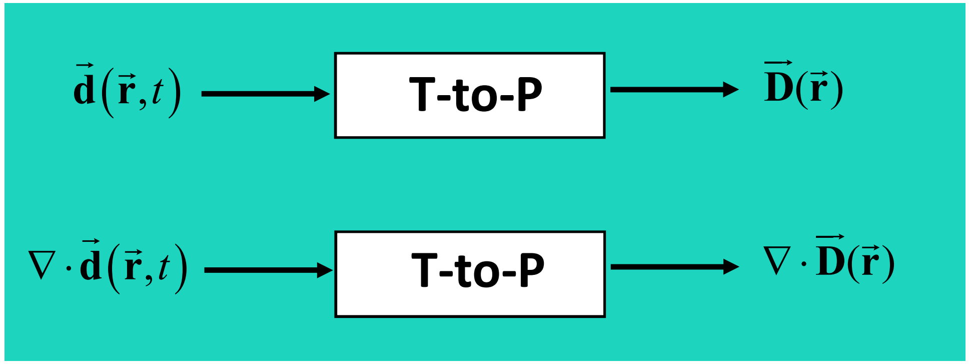
Time domain

$$
\begin{cases}
\nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\
\nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\
\nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\
\nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0
\end{cases}
$$

Phasor domain

$$
\begin{cases}
\nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}}) = -j\omega_0 \vec{\mathbf{B}}(\vec{\mathbf{r}}) \\
\nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}}) = j\omega_0 \vec{\mathbf{D}}(\vec{\mathbf{r}}) + \vec{\mathbf{J}}(\vec{\mathbf{r}})
\end{cases}
$$





Maxwell equations
Time domain & Phasor domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

Phasor domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}}) = -j\omega_0 \vec{\mathbf{B}}(\vec{\mathbf{r}}) \\ \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}}) = j\omega_0 \vec{\mathbf{D}}(\vec{\mathbf{r}}) + \vec{\mathbf{J}}(\vec{\mathbf{r}}) \\ \nabla \cdot \vec{\mathbf{D}}(\vec{\mathbf{r}}) \end{cases}$$

$\vec{\mathbf{f}}(x,y,z,t)$ → T-to-P → $\vec{\mathbf{F}}(x,y,z)$

$\dfrac{\partial \vec{\mathbf{f}}}{\partial t}$ → T-to-P → $j\omega_0 \vec{\mathbf{F}}(x,y,z)$

$\nabla \cdot \vec{\mathbf{f}}$ → T-to-P → $\nabla \cdot \vec{\mathbf{F}}(x,y,z)$

$\nabla \times \vec{\mathbf{f}}$ → T-to-P → $\nabla \times \vec{\mathbf{F}}(x,y,z)$

$\vec{\mathbf{d}}(\vec{\mathbf{r}},t)$ → T-to-P → $\vec{\mathbf{D}}(\vec{\mathbf{r}})$

$\nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t)$ → T-to-P → $\nabla \cdot \vec{\mathbf{D}}(\vec{\mathbf{r}})$

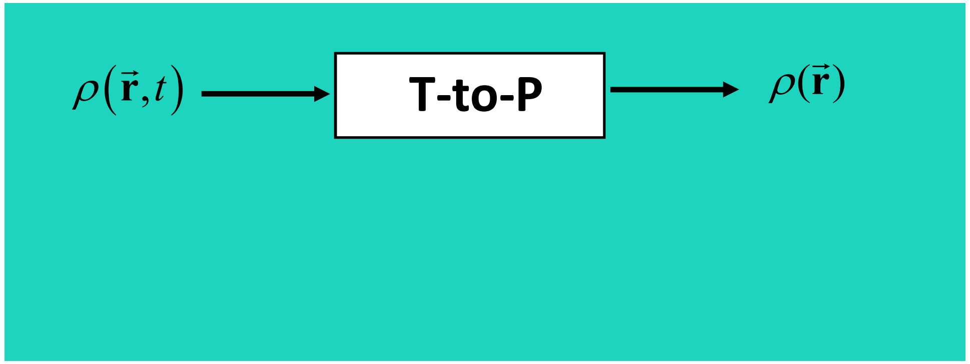
Maxwell equations
Time domain & Phasor domain

Time domain

$$
\begin{cases}
\nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\
\nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\
\nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\
\nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0
\end{cases}
$$

Phasor domain

$$
\begin{cases}
\nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}}) = -j\omega_0 \vec{\mathbf{B}}(\vec{\mathbf{r}}) \\
\nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}}) = j\omega_0 \vec{\mathbf{D}}(\vec{\mathbf{r}}) + \vec{\mathbf{J}}(\vec{\mathbf{r}}) \\
\nabla \cdot \vec{\mathbf{D}}(\vec{\mathbf{r}})
\end{cases}
$$



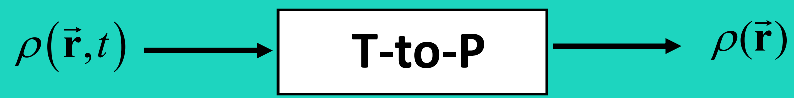
Maxwell equations
Time domain & Phasor domain

Time domain

$$
\begin{cases}
\nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\
\nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\
\nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\
\nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0
\end{cases}
$$

Phasor domain

$$
\begin{cases}
\nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}}) = -j\omega_0 \vec{\mathbf{B}}(\vec{\mathbf{r}}) \\
\nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}}) = j\omega_0 \vec{\mathbf{D}}(\vec{\mathbf{r}}) + \vec{\mathbf{J}}(\vec{\mathbf{r}}) \\
\nabla \cdot \vec{\mathbf{D}}(\vec{\mathbf{r}}) = \rho(\vec{\mathbf{r}})
\end{cases}
$$



Maxwell equations
Time domain & Phasor domain

Time domain

$$
\begin{cases}
\nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\
\nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\
\nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\
\nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0
\end{cases}
$$

Phasor domain

$$
\begin{cases}
\nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}}) = -j\omega_0 \vec{\mathbf{B}}(\vec{\mathbf{r}}) \\
\nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}}) = j\omega_0 \vec{\mathbf{D}}(\vec{\mathbf{r}}) + \vec{\mathbf{J}}(\vec{\mathbf{r}}) \\
\nabla \cdot \vec{\mathbf{D}}(\vec{\mathbf{r}}) = \rho(\vec{\mathbf{r}})
\end{cases}
$$

$\vec{\mathbf{f}}(x,y,z,t) \longrightarrow$ T-to-P $\longrightarrow \vec{\mathbf{F}}(x,y,z)$

$\dfrac{\partial \vec{\mathbf{f}}}{\partial t} \longrightarrow$ T-to-P $\longrightarrow j\omega_0 \vec{\mathbf{F}}(x,y,z)$

$\nabla \cdot \vec{\mathbf{f}} \longrightarrow$ T-to-P $\longrightarrow \nabla \cdot \vec{\mathbf{F}}(x,y,z)$

$\nabla \times \vec{\mathbf{f}} \longrightarrow$ T-to-P $\longrightarrow \nabla \times \vec{\mathbf{F}}(x,y,z)$

$\vec{\mathbf{b}}(\vec{\mathbf{r}},t) \longrightarrow$ T-to-P $\longrightarrow \vec{\mathbf{B}}(\vec{\mathbf{r}})$

Maxwell equations
Time domain & Phasor domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

Phasor domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}}) = -j\omega_0 \vec{\mathbf{B}}(\vec{\mathbf{r}}) \\ \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}}) = j\omega_0 \vec{\mathbf{D}}(\vec{\mathbf{r}}) + \vec{\mathbf{J}}(\vec{\mathbf{r}}) \\ \nabla \cdot \vec{\mathbf{D}}(\vec{\mathbf{r}}) = \rho(\vec{\mathbf{r}}) \end{cases}$$

$\vec{\mathbf{f}}(x,y,z,t) \longrightarrow$ T-to-P $\longrightarrow \vec{\mathbf{F}}(x,y,z)$

$\dfrac{\partial \vec{\mathbf{f}}}{\partial t} \longrightarrow$ T-to-P $\longrightarrow j\omega_0 \vec{\mathbf{F}}(x,y,z)$

$\nabla \cdot \vec{\mathbf{f}} \longrightarrow$ T-to-P $\longrightarrow \nabla \cdot \vec{\mathbf{F}}(x,y,z)$

$\nabla \times \vec{\mathbf{f}} \longrightarrow$ T-to-P $\longrightarrow \nabla \times \vec{\mathbf{F}}(x,y,z)$

$\vec{\mathbf{b}}(\vec{\mathbf{r}},t) \longrightarrow$ T-to-P $\longrightarrow \vec{\mathbf{B}}(\vec{\mathbf{r}})$

$\nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) \longrightarrow$ T-to-P $\longrightarrow \nabla \cdot \vec{\mathbf{B}}(\vec{\mathbf{r}})$

Maxwell equations
Time domain & Phasor domain

Time domain

$$
\begin{cases}
\nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\
\nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\
\nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\
\nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0
\end{cases}
$$

Phasor domain

$$
\begin{cases}
\nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}}) = -j\omega_0 \vec{\mathbf{B}}(\vec{\mathbf{r}}) \\
\nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}}) = j\omega_0 \vec{\mathbf{D}}(\vec{\mathbf{r}}) + \vec{\mathbf{J}}(\vec{\mathbf{r}}) \\
\nabla \cdot \vec{\mathbf{D}}(\vec{\mathbf{r}}) = \rho(\vec{\mathbf{r}}) \\
\nabla \cdot \vec{\mathbf{B}}(\vec{\mathbf{r}})
\end{cases}
$$

$\vec{\mathbf{f}}(x,y,z,t)$ → **T-to-P** → $\vec{\mathbf{F}}(x,y,z)$

$\dfrac{\partial \vec{\mathbf{f}}}{\partial t}$ → **T-to-P** → $j\omega_0 \vec{\mathbf{F}}(x,y,z)$

$\nabla \cdot \vec{\mathbf{f}}$ → **T-to-P** → $\nabla \cdot \vec{\mathbf{F}}(x,y,z)$

$\nabla \times \vec{\mathbf{f}}$ → **T-to-P** → $\nabla \times \vec{\mathbf{F}}(x,y,z)$

$\vec{\mathbf{b}}(\vec{\mathbf{r}},t)$ → **T-to-P** → $\vec{\mathbf{B}}(\vec{\mathbf{r}})$

$\nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t)$ → **T-to-P** → $\nabla \cdot \vec{\mathbf{B}}(\vec{\mathbf{r}})$

Maxwell equations
Time domain & Phasor domain

Time domain

$$
\begin{cases}
\nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\
\nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\
\nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\
\nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0
\end{cases}
$$

Phasor domain

$$
\begin{cases}
\nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}}) = -j\omega_0 \vec{\mathbf{B}}(\vec{\mathbf{r}}) \\
\nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}}) = j\omega_0 \vec{\mathbf{D}}(\vec{\mathbf{r}}) + \vec{\mathbf{J}}(\vec{\mathbf{r}}) \\
\nabla \cdot \vec{\mathbf{D}}(\vec{\mathbf{r}}) = \rho(\vec{\mathbf{r}}) \\
\nabla \cdot \vec{\mathbf{B}}(\vec{\mathbf{r}}) = 0
\end{cases}
$$

Maxwell equations
Time domain & Phasor domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

Phasor domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}}) = -j\omega_0 \vec{\mathbf{B}}(\vec{\mathbf{r}}) \\ \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}}) = j\omega_0 \vec{\mathbf{D}}(\vec{\mathbf{r}}) + \vec{\mathbf{J}}(\vec{\mathbf{r}}) \\ \nabla \cdot \vec{\mathbf{D}}(\vec{\mathbf{r}}) = \rho(\vec{\mathbf{r}}) \\ \nabla \cdot \vec{\mathbf{B}}(\vec{\mathbf{r}}) = 0 \end{cases}$$

Maxwell equations
Time domain & Phasor domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

Phasor domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}}) = -j\omega_0 \vec{\mathbf{B}}(\vec{\mathbf{r}}) \\ \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}}) = j\omega_0 \vec{\mathbf{D}}(\vec{\mathbf{r}}) + \vec{\mathbf{J}}(\vec{\mathbf{r}}) \\ \nabla \cdot \vec{\mathbf{D}}(\vec{\mathbf{r}}) = \rho(\vec{\mathbf{r}}) \\ \nabla \cdot \vec{\mathbf{B}}(\vec{\mathbf{r}}) = 0 \end{cases}$$

$\vec{\mathbf{e}}(\vec{\mathbf{r}},t)$	Volt/m
$\vec{\mathbf{d}}(\vec{\mathbf{r}},t)$	Coulomb/m^2
$\vec{\mathbf{h}}(\vec{\mathbf{r}},t)$	Ampere/m
$\vec{\mathbf{b}}(\vec{\mathbf{r}},t)$	Weber/m^2
$\vec{\mathbf{j}}(\vec{\mathbf{r}},t)$	Ampere/m^2
$\rho(\vec{\mathbf{r}},t)$	Coulomb/m^3

Maxwell equations
Time domain & Phasor domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

Phasor domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}}) = -j\omega_0 \vec{\mathbf{B}}(\vec{\mathbf{r}}) \\ \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}}) = j\omega_0 \vec{\mathbf{D}}(\vec{\mathbf{r}}) + \vec{\mathbf{J}}(\vec{\mathbf{r}}) \\ \nabla \cdot \vec{\mathbf{D}}(\vec{\mathbf{r}}) = \rho(\vec{\mathbf{r}}) \\ \nabla \cdot \vec{\mathbf{B}}(\vec{\mathbf{r}}) = 0 \end{cases}$$

$\vec{\mathbf{e}}(\vec{\mathbf{r}},t)$	Volt/m	$\vec{\mathbf{E}}(\vec{\mathbf{r}})$
$\vec{\mathbf{d}}(\vec{\mathbf{r}},t)$	Coulomb/m^2	$\vec{\mathbf{D}}(\vec{\mathbf{r}})$
$\vec{\mathbf{h}}(\vec{\mathbf{r}},t)$	Ampere/m	$\vec{\mathbf{H}}(\vec{\mathbf{r}})$
$\vec{\mathbf{b}}(\vec{\mathbf{r}},t)$	Weber/m^2	$\vec{\mathbf{B}}(\vec{\mathbf{r}})$
$\vec{\mathbf{j}}(\vec{\mathbf{r}},t)$	Ampere/m^2	$\vec{\mathbf{J}}(\vec{\mathbf{r}})$
$\rho(\vec{\mathbf{r}},t)$	Coulomb/m^3	$\rho(\vec{\mathbf{r}})$

Maxwell equations
Time domain & Phasor domain

Time domain

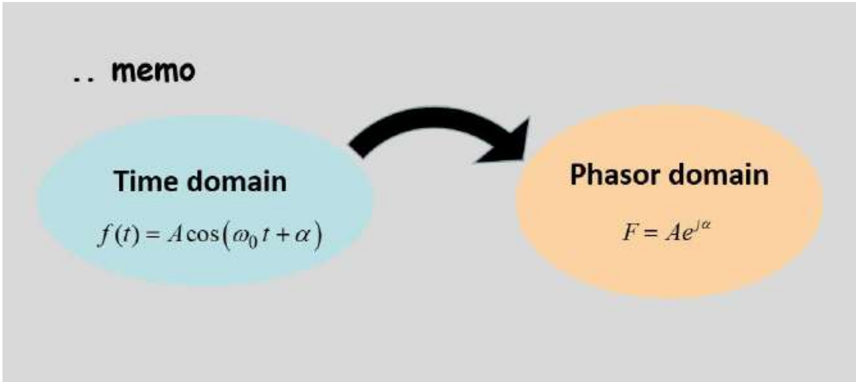
$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

Phasor domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}}) = -j\omega_0 \vec{\mathbf{B}}(\vec{\mathbf{r}}) \\ \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}}) = j\omega_0 \vec{\mathbf{D}}(\vec{\mathbf{r}}) + \vec{\mathbf{J}}(\vec{\mathbf{r}}) \\ \nabla \cdot \vec{\mathbf{D}}(\vec{\mathbf{r}}) = \rho(\vec{\mathbf{r}}) \\ \nabla \cdot \vec{\mathbf{B}}(\vec{\mathbf{r}}) = 0 \end{cases}$$

$\vec{\mathbf{e}}(\vec{\mathbf{r}},t)$	Volt/m
$\vec{\mathbf{d}}(\vec{\mathbf{r}},t)$	Coulomb/m^2
$\vec{\mathbf{h}}(\vec{\mathbf{r}},t)$	Ampere/m
$\vec{\mathbf{b}}(\vec{\mathbf{r}},t)$	Weber/m^2
$\vec{\mathbf{j}}(\vec{\mathbf{r}},t)$	Ampere/m^2
$\rho(\vec{\mathbf{r}},t)$	Coulomb/m^3

$\vec{\mathbf{E}}(\vec{\mathbf{r}})$



Maxwell equations
Time domain & Phasor domain

Time domain

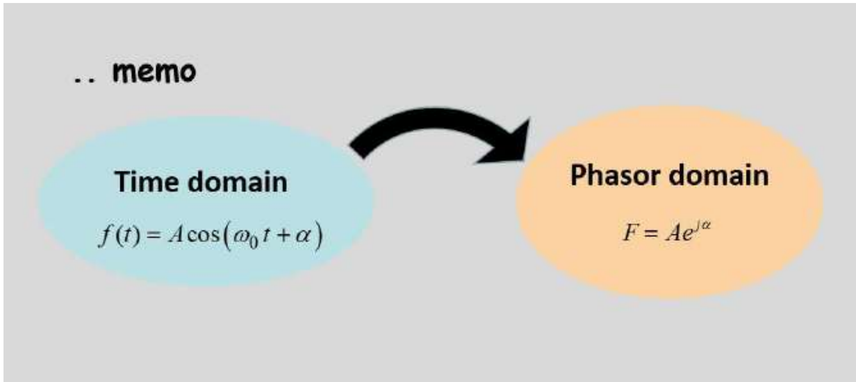
$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

Phasor domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}}) = -j\omega_0 \vec{\mathbf{B}}(\vec{\mathbf{r}}) \\ \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}}) = j\omega_0 \vec{\mathbf{D}}(\vec{\mathbf{r}}) + \vec{\mathbf{J}}(\vec{\mathbf{r}}) \\ \nabla \cdot \vec{\mathbf{D}}(\vec{\mathbf{r}}) = \rho(\vec{\mathbf{r}}) \\ \nabla \cdot \vec{\mathbf{B}}(\vec{\mathbf{r}}) = 0 \end{cases}$$

$\vec{\mathbf{e}}(\vec{\mathbf{r}},t)$	Volt/m
$\vec{\mathbf{d}}(\vec{\mathbf{r}},t)$	Coulomb/m^2
$\vec{\mathbf{h}}(\vec{\mathbf{r}},t)$	Ampere/m
$\vec{\mathbf{b}}(\vec{\mathbf{r}},t)$	Weber/m^2
$\vec{\mathbf{j}}(\vec{\mathbf{r}},t)$	Ampere/m^2
$\rho(\vec{\mathbf{r}},t)$	Coulomb/m^3

$\vec{\mathbf{E}}(\vec{\mathbf{r}})$ Volt/m



Maxwell equations
Time domain & Phasor domain

Time domain

$$
\begin{cases}
\nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\
\nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\
\nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\
\nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0
\end{cases}
$$

Phasor domain

$$
\begin{cases}
\nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}}) = -j\omega_0 \vec{\mathbf{B}}(\vec{\mathbf{r}}) \\
\nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}}) = j\omega_0 \vec{\mathbf{D}}(\vec{\mathbf{r}}) + \vec{\mathbf{J}}(\vec{\mathbf{r}}) \\
\nabla \cdot \vec{\mathbf{D}}(\vec{\mathbf{r}}) = \rho(\vec{\mathbf{r}}) \\
\nabla \cdot \vec{\mathbf{B}}(\vec{\mathbf{r}}) = 0
\end{cases}
$$

$\vec{\mathbf{e}}(\vec{\mathbf{r}},t)$	Volt/m	$\vec{\mathbf{E}}(\vec{\mathbf{r}})$	Volt/m
$\vec{\mathbf{d}}(\vec{\mathbf{r}},t)$	Coulomb/m^2	$\vec{\mathbf{D}}(\vec{\mathbf{r}})$	Coulomb/m^2
$\vec{\mathbf{h}}(\vec{\mathbf{r}},t)$	Ampere/m	$\vec{\mathbf{H}}(\vec{\mathbf{r}})$	Ampere/m
$\vec{\mathbf{b}}(\vec{\mathbf{r}},t)$	Weber/m^2	$\vec{\mathbf{B}}(\vec{\mathbf{r}})$	Weber/m^2
$\vec{\mathbf{j}}(\vec{\mathbf{r}},t)$	Ampere/m^2	$\vec{\mathbf{J}}(\vec{\mathbf{r}})$	Ampere/m^2
$\rho(\vec{\mathbf{r}},t)$	Coulomb/m^3	$\rho(\vec{\mathbf{r}})$	Coulomb/m^3

Maxwell equations
Frequency domain & Phasor domain

Frequency domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}},\omega) = -j\omega \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) \\ \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}},\omega) = j\omega \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) + \vec{\mathbf{J}}(\vec{\mathbf{r}},\omega) \\ \nabla \cdot \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) = \rho(\vec{\mathbf{r}},\omega) \\ \nabla \cdot \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) = 0 \end{cases}$$

Phasor domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}}) = -j\omega_0 \vec{\mathbf{B}}(\vec{\mathbf{r}}) \\ \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}}) = j\omega_0 \vec{\mathbf{D}}(\vec{\mathbf{r}}) + \vec{\mathbf{J}}(\vec{\mathbf{r}}) \\ \nabla \cdot \vec{\mathbf{D}}(\vec{\mathbf{r}}) = \rho(\vec{\mathbf{r}}) \\ \nabla \cdot \vec{\mathbf{B}}(\vec{\mathbf{r}}) = 0 \end{cases}$$

The Maxwell equations in the Fourier domain and Phasor domain are formally equivalent.

However, they exhibit noticeable differences:

i) The dimensions of the involved quantities (f.i., $\vec{\mathbf{E}}$) are different in the two domains.

ii) In the Frequency domain ω is an independent variable, whereas in the Phasor domain ω_0 is fixed.

Color legend

New formulas, important considerations,
important formulas, important concepts

Very important for the discussion

Memo

Mathematical tools to be exploited

Mathematics

Maxwell equations
Time domain & Phasor domain

Time domain

$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$

$$\frac{\partial \rho(\vec{\mathbf{r}},t)}{\partial t} + \nabla \cdot \vec{\mathbf{j}}(\vec{\mathbf{r}},t) = 0$$

Frequency domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}},\omega) = -j\omega \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) \\ \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}},\omega) = j\omega \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) + \vec{\mathbf{J}}(\vec{\mathbf{r}},\omega) \\ \nabla \cdot \vec{\mathbf{D}}(\vec{\mathbf{r}},\omega) = \rho(\vec{\mathbf{r}},\omega) \\ \nabla \cdot \vec{\mathbf{B}}(\vec{\mathbf{r}},\omega) = 0 \end{cases}$$

$$j\omega\rho(\vec{\mathbf{r}},\omega) + \nabla \cdot \vec{\mathbf{J}}(\vec{\mathbf{r}},\omega) = 0$$

Phasor domain

$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}}) = -j\omega_0 \vec{\mathbf{B}}(\vec{\mathbf{r}}) \\ \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}}) = j\omega_0 \vec{\mathbf{D}}(\vec{\mathbf{r}}) + \vec{\mathbf{J}}(\vec{\mathbf{r}}) \\ \nabla \cdot \vec{\mathbf{D}}(\vec{\mathbf{r}}) = \rho(\vec{\mathbf{r}}) \\ \nabla \cdot \vec{\mathbf{B}}(\vec{\mathbf{r}}) = 0 \end{cases}$$

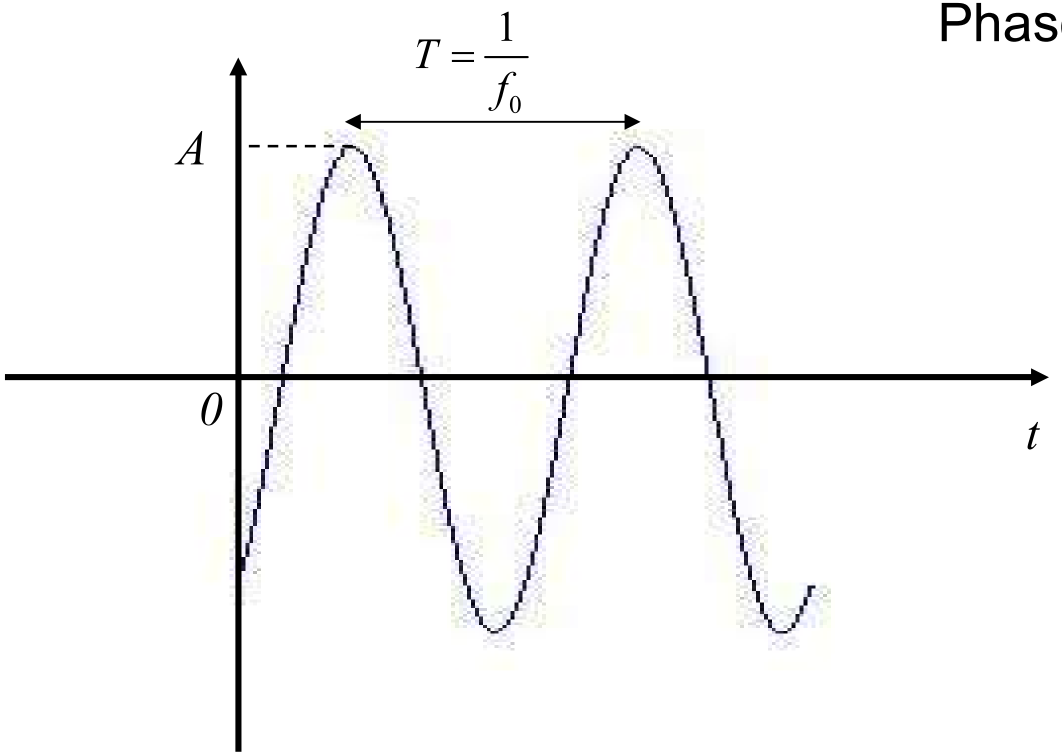
$$j\omega_0\rho(\vec{\mathbf{r}}) + \nabla \cdot \vec{\mathbf{J}}(\vec{\mathbf{r}}) = 0$$

Memo: Phasors

Phasors

$$v(t) = A\cos\left(2\pi f_0 t + \alpha\right) \longrightarrow V = Ae^{j\alpha}$$

Phasor (complex number)



Phasors

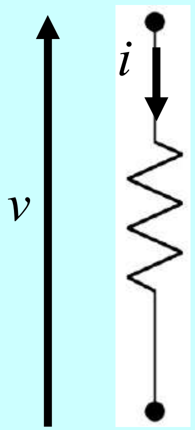
$$v(t) = A\cos\left(\omega_0 t + \alpha\right) \longrightarrow V = Ae^{j\alpha}$$

$$k \cdot v(t) \longrightarrow k \cdot V = k \cdot Ae^{j\alpha}$$

Phasors

$$v(t) = A\cos(\omega_0 t + \alpha) \longrightarrow V = Ae^{j\alpha}$$

$$k \cdot v(t) \longrightarrow k \cdot V = k \cdot Ae^{j\alpha}$$



$$v(t) = R \cdot i(t)$$

$$i(t) \rightarrow I$$

$$v(t) \rightarrow V$$

$$V = R \cdot I$$

$$V = Z \cdot I$$

$$Z = R$$

Phasors

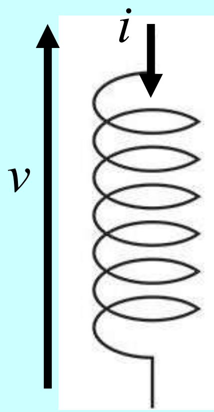
$$v(t) = A\cos\left(\omega_0 t + \alpha\right) \longrightarrow V = Ae^{j\alpha}$$

$$\frac{dv(t)}{dt} \longrightarrow j\omega_0 V = j\omega_0 A e^{j\alpha}$$

Phasors

$$v(t) = A\cos(\omega_0 t + \alpha) \longrightarrow V = Ae^{j\alpha}$$

$$\frac{dv(t)}{dt} \longrightarrow j\omega_0 V = j\omega_0 A e^{j\alpha}$$



$$v(t) = L\frac{di(t)}{dt}$$

$$i(t) \rightarrow I$$

$$v(t) \rightarrow V$$

$$V = j\omega_0 L I$$

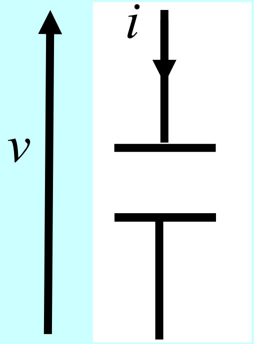
$$V = Z \cdot I$$

$$Z = j\omega_0 L$$

Phasors

$$v(t) = A\cos(\omega_0 t + \alpha) \longrightarrow V = Ae^{j\alpha}$$

$$\frac{dv(t)}{dt} \longrightarrow j\omega_0 V = j\omega_0 A e^{j\alpha}$$



$$i(t) = C\frac{dv(t)}{dt}$$

$$i(t) \rightarrow I$$

$$v(t) \rightarrow V$$

$$I = j\omega_0 C V$$

$$V = Z \cdot I$$

$$Z = -j\frac{1}{\omega_0 C}$$

Phasors

$$v(t) = A\cos\left(\omega_0 t + \alpha\right) \longrightarrow V = Ae^{j\alpha}$$

$$i(t) = B\cos\left(\omega_0 t + \beta\right) \longrightarrow I = Be^{j\beta}$$

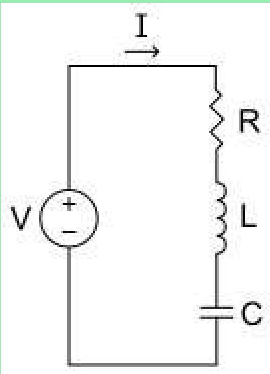
$$\left\langle v(t)\cdot i(t)\right\rangle = \frac{1}{T}\int_0^T v(t)\cdot i(t)\,dt \;= \frac{1}{2}\mathrm{Re}\left\{V\cdot I^*\right\}$$

Phasors

$$v(t) = A\cos\left(\omega_0 t + \alpha\right) \longrightarrow V = Ae^{j\alpha}$$

$$i(t) = B\cos\left(\omega_0 t + \beta\right) \longrightarrow I = Be^{j\beta}$$

$$\left\langle v(t)\cdot i(t)\right\rangle = \frac{1}{T}\int_0^T v(t)\cdot i(t)\,dt = \frac{1}{2}\mathrm{Re}\left\{V\cdot I^*\right\}$$



$$P = \frac{1}{2}V\cdot I^* = P_1 + jP_2$$

$$P = \frac{1}{2}V\cdot I^* = \frac{1}{2}\left(Z_R + Z_L + Z_C\right)I\cdot I^* = \frac{1}{2}\left(R + j\omega_0 L - \frac{j}{\omega_0 C}\right)\left|I\right|^2$$

$$P_1 = \frac{1}{2}R\left|I\right|^2 \quad ; \quad P_2 = \frac{1}{2}\left(\omega_0 L - \frac{1}{\omega_0 C}\right)\left|I\right|^2$$

Phasors and vector functions of *n* variables

$$\vec{\mathbf{f}}_1(x, y, z, t) \longrightarrow \vec{\mathbf{F}}_1(x, y, z)$$

$$\vec{\mathbf{f}}_2(x, y, z, t) \longrightarrow \vec{\mathbf{F}}_2(x, y, z)$$

Phasors and vector functions of *n* variables

$$\vec{\mathbf{f}}_1(\vec{\mathbf{r}},t) \longrightarrow \vec{\mathbf{F}}_1(\vec{\mathbf{r}})$$

$$\vec{\mathbf{f}}_2(\vec{\mathbf{r}},t) \longrightarrow \vec{\mathbf{F}}_2(\vec{\mathbf{r}})$$

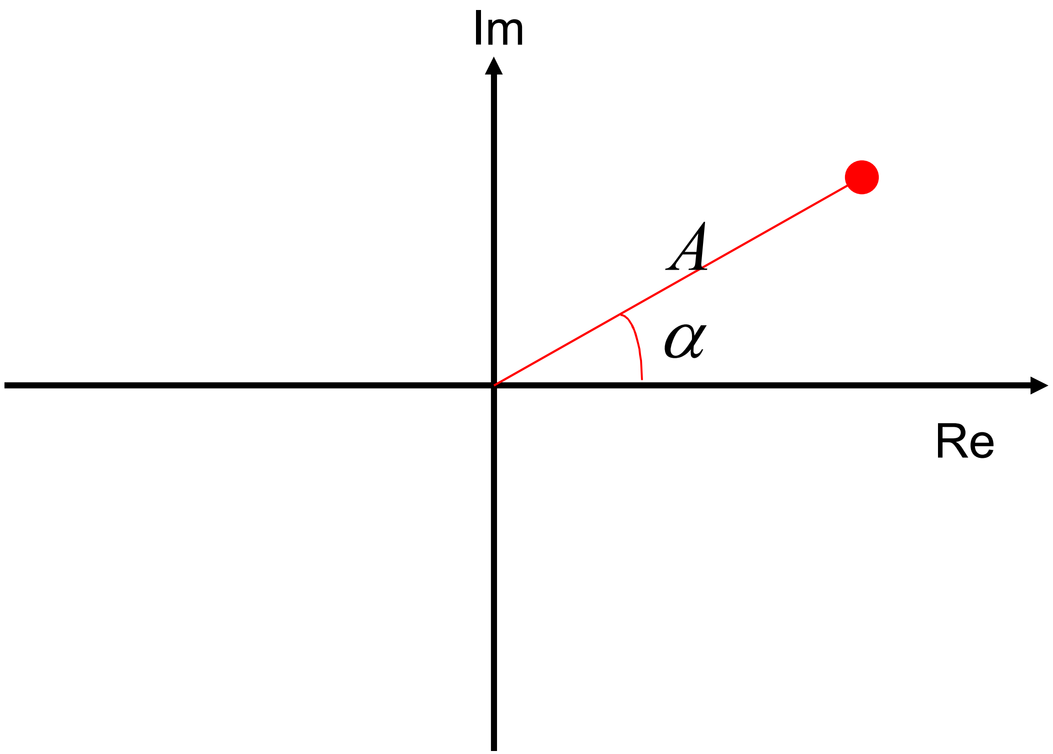
$$\left\langle \vec{\mathbf{f}}_1(\vec{\mathbf{r}},t)\cdot\vec{\mathbf{f}}_2(\vec{\mathbf{r}},t) \right\rangle = \frac{1}{T}\int_0^T \vec{\mathbf{f}}_1(\vec{\mathbf{r}},t)\cdot\vec{\mathbf{f}}_2(\vec{\mathbf{r}},t)\,dt \quad = \frac{1}{2}\mathrm{Re}\left\{\vec{\mathbf{F}}_1(\vec{\mathbf{r}})\cdot\vec{\mathbf{F}}_2^*(\vec{\mathbf{r}})\right\}$$

$$\left\langle \vec{\mathbf{f}}_1(\vec{\mathbf{r}},t)\times\vec{\mathbf{f}}_2(\vec{\mathbf{r}},t) \right\rangle = \frac{1}{T}\int_0^T \vec{\mathbf{f}}_1(\vec{\mathbf{r}},t)\times\vec{\mathbf{f}}_2(\vec{\mathbf{r}},t)\,dt \quad = \frac{1}{2}\mathrm{Re}\left\{\vec{\mathbf{F}}_1(\vec{\mathbf{r}})\times\vec{\mathbf{F}}_2^*(\vec{\mathbf{r}})\right\}$$

Memo: complex numbers

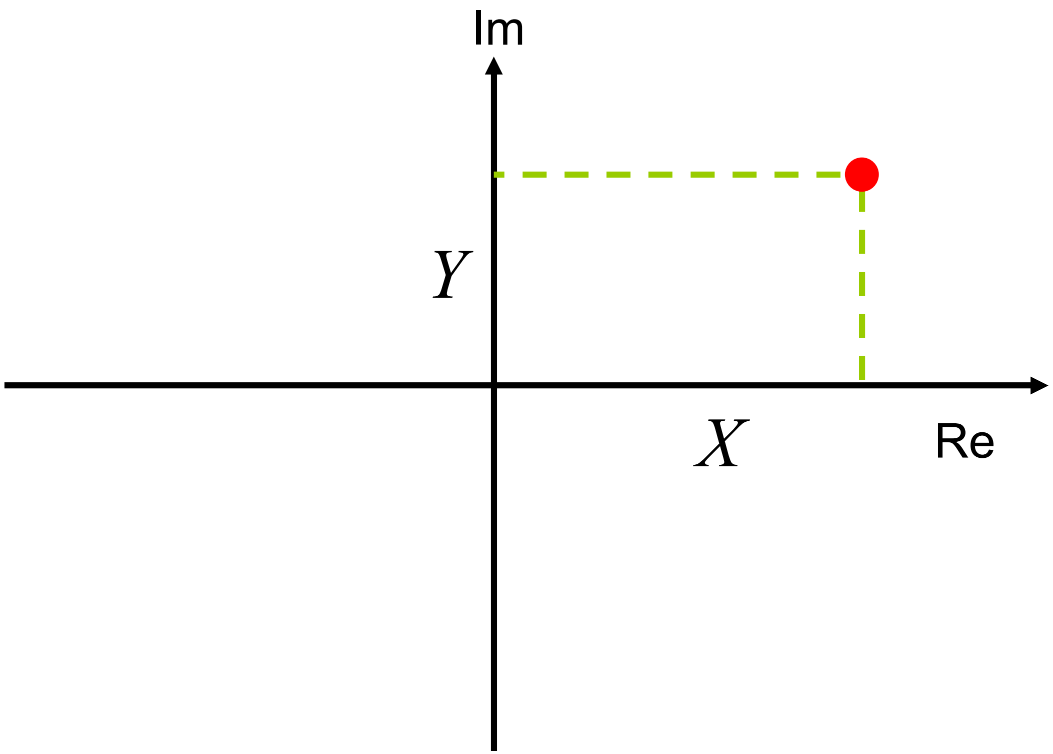
Complex numbers

$$Ae^{j\alpha}$$



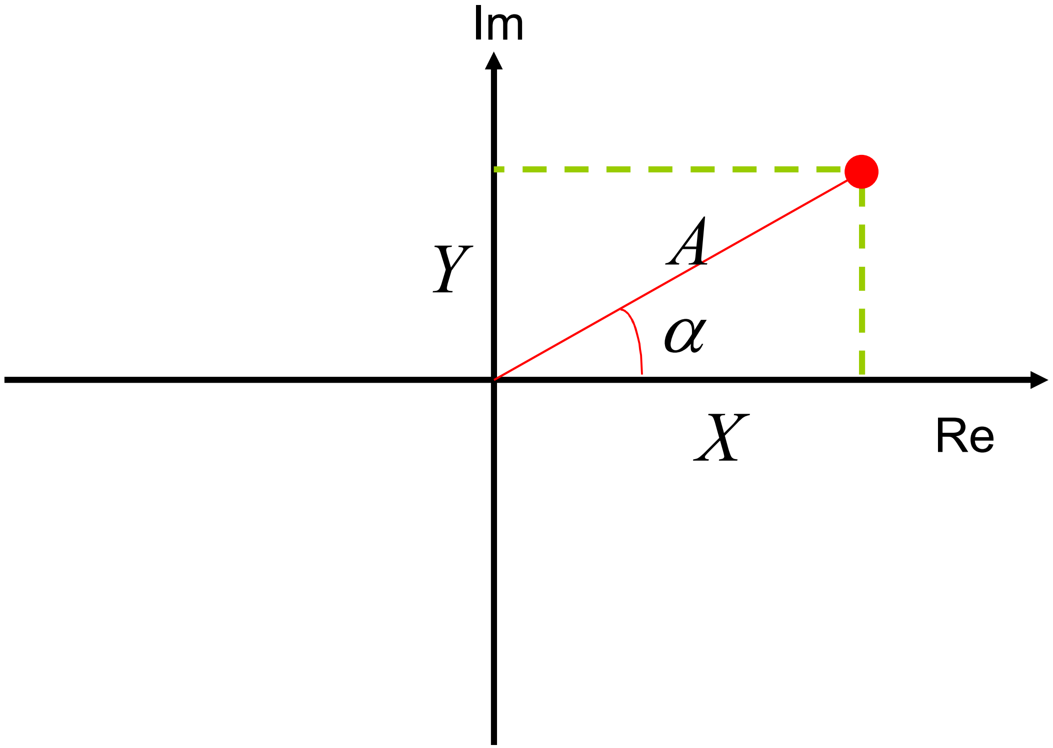
Complex numbers

$$Ae^{j\alpha} = X + jY$$



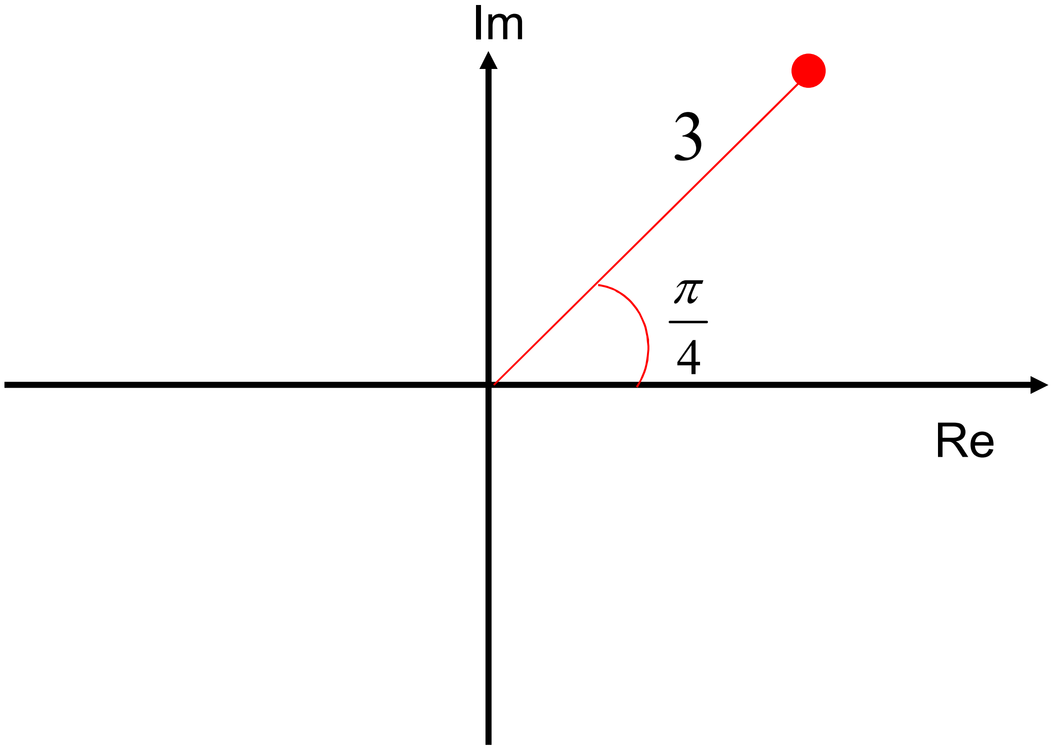
Complex numbers

$$Ae^{j\alpha} = X + jY$$



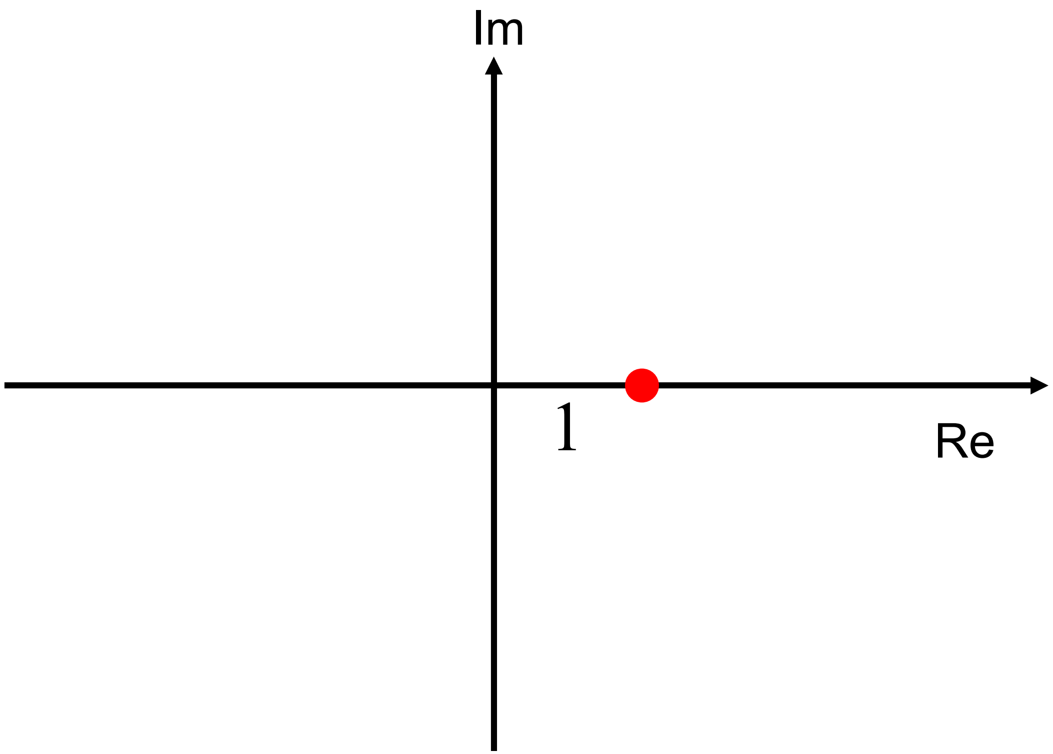
Complex numbers: some examples

$$3e^{j\frac{\pi}{4}}$$



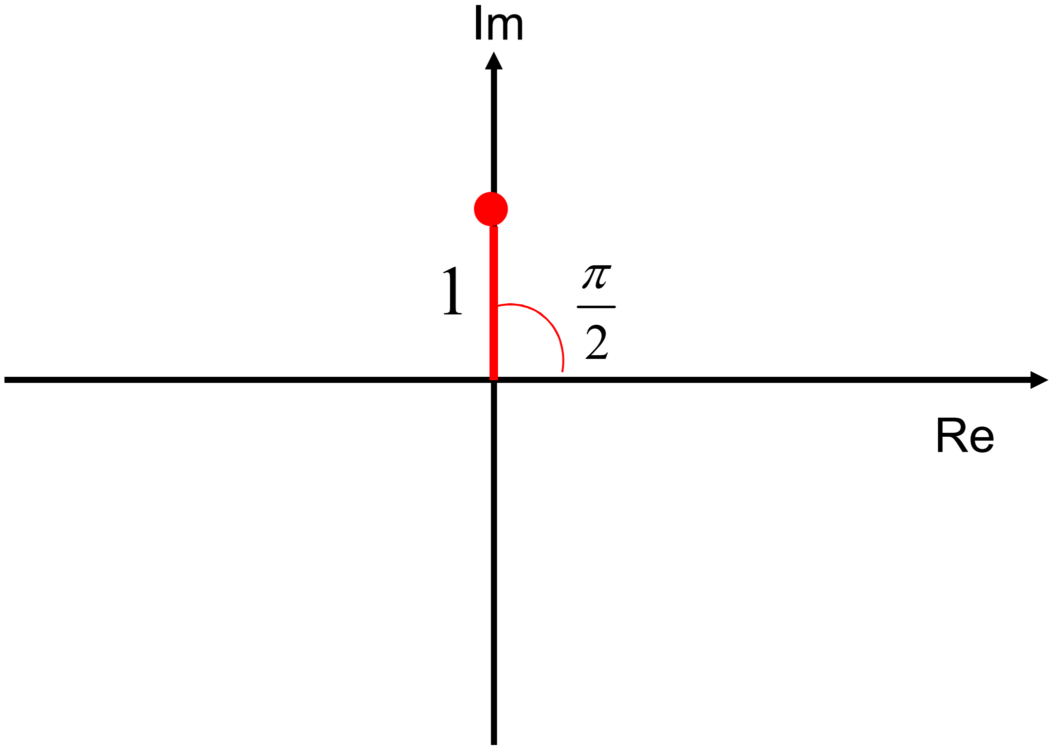
Complex numbers: some examples

$$1$$



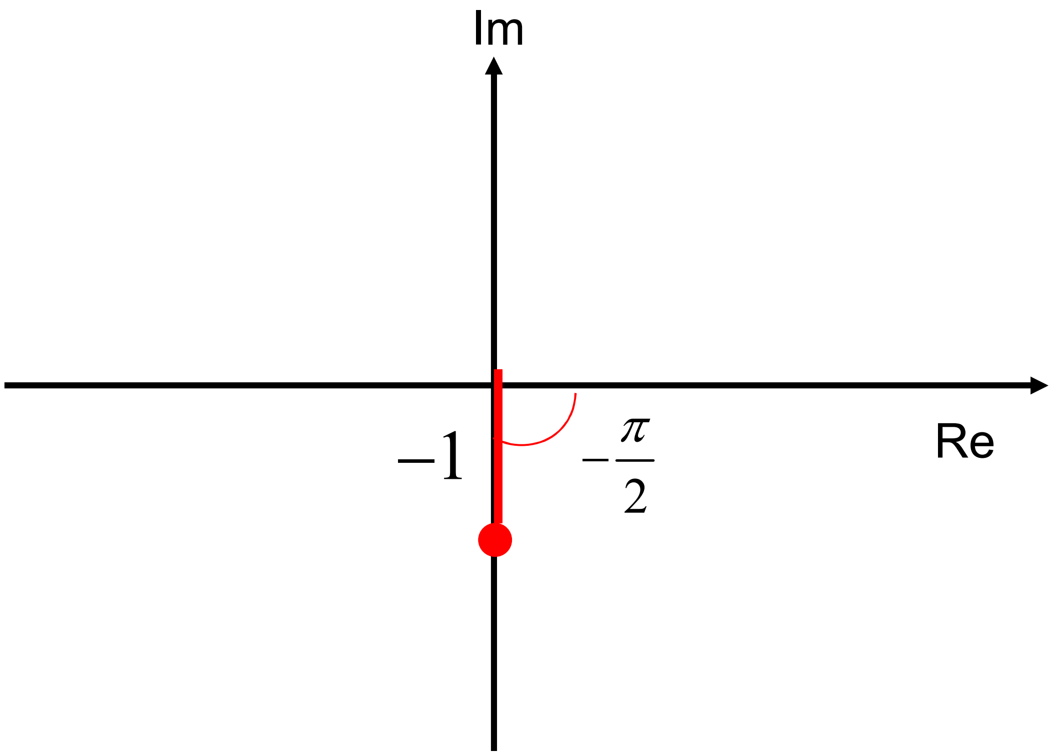
Complex numbers: some examples

$$j = e^{j\frac{\pi}{2}} = e^{j\left(\frac{\pi}{2}+2\pi\right)}$$



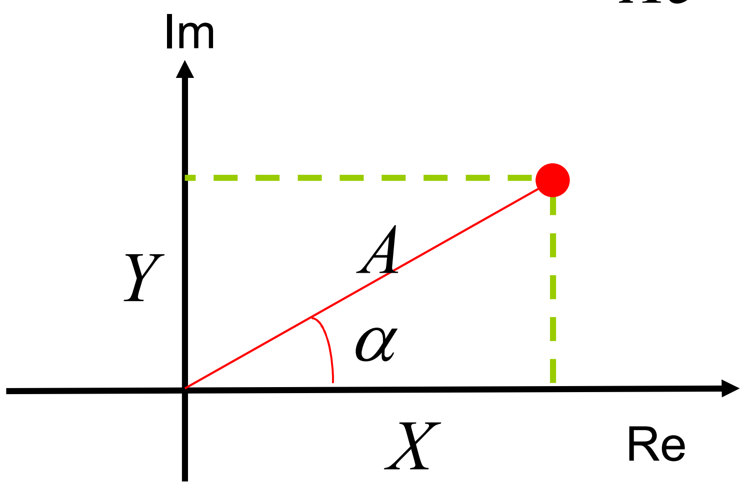
Complex numbers: some examples

$$-j = e^{-j\frac{\pi}{2}}$$



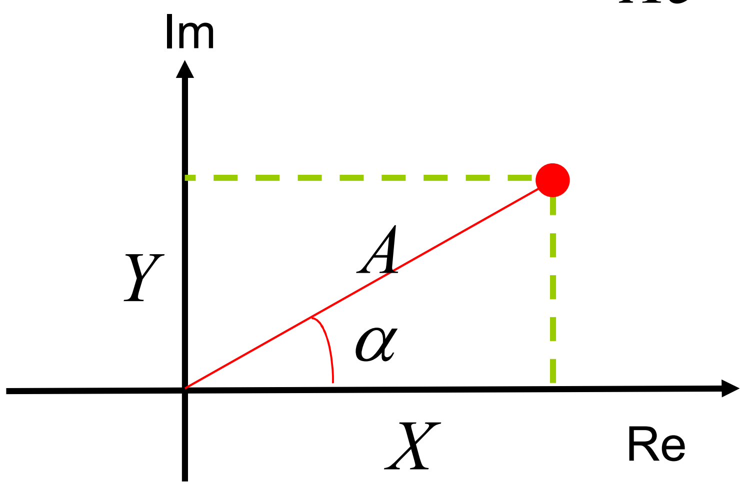
Complex numbers: conversion formulas

$$Ae^{j\alpha} = X + jY$$



Complex numbers: conversion formulas

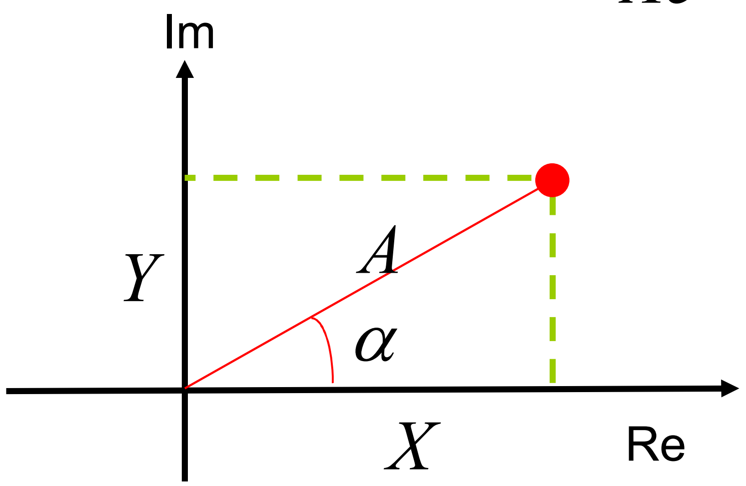
$$Ae^{j\alpha} = X + jY$$



$$Ae^{j\alpha} \longrightarrow X + jY$$

Complex numbers: conversion formulas

$$Ae^{j\alpha} = X + jY$$



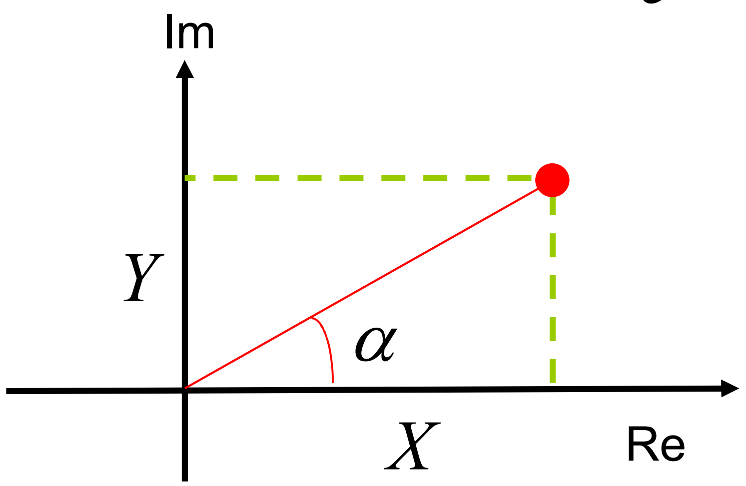
$$Ae^{j\alpha} \longrightarrow X + jY$$

$$X = A\cos\alpha$$

$$Y = A\sin\alpha$$

Complex numbers: conversion formulas

$$e^{j\alpha} = \cos\alpha + j\sin\alpha$$



$$Ae^{j\alpha} \longrightarrow X + jY$$

$$X = A\cos\alpha$$

$$Y = A\sin\alpha$$

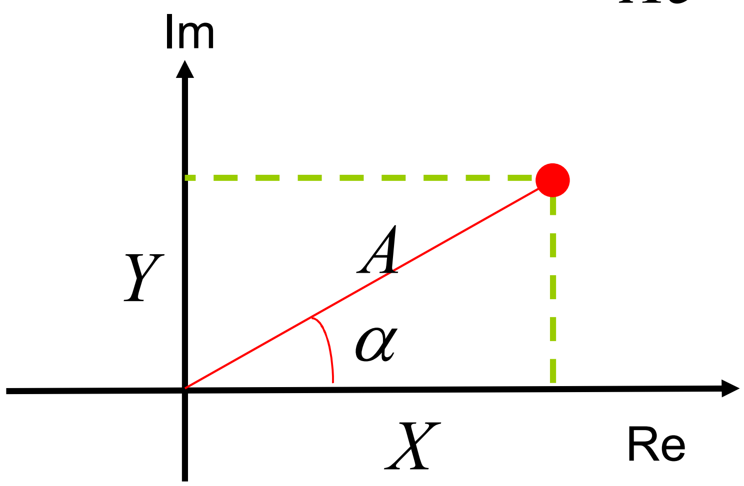
Eulero's formulas

$$\cos\alpha = \frac{e^{j\alpha} + e^{-j\alpha}}{2}$$

$$\sin\alpha = \frac{e^{j\alpha} - e^{-j\alpha}}{2j}$$

Complex numbers: conversion formulas

$$Ae^{j\alpha} = X + jY$$



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Complex numbers: conversion formulas

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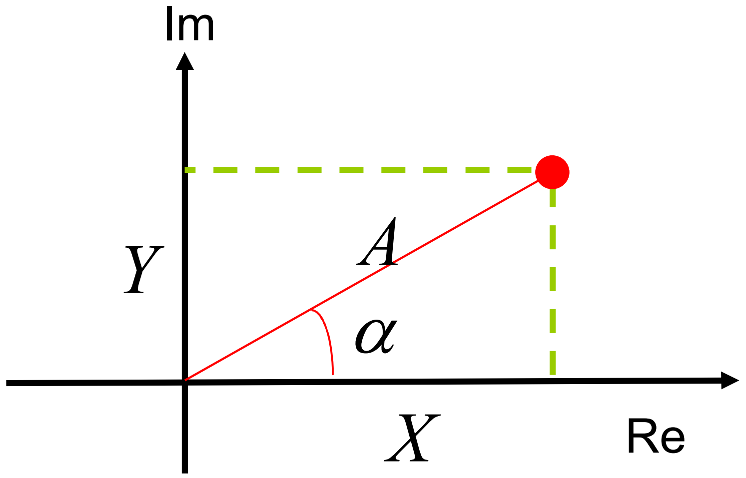


$$Ae^{j\alpha} \longrightarrow X + jY$$

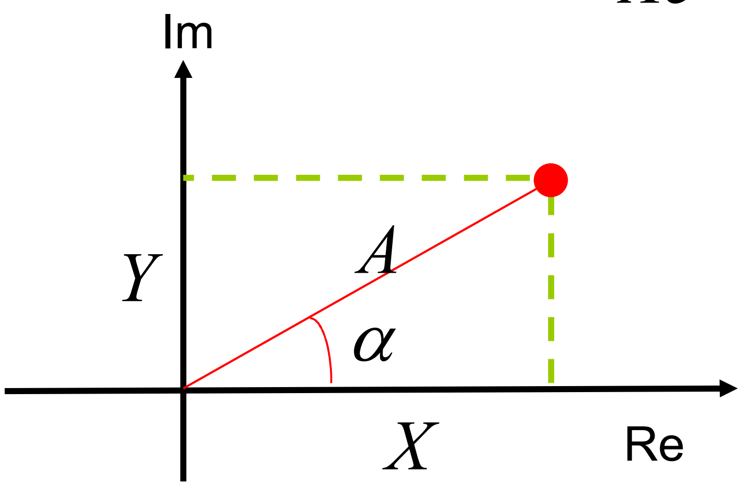
$$X = A\cos\alpha$$

$$Y = A\sin\alpha$$

$$X + jY \longrightarrow Ae^{j\alpha}$$

Complex numbers: conversion formulas

$$Ae^{j\alpha} = X + jY$$



$$Ae^{j\alpha} \longrightarrow X + jY$$

$$X = A\cos\alpha$$

$$Y = A\sin\alpha$$

$$X + jY \longrightarrow Ae^{j\alpha}$$

$$A = \sqrt{X^2 + Y^2}$$

$$\begin{cases} \alpha = \operatorname{acos}\left(\dfrac{X}{A}\right) & se\ Y \geq 0 \\ \alpha = -\operatorname{acos}\left(\dfrac{X}{A}\right) & se\ Y < 0 \end{cases}$$

Complex numbers: conversion formulas

Some examples

$$Ae^{j\alpha} \longrightarrow X + jY$$

$$X = A\cos\alpha$$

$$Y = A\sin\alpha$$

$$2e^{j\frac{3}{4}\pi} = -\sqrt{2} + j\sqrt{2}$$

Complex numbers: conversion formulas

Some examples

$$X + jY \longrightarrow Ae^{j\alpha}$$

$$A = \sqrt{X^2 + Y^2}$$

$$\begin{cases} \alpha = \operatorname{acos}\left(\dfrac{X}{A}\right) & se\ Y \geq 0 \\ \alpha = -\operatorname{acos}\left(\dfrac{X}{A}\right) & se\ Y < 0 \end{cases}$$

$$\sqrt{3} + j = 2e^{j\frac{\pi}{6}}$$

$$\sqrt{3} - j = 2e^{-j\frac{\pi}{6}}$$

Complex numbers: summation

$$Z_1 = A_1 e^{j\alpha_1} = X_1 + jY_1$$

$$Z_2 = A_2 e^{j\alpha_2} = X_2 + jY_2$$

$$Z_1 + Z_2 = \left(X_1 + X_2\right) + j\left(Y_1 + Y_2\right)$$

Complex numbers: product

$$Z_1 = A_1 e^{j\alpha_1} = X_1 + jY_1$$

$$Z_2 = A_2 e^{j\alpha_2} = X_2 + jY_2$$

$$Z_1 \cdot Z_2 = \left(X_1 \cdot X_2 - Y_1 \cdot Y_2 \right) + j\left(X_1 \cdot Y_2 + Y_1 \cdot X_2 \right)$$

$$Z_1 \cdot Z_2 = A_1 \cdot A_2 e^{j\left(\alpha_1 + \alpha_2\right)}$$

Complex numbers: product

Some examples

$$Z_1 = A_1 e^{j\alpha_1} = X_1 + jY_1$$

$$Z_2 = A_2 e^{j\alpha_2} = X_2 + jY_2$$

$$Z_1 \cdot Z_2 = A_1 \cdot A_2 e^{j(\alpha_1 + \alpha_2)}$$

$$z_1 = 3e^{j\frac{\pi}{6}}$$

$$z_2 = 4e^{j\frac{\pi}{4}}$$

$$z_1 \cdot z_2 = 12e^{j\left(\frac{\pi}{6} + \frac{\pi}{4}\right)} = 12e^{j\left(\frac{5}{12}\pi\right)}$$

Complex numbers: product

Some examples

$$Z_1 = A_1 e^{j\alpha_1} = X_1 + jY_1$$

$$Z_2 = A_2 e^{j\alpha_2} = X_2 + jY_2$$

$$Z_1 \cdot Z_2 = A_1 \cdot A_2 e^{j(\alpha_1 + \alpha_2)}$$

$$z_1 = \sqrt{3} + j \quad = 2e^{j\frac{\pi}{6}}$$

$$z_2 = -\sqrt{2} + j\sqrt{2} \quad = 2e^{j\frac{3}{4}\pi}$$

$$z_1 \cdot z_2 = \quad 4e^{j\left(\frac{\pi}{6} + \frac{3\pi}{4}\right)} = 4e^{j\left(\frac{11}{12}\pi\right)}$$

Complex numbers: product

Some examples

$$Z_1 = A_1 e^{j\alpha_1} = X_1 + jY_1$$

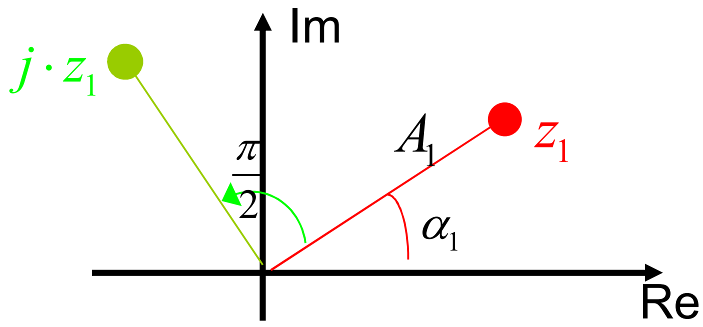
$$Z_2 = A_2 e^{j\alpha_2} = X_2 + jY_2$$

$$Z_1 \cdot Z_2 = A_1 \cdot A_2 e^{j(\alpha_1 + \alpha_2)}$$

$$z_1 = A_1 e^{j\alpha_1}$$

$$z_2 = j = e^{j\frac{\pi}{2}}$$

$$j \cdot z_1 = A_1 e^{j\left(\alpha_1 + \frac{\pi}{2}\right)}$$



Complex numbers: product

Some examples

$$Z_1 = A_1 e^{j\alpha_1} = X_1 + jY_1$$

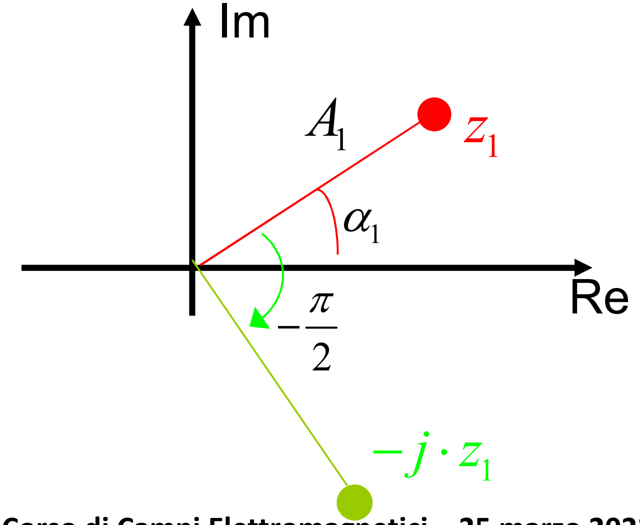
$$Z_2 = A_2 e^{j\alpha_2} = X_2 + jY_2$$

$$Z_1 \cdot Z_2 = A_1 \cdot A_2 e^{j(\alpha_1 + \alpha_2)}$$

$$z_1 = A_1 e^{j\alpha_1}$$

$$z_2 = -j = e^{-j\frac{\pi}{2}}$$

$$-j \cdot z_1 = A_1 e^{j\left(\alpha_1 - \frac{\pi}{2}\right)}$$



Complex numbers: product

Some examples

$$Z_1 = A_1 e^{j\alpha_1} = X_1 + jY_1$$

$$Z_2 = A_2 e^{j\alpha_2} = X_2 + jY_2$$

$$Z_1 \cdot Z_2 = A_1 \cdot A_2 e^{j(\alpha_1 + \alpha_2)}$$

$$z_1 = A_1 e^{j\alpha_1}$$

$$z_2 = -1 = e^{j\pi}$$

$$-z_1 = A_1 e^{j(\alpha_1 + \pi)}$$