Corso di Laurea in Ingegneria Informatica, Biomedica e delle Telecomunicazioni

Corso di Campi Elettromagnetici
a.a. 2020-2021

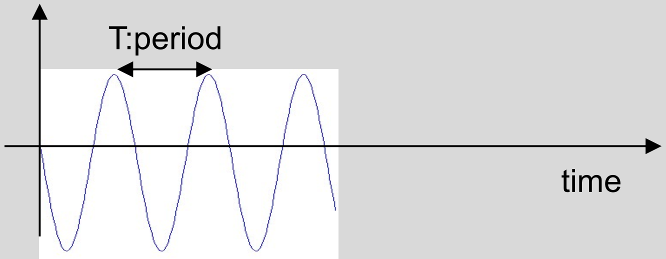
Maxwell equations
Time domain & Phasors

Phasors

Time domain

$f(t)$

Signals usually adopted in ICT applications



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

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

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

Phasors

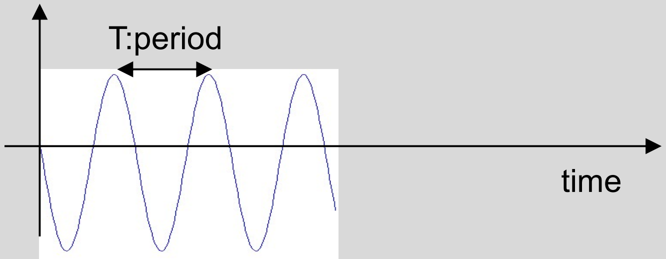
Time domain

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

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

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

→

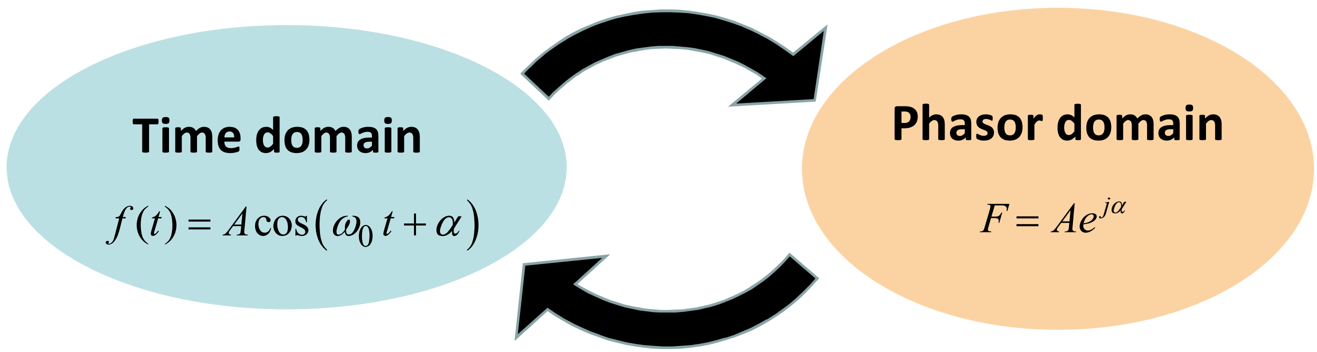
Phasor domain

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

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

2) Time domain derivative and Phasors

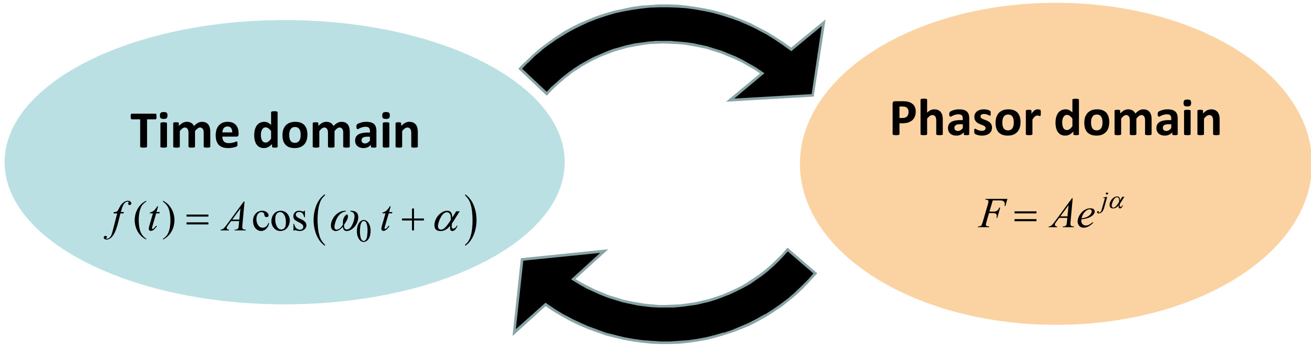
Phasors



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

$$f(t) = \mathrm{Re}\left\{ Fe^{j\omega_0 t} \right\} = \mathrm{Re}\left\{ Ae^{j\alpha} e^{j\omega_0 t} \right\} = A\cos(\omega_0 t + \alpha)$$

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

Time domain

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

Phasor domain

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

… 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

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

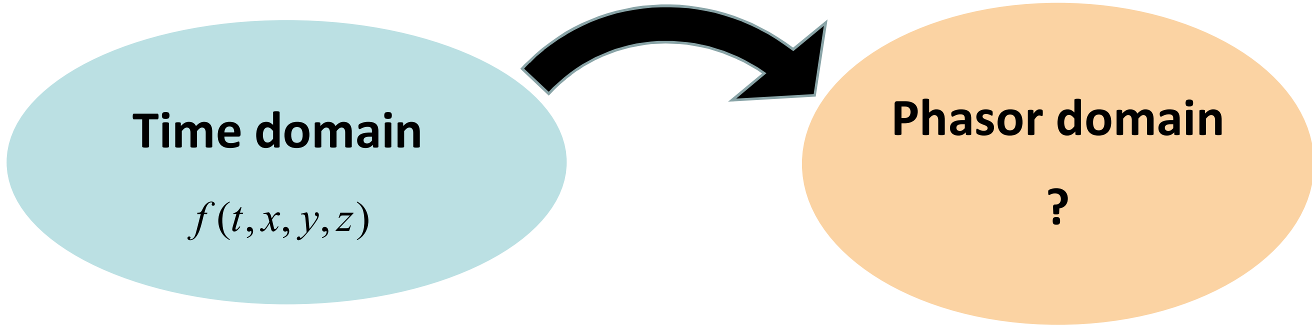
- Phasors and vector functions

- 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 functions of *n* variables



$$f(t,x,y,z) = A(x,y,z)\cos\left(\omega_0 t + \alpha(x,y,z)\right)$$

Phasors and functions of *n* variables

Time domain

$f(t,x,y,z)$

Phasor domain

$F(x,y,z)= A(x,y,z)e^{j\alpha(x,y,z)}$

$$f(t,x,y,z) = A\left(x,y,z\right)\cos\left(\omega_0 t + \alpha\left(x,y,z\right)\right)$$

$$F(x,y,z)= A(x,y,z)e^{j\alpha(x,y,z)}$$

Phasors and functions of *n* variables

Time domain

$f(t,x,y,z)$

Phasor domain

$F(x,y,z)= A(x,y,z)e^{j\alpha(x,y,z)}$

$$f(t,x,y,z) = A\left(x,y,z\right)\cos\left(\omega_0 t + \alpha\left(x,y,z\right)\right)$$

$$F(x,y,z)= A(x,y,z)e^{j\alpha(x,y,z)}$$

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

Phasors and functions of *n* variables

Time domain

$f(t,x,y,z)$

Phasor domain

$F(x,y,z)=A(x,y,z)e^{j\alpha(x,y,z)}$

$$f(t,x,y,z)=A(x,y,z)\cos\left(\omega_0 t+\alpha(x,y,z)\right)$$

$$F(x,y,z)=A(x,y,z)e^{j\alpha(x,y,z)}$$

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

$$f(t,x,y,z)=\mathrm{Re}\left\{F(x,y,z)e^{j\omega_0 t}\right\}$$

Phasors and functions of *n* variables

Time domain

$f(t,x,y,z)$

Phasor domain

$F(x,y,z) = A(x,y,z)e^{j\alpha(x,y,z)}$

$$f(t,x,y,z) = A(x,y,z)\cos\left(\omega_0 t + \alpha(x,y,z)\right)$$

2) Time domain derivative and Phasors

$f(t,x,y,z)$ → **T-to-P** → $F(x,y,z)$

$\dfrac{\partial f}{\partial t}$ → **T-to-P** → **?**

Phasors and functions of *n* variables

Time domain

$f(t,x,y,z)$

Phasor domain

$F(x,y,z) = A(x,y,z)e^{j\alpha(x,y,z)}$

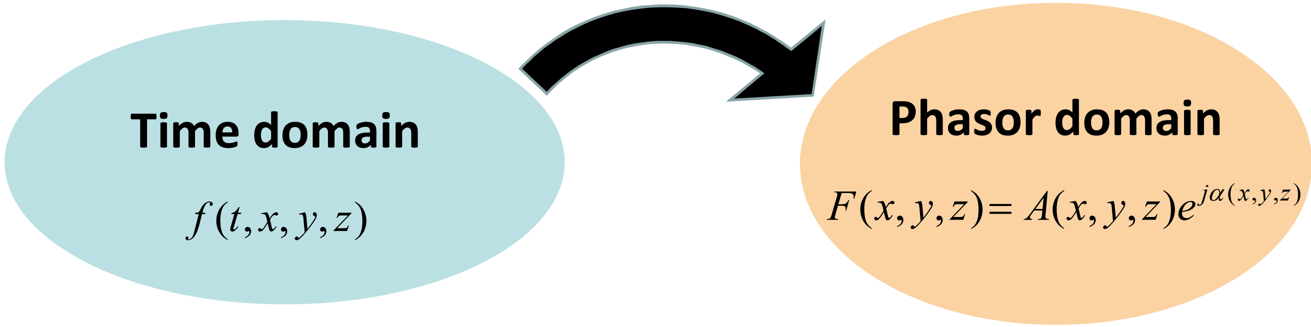
$$f(t,x,y,z) = A(x,y,z)\cos\left(\omega_0 t + \alpha(x,y,z)\right)$$

2) Time domain derivative and Phasors

$f(t,x,y,z)$ → **T-to-P** → $F(x,y,z)$

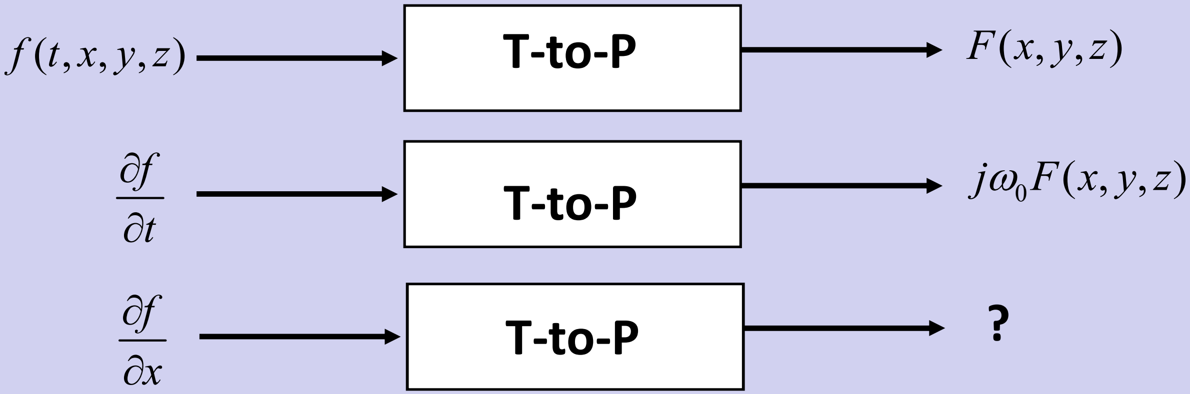
$\dfrac{\partial f}{\partial t}$ → **T-to-P** → $j\omega_0 F(x,y,z)$

Phasors and functions of *n* variables

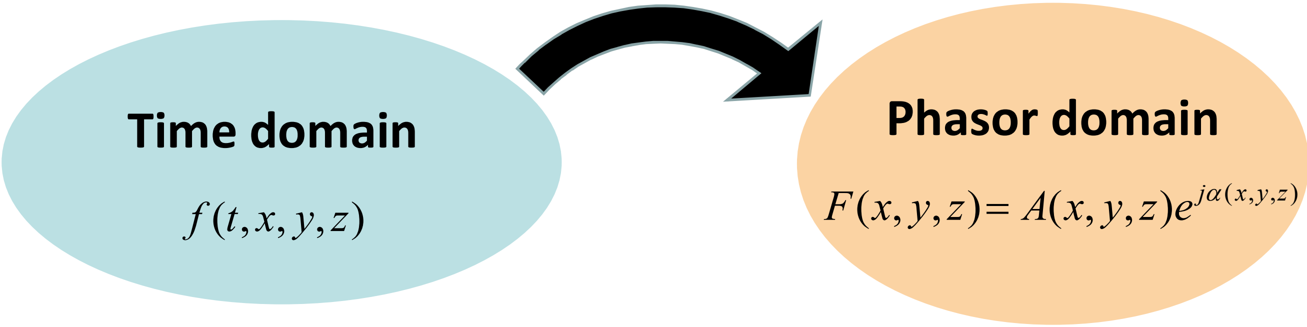


$$f(t,x,y,z) = A(x,y,z)\cos\left(\omega_0 t + \alpha(x,y,z)\right)$$

2) Time domain derivative and Phasors



Phasors and functions of *n* variables



$$f(t,x,y,z) = A(x,y,z)\cos\left(\omega_0 t + \alpha(x,y,z)\right)$$

2) Time domain derivative and Phasors

$f(t,x,y,z)$ → **T-to-P** → $F(x,y,z)$

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

$\frac{\partial f}{\partial x}$ → **T-to-P** → $\frac{\partial F(x,y,z)}{\partial x}$

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

Time domain

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

Phasor domain

?

$$f_x(t) = A_x \cos\left(\omega_0 t + \alpha_x\right)$$

$$f_y(t) = A_y \cos\left(\omega_0 t + \alpha_y\right)$$

$$f_z(t) = A_z \cos\left(\omega_0 t + \alpha_z\right)$$

Phasors and vector functions

Time domain

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

Phasor domain

?

$$f_x(t) = A_x \cos\left(\omega_0 t + \alpha_x\right)$$ → **T-to-P** →

$$f_y(t) = A_y \cos\left(\omega_0 t + \alpha_y\right)$$ → **T-to-P** →

$$f_z(t) = A_z \cos\left(\omega_0 t + \alpha_z\right)$$ → **T-to-P** →

Phasors and vector functions

Time domain

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

Phasor domain

?

$f_x(t) = A_x \cos\left(\omega_0 t + \alpha_x\right)$ → **T-to-P** → $F_x = A_x e^{j\alpha_x}$

$f_y(t) = A_y \cos\left(\omega_0 t + \alpha_y\right)$ → **T-to-P** → $F_y = A_y e^{j\alpha_y}$

$f_z(t) = A_z \cos\left(\omega_0 t + \alpha_z\right)$ → **T-to-P** → $F_z = A_z e^{j\alpha_z}$

Phasors and vector functions

Time domain

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

Phasor domain

$$\vec{\mathbf{F}} = F_x\hat{i}_x + F_y\hat{i}_y + F_z\hat{i}_z$$

$f_x(t) = A_x \cos(\omega_0 t + \alpha_x)$ → **T-to-P** → $F_x = A_x e^{j\alpha_x}$

$f_y(t) = A_y \cos(\omega_0 t + \alpha_y)$ → **T-to-P** → $F_y = A_y e^{j\alpha_y}$

$f_z(t) = A_z \cos(\omega_0 t + \alpha_z)$ → **T-to-P** → $F_z = A_z e^{j\alpha_z}$

Phasors and vector functions

Time domain

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

Phasor domain

$$\vec{\mathbf{F}} = F_x\hat{i}_x + F_y\hat{i}_y + F_z\hat{i}_z$$

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

$$\vec{\mathbf{f}}(t) = f_x(t)\hat{i}_x + f_y(t)\hat{i}_y + f_z(t)\hat{i}_z = A_x\cos\left(\omega_0 t + \alpha_x\right)\hat{i}_x + A_y\cos\left(\omega_0 t + \alpha_y\right)\hat{i}_y + A_z\cos\left(\omega_0 t + \alpha_z\right)\hat{i}_z$$

$$\vec{\mathbf{F}} = F_x\hat{i}_x + F_y\hat{i}_y + F_z\hat{i}_z = A_x e^{j\alpha_x}\hat{i}_x + A_y e^{j\alpha_y}\hat{i}_y + A_z e^{j\alpha_z}\hat{i}_z$$

Phasors and vector functions

Time domain

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

Phasor domain

$$\vec{\mathbf{F}} = F_x\hat{i}_x + F_y\hat{i}_y + F_z\hat{i}_z$$

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

Phasors and vector functions

Time domain

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

Phasor domain

$$\vec{\mathbf{F}} = F_x\hat{i}_x + F_y\hat{i}_y + F_z\hat{i}_z$$

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

$F_x = A_x e^{j\alpha_x}$ → **P-to-T** →

$F_y = A_y e^{j\alpha_y}$ → **P-to-T** →

$F_z = A_z e^{j\alpha_z}$ → **P-to-T** →

Phasors and vector functions

Time domain

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

Phasor domain

$$\vec{\mathbf{F}} = F_x\hat{i}_x + F_y\hat{i}_y + F_z\hat{i}_z$$

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

$F_x = A_x e^{j\alpha_x}$ → **P-to-T** → $f_x(t)$

$F_y = A_y e^{j\alpha_y}$ → **P-to-T** → $f_y(t)$

$F_z = A_z e^{j\alpha_z}$ → **P-to-T** → $f_z(t)$

Phasors and vector functions

Time domain

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

Phasor domain

$$\vec{\mathbf{F}} = F_x\hat{i}_x + F_y\hat{i}_y + F_z\hat{i}_z$$

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

$F_x = A_x e^{j\alpha_x}$ → **P-to-T** → $f_x(t) = \mathrm{Re}\left\{F_x e^{j\omega_0 t}\right\} = A_x \cos(\omega_0 t + \alpha_x)$

$F_y = A_y e^{j\alpha_y}$ → **P-to-T** → $f_y(t) = \mathrm{Re}\left\{F_y e^{j\omega_0 t}\right\} = A_y \cos(\omega_0 t + \alpha_y)$

$F_z = A_z e^{j\alpha_z}$ → **P-to-T** → $f_z(t) = \mathrm{Re}\left\{F_z e^{j\omega_0 t}\right\} = A_z \cos(\omega_0 t + \alpha_z)$

Phasors and vector functions

Time domain

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

Phasor domain

$$\vec{\mathbf{F}} = F_x\hat{i}_x + F_y\hat{i}_y + F_z\hat{i}_z$$

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

$F_x = A_x e^{j\alpha_x}$ → **P-to-T** → $f_x(t) = \mathrm{Re}\left\{F_x e^{j\omega_0 t}\right\} = A_x \cos(\omega_0 t + \alpha_x)$

$F_y = A_y e^{j\alpha_y}$ → **P-to-T** → $f_y(t) = \mathrm{Re}\left\{F_y e^{j\omega_0 t}\right\} = A_y \cos(\omega_0 t + \alpha_y)$

$F_z = A_z e^{j\alpha_z}$ → **P-to-T** → $f_z(t) = \mathrm{Re}\left\{F_z e^{j\omega_0 t}\right\} = A_z \cos(\omega_0 t + \alpha_z)$

Phasors and vector functions

Time domain

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

Phasor domain

$$\vec{\mathbf{F}} = F_x\hat{i}_x + F_y\hat{i}_y + F_z\hat{i}_z$$

2) Time domain derivative and Phasors

Phasors and vector functions

Time domain

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

Phasor domain

$$\vec{\mathbf{F}} = F_x\hat{i}_x + F_y\hat{i}_y + F_z\hat{i}_z$$

2) Time domain derivative and Phasors

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

$\dfrac{d\vec{\mathbf{f}}(t)}{dt}$ → **T-to-P** → **?**

Phasors and vector functions

Time domain

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

Phasor domain

$$\vec{\mathbf{F}} = F_x\hat{i}_x + F_y\hat{i}_y + F_z\hat{i}_z$$

2) Time domain derivative and Phasors

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

$\dfrac{d\vec{\mathbf{f}}(t)}{dt}$ → **T-to-P** → **?**

$$\frac{d\vec{\mathbf{f}}(t)}{dt} = \frac{df_x(t)}{dt}\hat{i}_x + \frac{df_y(t)}{dt}\hat{i}_y + \frac{df_z(t)}{dt}\hat{i}_z$$

Phasors and vector functions

Time domain

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

Phasor domain

$$\vec{\mathbf{F}} = F_x\hat{i}_x + F_y\hat{i}_y + F_z\hat{i}_z$$

2) Time domain derivative and Phasors

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

$\dfrac{d\vec{\mathbf{f}}(t)}{dt}$ → **T-to-P** → **?**

$$\frac{d\vec{\mathbf{f}}(t)}{dt} = \frac{df_x(t)}{dt}\hat{i}_x + \frac{df_y(t)}{dt}\hat{i}_y + \frac{df_z(t)}{dt}\hat{i}_z$$

$\dfrac{df_x(t)}{dt}$ → **T-to-P** → **?**

$\dfrac{df_y(t)}{dt}$ → **T-to-P** → **?**

$\dfrac{df_z(t)}{dt}$ → **T-to-P** → **?**

Phasors and vector functions

Time domain

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

Phasor domain

$$\vec{\mathbf{F}} = F_x\hat{i}_x + F_y\hat{i}_y + F_z\hat{i}_z$$

2) Time domain derivative and Phasors

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

$\dfrac{d\vec{\mathbf{f}}(t)}{dt}$ → **T-to-P** → **?**

$$\frac{d\vec{\mathbf{f}}(t)}{dt} = \frac{df_x(t)}{dt}\hat{i}_x + \frac{df_y(t)}{dt}\hat{i}_y + \frac{df_z(t)}{dt}\hat{i}_z$$

$\dfrac{df_x(t)}{dt}$ → **T-to-P** → $j\omega_0 F_x$

$\dfrac{df_y(t)}{dt}$ → **T-to-P** → $j\omega_0 F_y$

$\dfrac{df_z(t)}{dt}$ → **T-to-P** → $j\omega_0 F_z$

Phasors and vector functions

Time domain

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

→

Phasor domain

$$\vec{\mathbf{F}} = F_x\hat{i}_x + F_y\hat{i}_y + F_z\hat{i}_z$$

2) Time domain derivative and Phasors

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

$\dfrac{d\vec{\mathbf{f}}(t)}{dt}$ → **T-to-P** → $j\omega_0 F_x\hat{i}_x + j\omega_0 F_y\hat{i}_y + j\omega_0 F_z\hat{i}_z$

$$\frac{d\vec{\mathbf{f}}(t)}{dt} = \frac{df_x(t)}{dt}\hat{i}_x + \frac{df_y(t)}{dt}\hat{i}_y + \frac{df_z(t)}{dt}\hat{i}_z$$

$\dfrac{df_x(t)}{dt}$ → **T-to-P** → $j\omega_0 F_x$

$\dfrac{df_y(t)}{dt}$ → **T-to-P** → $j\omega_0 F_y$

$\dfrac{df_z(t)}{dt}$ → **T-to-P** → $j\omega_0 F_z$

Phasors and vector functions

Time domain

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

Phasor domain

$$\vec{\mathbf{F}} = F_x\hat{i}_x + F_y\hat{i}_y + F_z\hat{i}_z$$

2) Time domain derivative and Phasors

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

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

$$\frac{d\vec{\mathbf{f}}(t)}{dt} = \frac{df_x(t)}{dt}\hat{i}_x + \frac{df_y(t)}{dt}\hat{i}_y + \frac{df_z(t)}{dt}\hat{i}_z$$

$\dfrac{df_x(t)}{dt}$ → **T-to-P** → $j\omega_0 F_x$

$\dfrac{df_y(t)}{dt}$ → **T-to-P** → $j\omega_0 F_y$

$\dfrac{df_z(t)}{dt}$ → **T-to-P** → $j\omega_0 F_z$

Phasors and vector functions

Time domain

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

Phasor domain

$$\vec{\mathbf{F}} = F_x\hat{i}_x + F_y\hat{i}_y + F_z\hat{i}_z$$

2) Time domain derivative and Phasors

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

$$\frac{d\vec{\mathbf{f}}(t)}{dt} \longrightarrow \boxed{\text{T-to-P}} \longrightarrow j\omega_0\vec{\mathbf{F}}$$

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

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

$$f_x(t,x,y,z)=A_x(x,y,z)\cos\left(\omega_0 t+\alpha_x(x,y,z)\right)$$

T-to-P

$$F_x(x,y,z)=A_x(x,y,z)e^{j\alpha_x(x,y,z)}$$

$$f_y(t,x,y,z)=A_y(x,y,z)\cos\left(\omega_0 t+\alpha_y(x,y,z)\right)$$

T-to-P

$$F_y(x,y,z)=A_y(x,y,z)e^{j\alpha_y(x,y,z)}$$

$$f_z(t,x,y,z)=A_z(x,y,z)\cos\left(\omega_0 t+\alpha_z(x,y,z)\right)$$

T-to-P

$$F_z(x,y,z)=A_z(x,y,z)e^{j\alpha_z(x,y,z)}$$

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

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

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

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

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

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

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

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

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** → $\nabla\cdot\vec{\mathbf{F}}(x,y,z)$

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

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

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

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

Phasors and vector functions of *n* variables

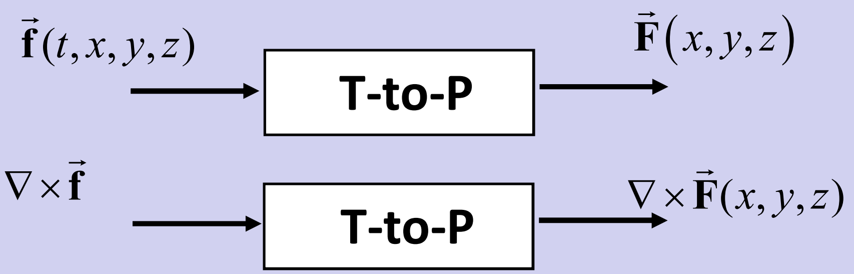
Time domain

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

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

$\vec{\mathbf{f}}(t,x,y,z)$ → **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** → $\nabla \times \vec{\mathbf{F}}(x,y,z)$

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

$\vec{\mathbf{f}}(x,y,z,t)$ → **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

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

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

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

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

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

$\vec{\mathbf{f}}(x,y,z,t)$ → **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** → $\nabla \times \vec{\mathbf{F}}(x,y,z)$

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

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

$\vec{\mathbf{f}}(x,y,z,t)$	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	$\nabla \times \vec{\mathbf{F}}(x,y,z)$

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

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

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

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

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

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

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

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

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

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

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

$\vec{\mathbf{f}}(x,y,z,t)$ → 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 → $\vec{\mathbf{B}}(\vec{\mathbf{r}})$

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

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

$\vec{\mathbf{f}}(x,y,z,t) \longrightarrow$ 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 $\longrightarrow \vec{\mathbf{B}}(\vec{\mathbf{r}})$

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

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	→ $\nabla \times \vec{\mathbf{F}}(x,y,z)$

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

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** → $\nabla \times \vec{\mathbf{F}}(x,y,z)$

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

$\nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t)$ → **T-to-P** → $\nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}})$

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

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

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

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

$\nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) \longrightarrow$ T-to-P $\longrightarrow \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}})$

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

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

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

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

$\vec{\mathbf{f}}(x,y,z,t)$ → **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** → $\nabla \times \vec{\mathbf{F}}(x,y,z)$

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

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

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

$\vec{\mathbf{f}}(x,y,z,t)$ → 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 → $\nabla\times\vec{\mathbf{F}}(x,y,z)$

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

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

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

$\vec{\mathbf{f}}(x,y,z,t)$ → 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 → $\vec{\mathbf{D}}(\vec{\mathbf{r}})$

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

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

$\vec{\mathbf{f}}(x,y,z,t)$ → 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

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

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

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

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

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

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

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

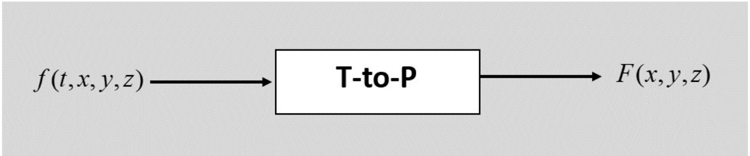
Maxwell equations
Time domain & Phasor domain

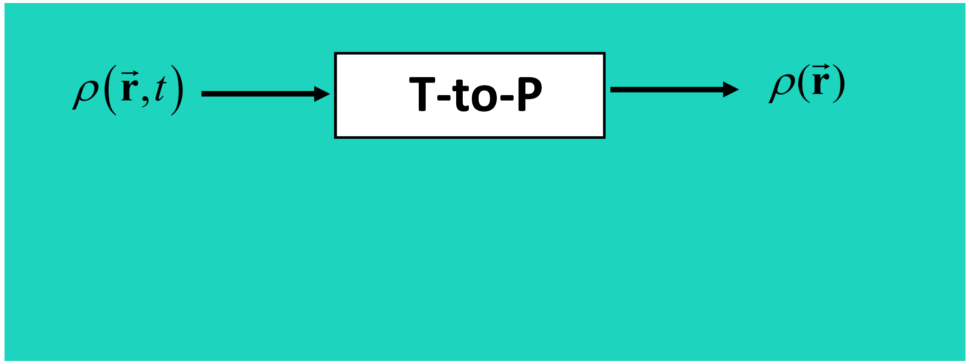
Time domain

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

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

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

$f(t,x,y,z)$ → **T-to-P** → $F(x,y,z)$

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

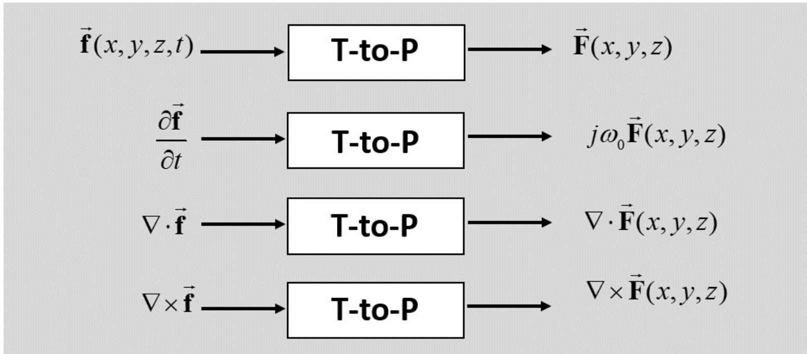
Maxwell equations
Time domain & Phasor domain

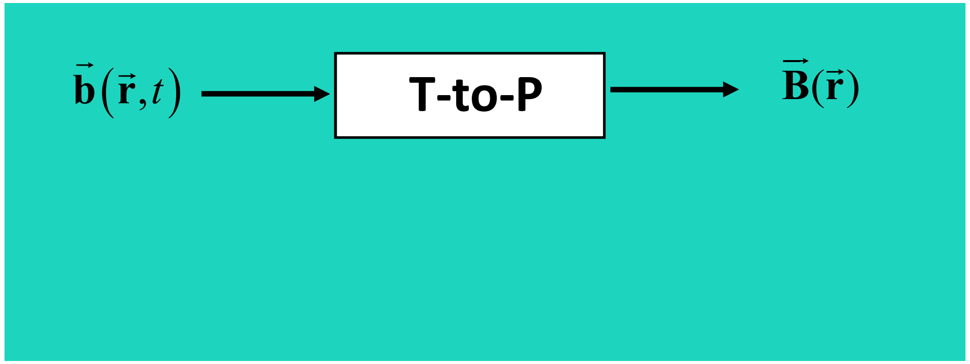
Time domain

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

Phasor domain

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





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 $\longrightarrow \vec{\mathbf{B}}(\vec{\mathbf{r}})$

$\nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) \longrightarrow$ 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	Phasor domain
$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$	$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}}) = -j\omega_0 \vec{\mathbf{B}}(\vec{\mathbf{r}}) \\ \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}}) = j\omega_0 \vec{\mathbf{D}}(\vec{\mathbf{r}}) + \vec{\mathbf{J}}(\vec{\mathbf{r}}) \\ \nabla \cdot \vec{\mathbf{D}}(\vec{\mathbf{r}}) = \rho(\vec{\mathbf{r}}) \\ \nabla \cdot \vec{\mathbf{B}}(\vec{\mathbf{r}}) = 0 \end{cases}$$

$\vec{\mathbf{e}}(\vec{\mathbf{r}},t)$	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

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

.. **memo**

Time domain: $f(t) = A\cos(\omega_0 t + \alpha)$ → **Phasor domain**: $F = Ae^{j\alpha}$

Maxwell equations
Time domain & Phasor domain

Time domain

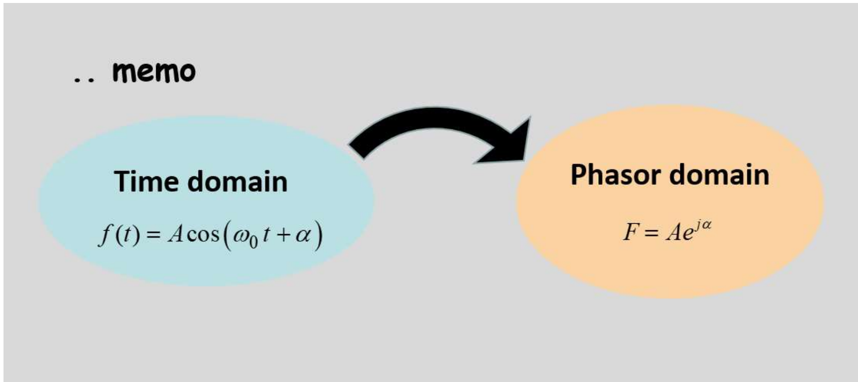
$$\begin{cases} \nabla\times\vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial\vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla\times\vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial\vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla\cdot\vec{\mathbf{d}}(\vec{\mathbf{r}},t)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

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

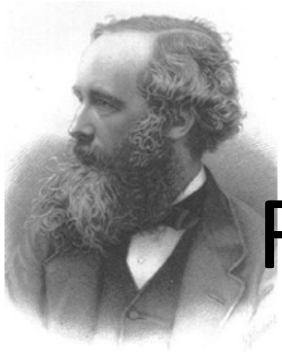
$\vec{\mathbf{E}}(\vec{\mathbf{r}})$ Volt/m



Maxwell equations
Time domain & Phasor domain

Time domain	Phasor domain
$$\begin{cases} \nabla \times \vec{\mathbf{e}}(\vec{\mathbf{r}},t) = -\dfrac{\partial \vec{\mathbf{b}}(\vec{\mathbf{r}},t)}{\partial t} \\ \nabla \times \vec{\mathbf{h}}(\vec{\mathbf{r}},t) = \dfrac{\partial \vec{\mathbf{d}}(\vec{\mathbf{r}},t)}{\partial t} + \vec{\mathbf{j}}(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{d}}(\vec{\mathbf{r}},t) = \rho(\vec{\mathbf{r}},t) \\ \nabla \cdot \vec{\mathbf{b}}(\vec{\mathbf{r}},t) = 0 \end{cases}$$	$$\begin{cases} \nabla \times \vec{\mathbf{E}}(\vec{\mathbf{r}}) = -j\omega_0 \vec{\mathbf{B}}(\vec{\mathbf{r}}) \\ \nabla \times \vec{\mathbf{H}}(\vec{\mathbf{r}}) = j\omega_0 \vec{\mathbf{D}}(\vec{\mathbf{r}}) + \vec{\mathbf{J}}(\vec{\mathbf{r}}) \\ \nabla \cdot \vec{\mathbf{D}}(\vec{\mathbf{r}}) = \rho(\vec{\mathbf{r}}) \\ \nabla \cdot \vec{\mathbf{B}}(\vec{\mathbf{r}}) = 0 \end{cases}$$

$\vec{\mathbf{e}}(\vec{\mathbf{r}},t)$	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

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

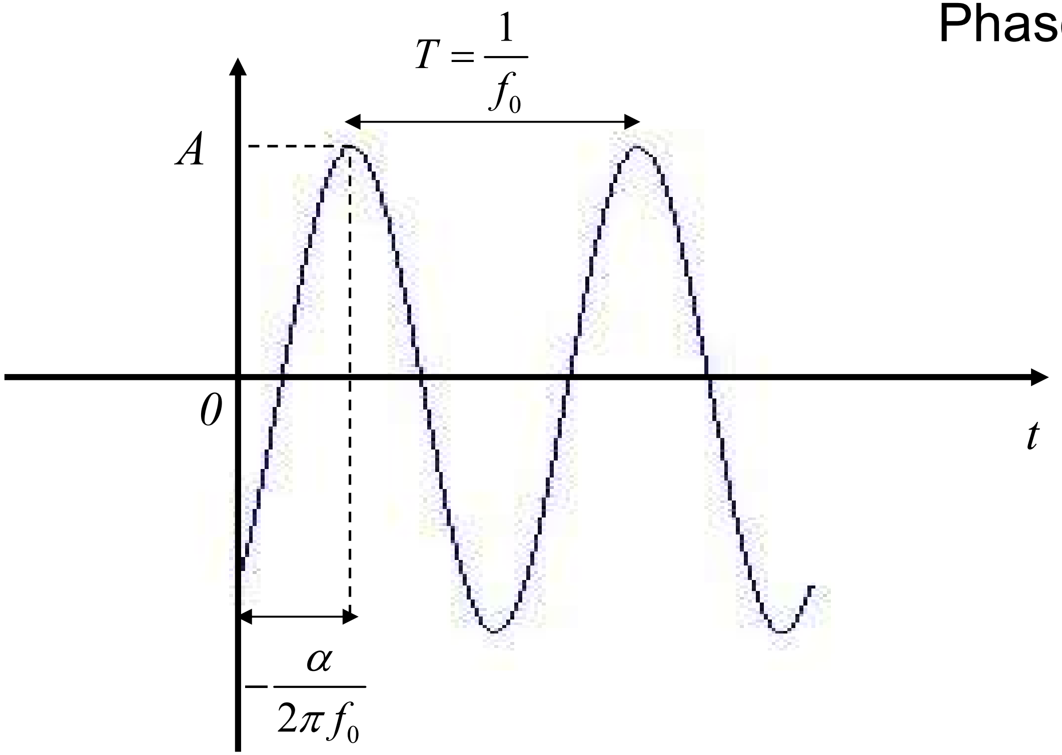
$$j\omega_0\rho(\vec{\mathbf{r}}) + \nabla \cdot \vec{\mathbf{J}}(\vec{\mathbf{r}}) = 0$$

Memo: Phasors

Phasors

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

Phasor (complex number)



Phasors

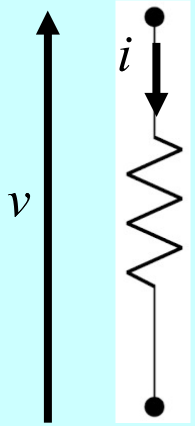
$$v(t) = A\cos\left(\omega_0 t + \alpha\right) \longrightarrow V = Ae^{j\alpha}$$

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

Phasors

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

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



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

$$i(t) \rightarrow I$$

$$v(t) \rightarrow V$$

$$V = R \cdot I$$

$$V = Z \cdot I$$

$$Z = R$$

Phasors

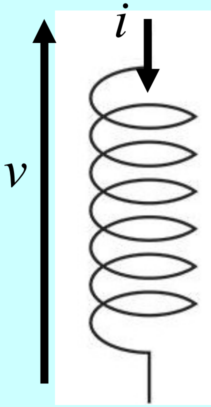
$$v(t) = A\cos\left(\omega_0 t + \alpha\right) \longrightarrow V = Ae^{j\alpha}$$

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

Phasors

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

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



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

$$i(t) \rightarrow I$$

$$v(t) \rightarrow V$$

$$V = j\omega_0 L I$$

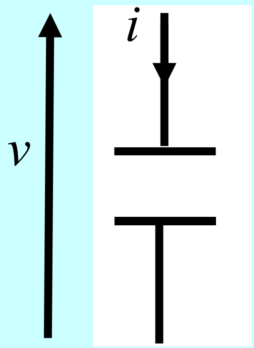
$$V = Z \cdot I$$

$$Z = j\omega_0 L$$

Phasors

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

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



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

$$i(t) \rightarrow I$$

$$v(t) \rightarrow V$$

$$I = j\omega_0 CV$$

$$V = Z \cdot I$$

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

Phasors

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

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

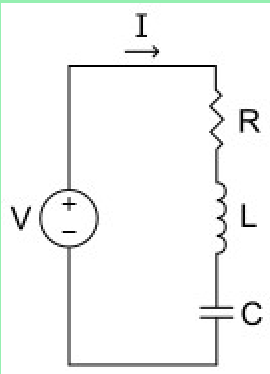
$$\left\langle v(t)\cdot i(t)\right\rangle = \frac{1}{T}\int_0^T v(t)\cdot i(t)\,dt \;= \frac{1}{2}\mathrm{Re}\left\{V\cdot I^*\right\}$$

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

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

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

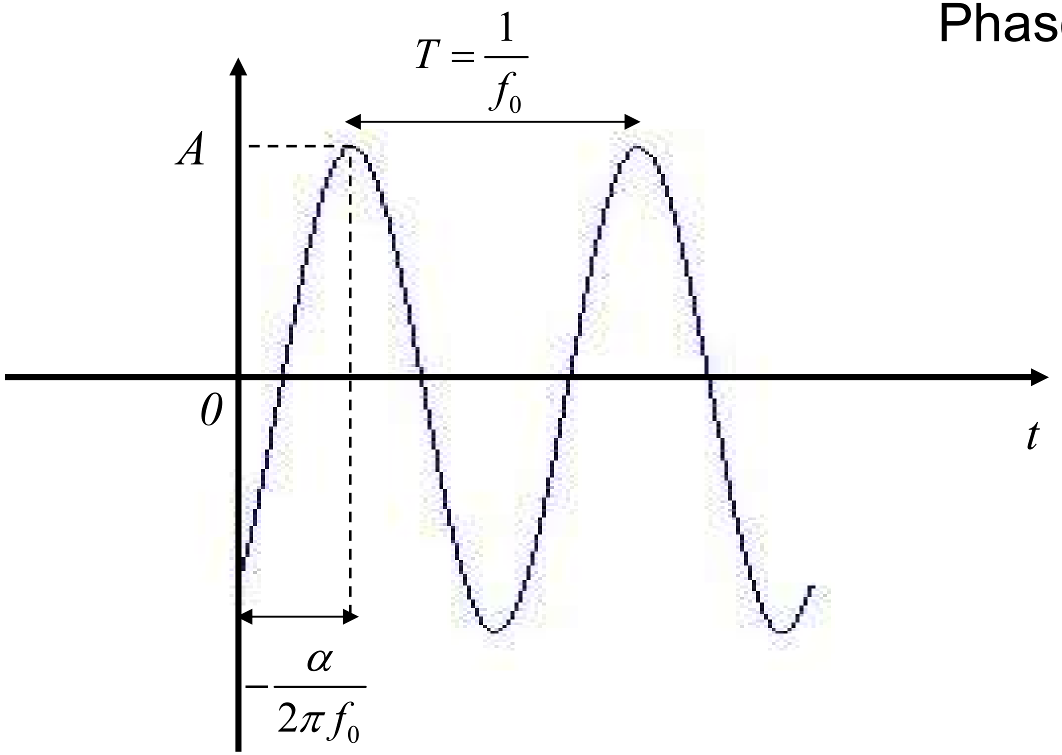
$$\left\langle \vec{\mathbf{f}}_1(\vec{\mathbf{r}},t)\cdot\vec{\mathbf{f}}_2(\vec{\mathbf{r}},t) \right\rangle = \frac{1}{T}\int_0^T \vec{\mathbf{f}}_1(\vec{\mathbf{r}},t)\cdot\vec{\mathbf{f}}_2(\vec{\mathbf{r}},t)\,dt \quad = \frac{1}{2}\mathrm{Re}\left\{\vec{\mathbf{F}}_1(\vec{\mathbf{r}})\cdot\vec{\mathbf{F}}_2^*(\vec{\mathbf{r}})\right\}$$

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

Phasors

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

Phasor (complex number)



Phasors

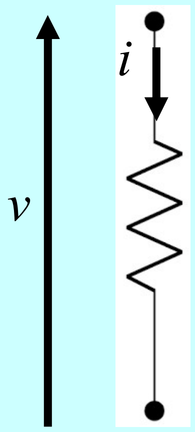
$$v(t) = A\cos\left(\omega_0 t + \alpha\right) \longrightarrow V = Ae^{j\alpha}$$

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

Phasors

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

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



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

$$i(t) \rightarrow I$$

$$v(t) \rightarrow V$$

$$V = R \cdot I$$

$$V = Z \cdot I$$

$$Z = R$$

Phasors

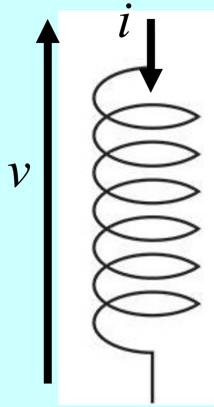
$$v(t) = A\cos\left(\omega_0 t + \alpha\right) \longrightarrow V = Ae^{j\alpha}$$

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

Phasors

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

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



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

$$i(t) \rightarrow I$$

$$v(t) \rightarrow V$$

$$V = j\omega_0 LI$$

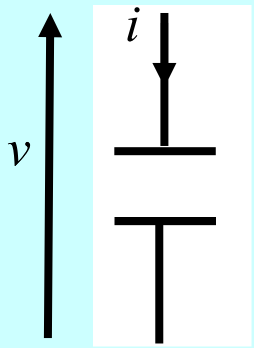
$$V = Z \cdot I$$

$$Z = j\omega_0 L$$

Phasors

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

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



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

$$i(t) \rightarrow I$$

$$v(t) \rightarrow V$$

$$I = j\omega_0 C V$$

$$V = Z \cdot I$$

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

Phasors

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

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

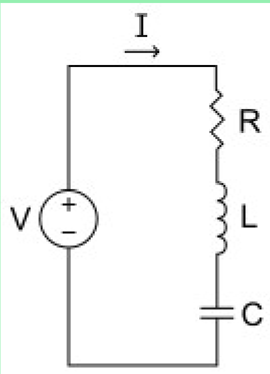
$$\left\langle v(t)\cdot i(t)\right\rangle = \frac{1}{T}\int_0^T v(t)\cdot i(t)\,dt \;= \frac{1}{2}\mathrm{Re}\left\{V\cdot I^*\right\}$$

Phasors

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

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

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



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

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

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

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

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

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

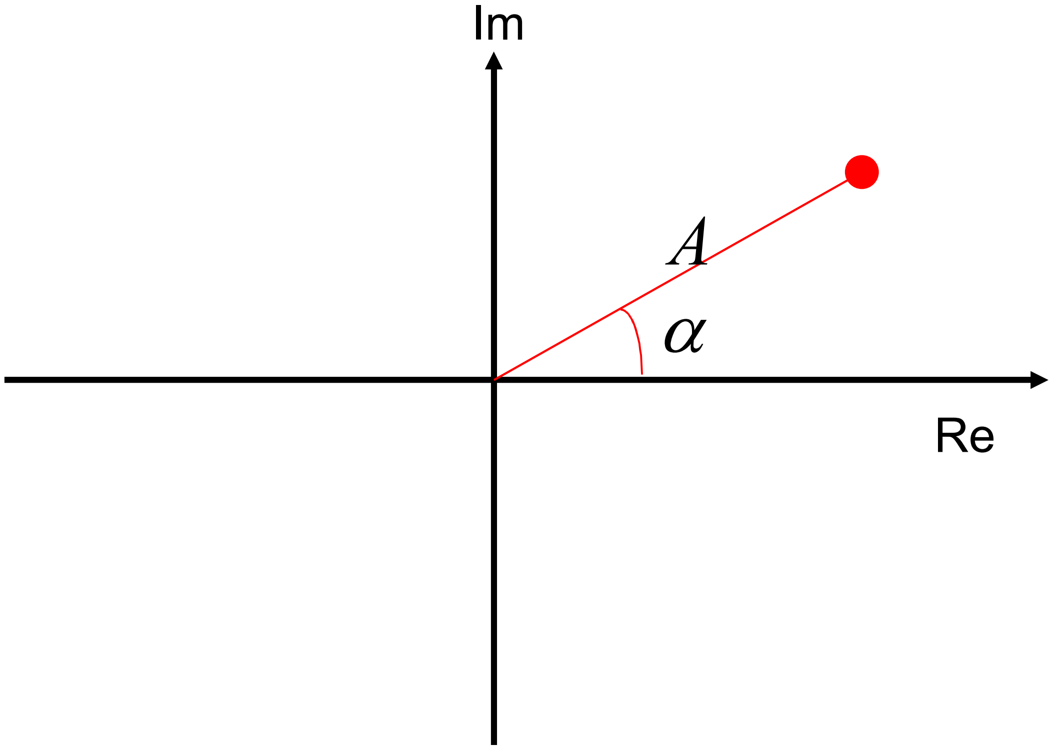
$$\left\langle \vec{\mathbf{f}}_1(\vec{\mathbf{r}},t)\cdot\vec{\mathbf{f}}_2(\vec{\mathbf{r}},t) \right\rangle = \frac{1}{T}\int_0^T \vec{\mathbf{f}}_1(\vec{\mathbf{r}},t)\cdot\vec{\mathbf{f}}_2(\vec{\mathbf{r}},t)\,dt \quad = \frac{1}{2}\mathrm{Re}\left\{\vec{\mathbf{F}}_1(\vec{\mathbf{r}})\cdot\vec{\mathbf{F}}_2^*(\vec{\mathbf{r}})\right\}$$

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

Memo: complex numbers

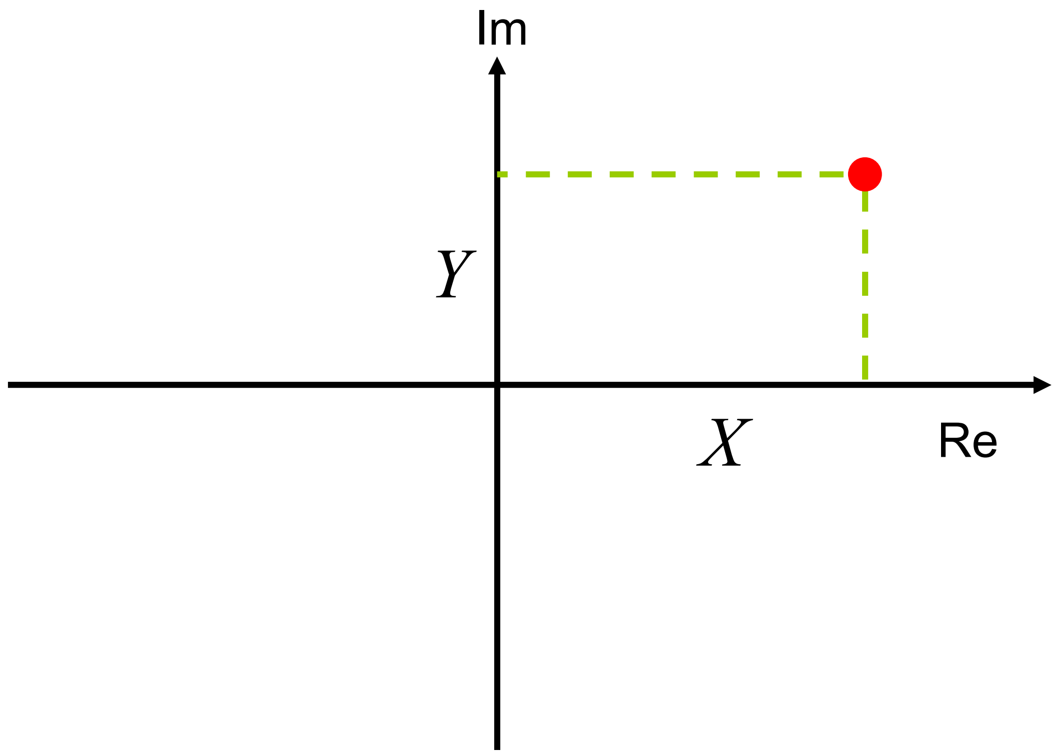
Complex numbers

$$Ae^{j\alpha}$$



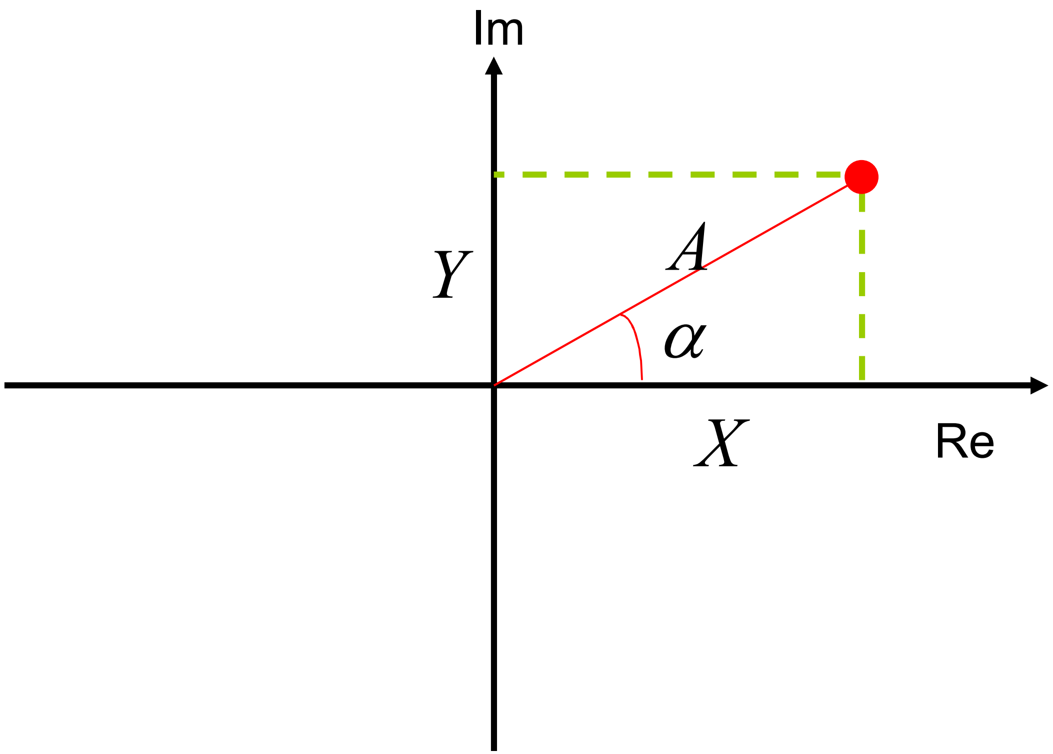
Complex numbers

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



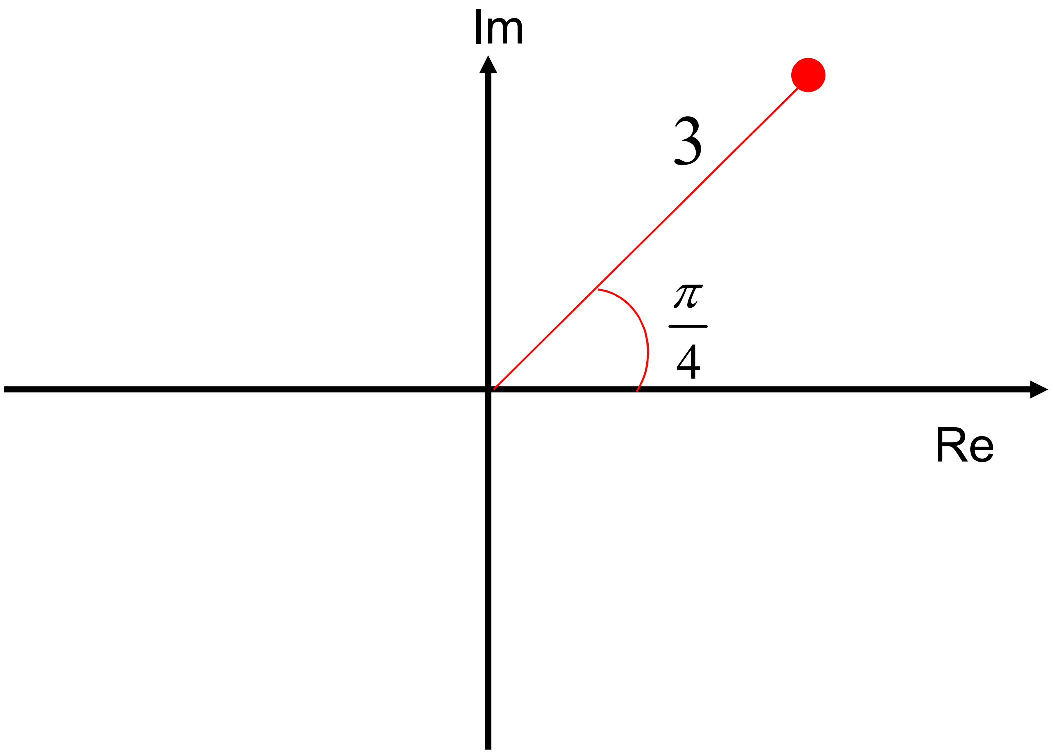
Complex numbers

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



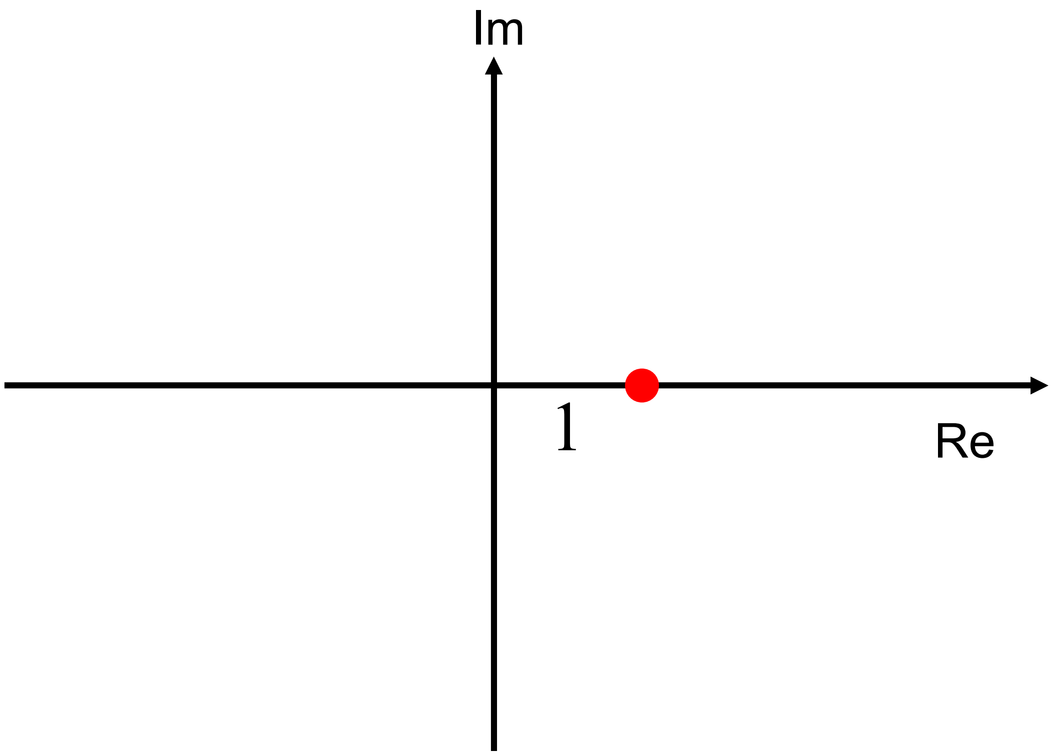
Complex numbers: some examples

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



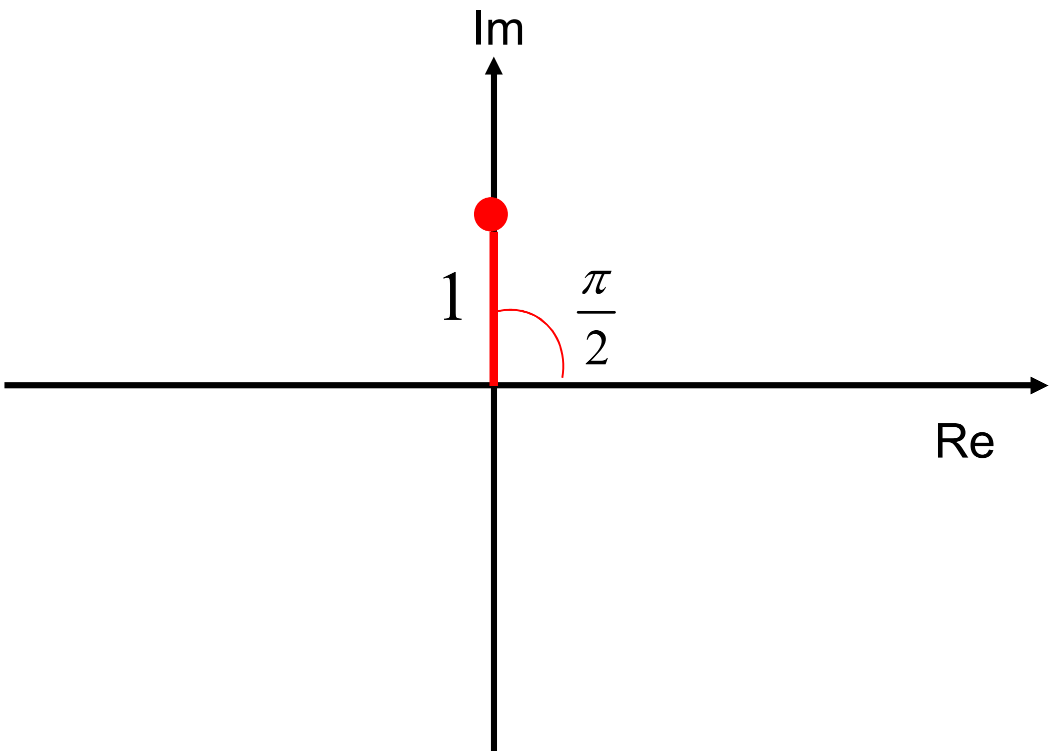
Complex numbers: some examples

1



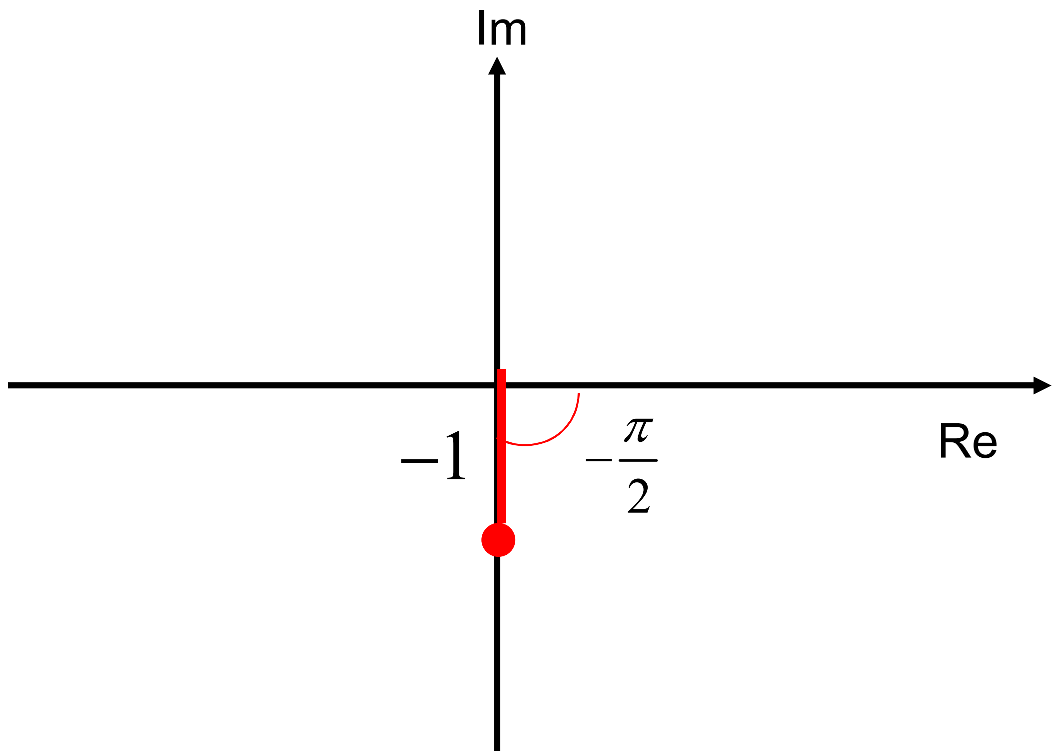
Complex numbers: some examples

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



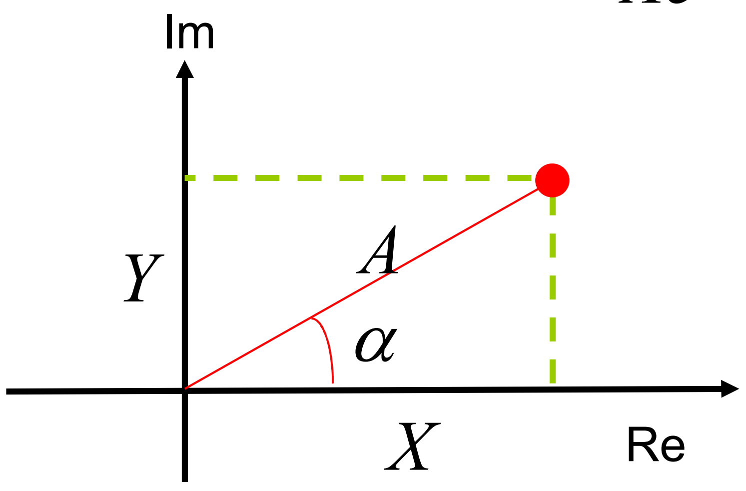
Complex numbers: some examples

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



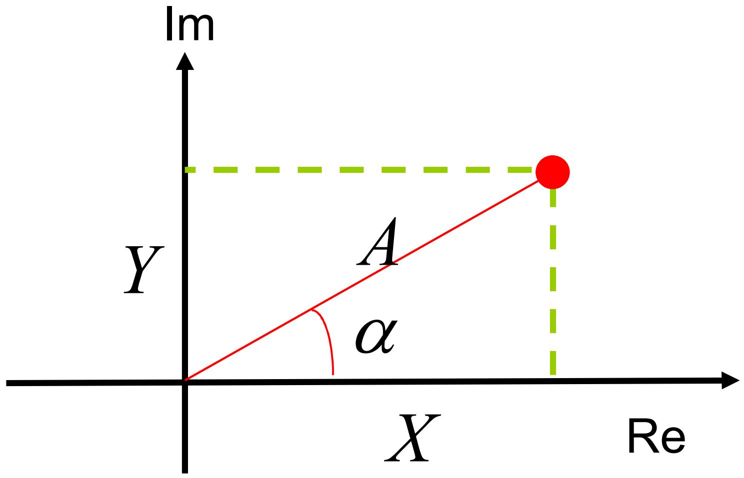
Complex numbers: conversion formulas

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



Complex numbers: conversion formulas

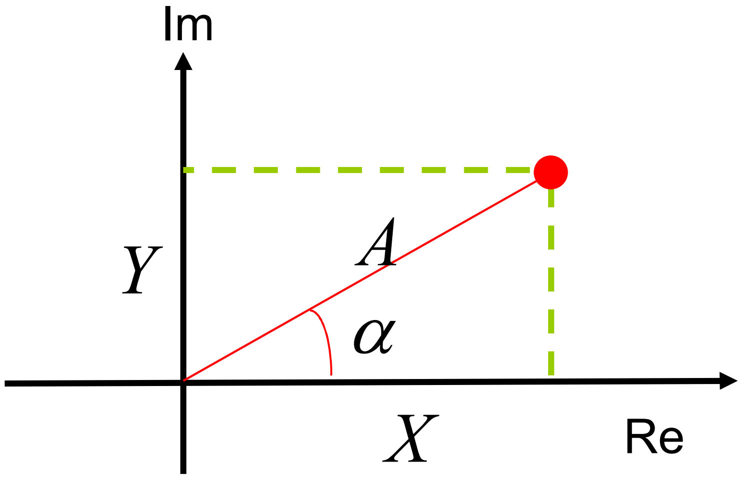
$$Ae^{j\alpha} = X + jY$$



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

Complex numbers: conversion formulas

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



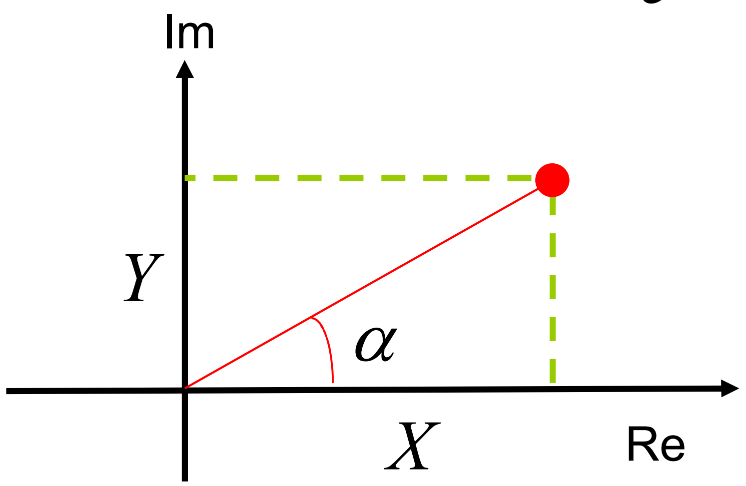
$$Ae^{j\alpha} \longrightarrow X + jY$$

$$X = A\cos\alpha$$

$$Y = A\sin\alpha$$

Complex numbers: conversion formulas

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



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

$$X = A\cos\alpha$$

$$Y = A\sin\alpha$$

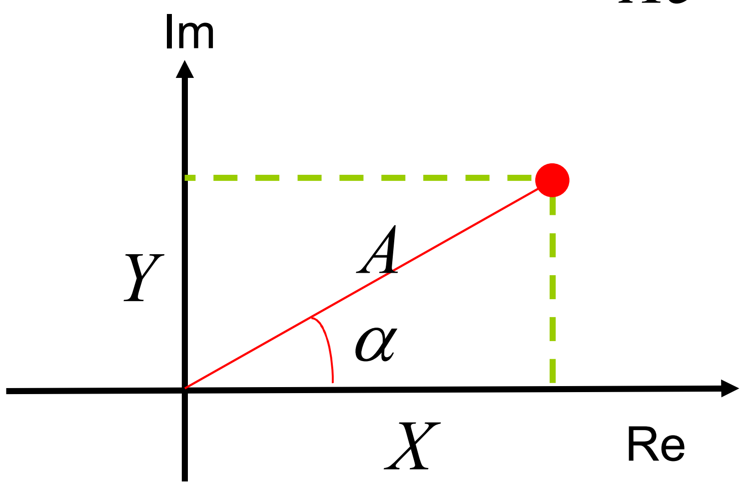
Eulero's formulas

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

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

Complex numbers: conversion formulas

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



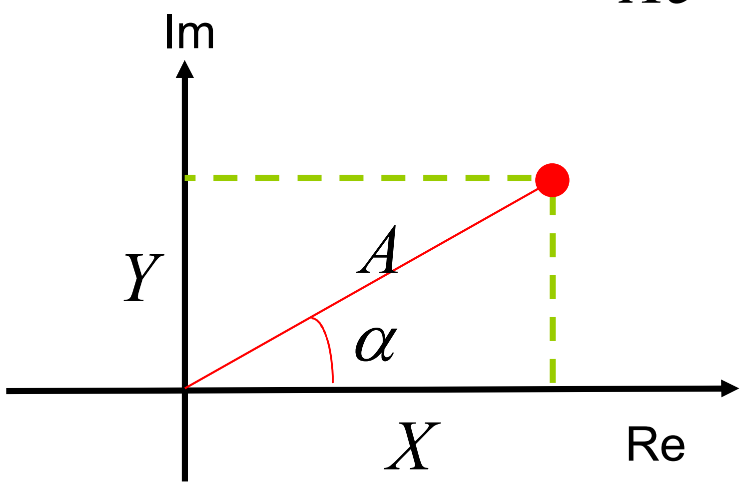
$$Ae^{j\alpha} \longrightarrow X + jY$$

$$X = A\cos\alpha$$

$$Y = A\sin\alpha$$

Complex numbers: conversion formulas

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



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

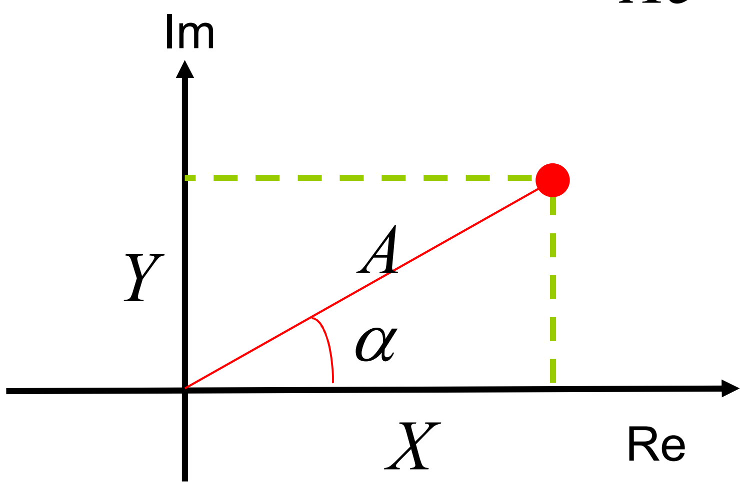
$$X = A\cos\alpha$$

$$Y = A\sin\alpha$$

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

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

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

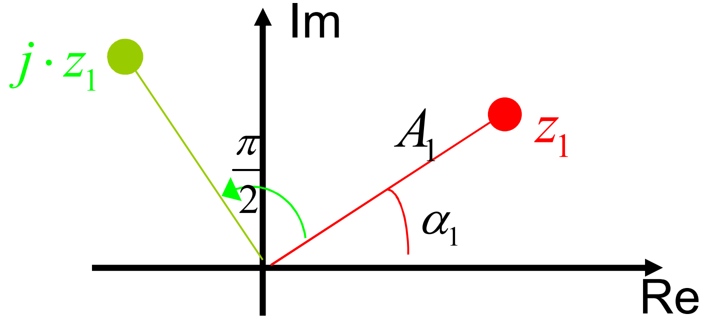
$$Z_2 = A_2 e^{j\alpha_2} = X_2 + jY_2$$

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

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

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

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



Complex numbers: product

Some examples

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

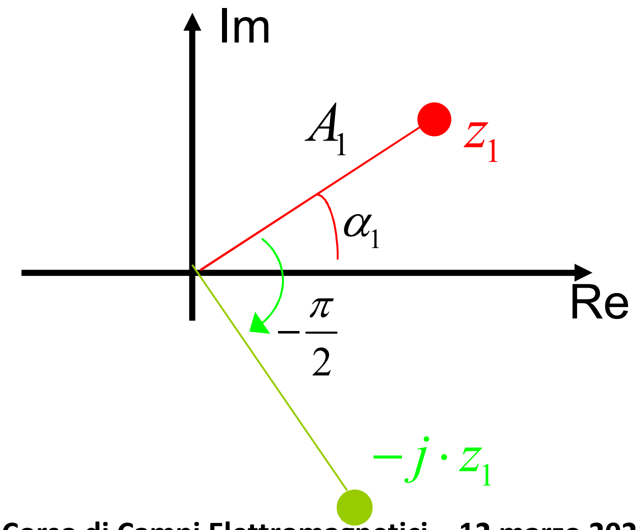
$$Z_2 = A_2 e^{j\alpha_2} = X_2 + jY_2$$

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

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

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

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



Complex numbers: product

Some examples

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

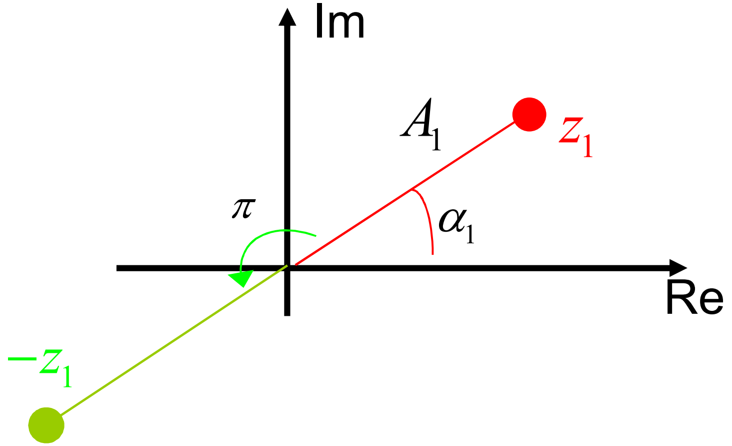
$$Z_2 = A_2 e^{j\alpha_2} = X_2 + jY_2$$

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

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

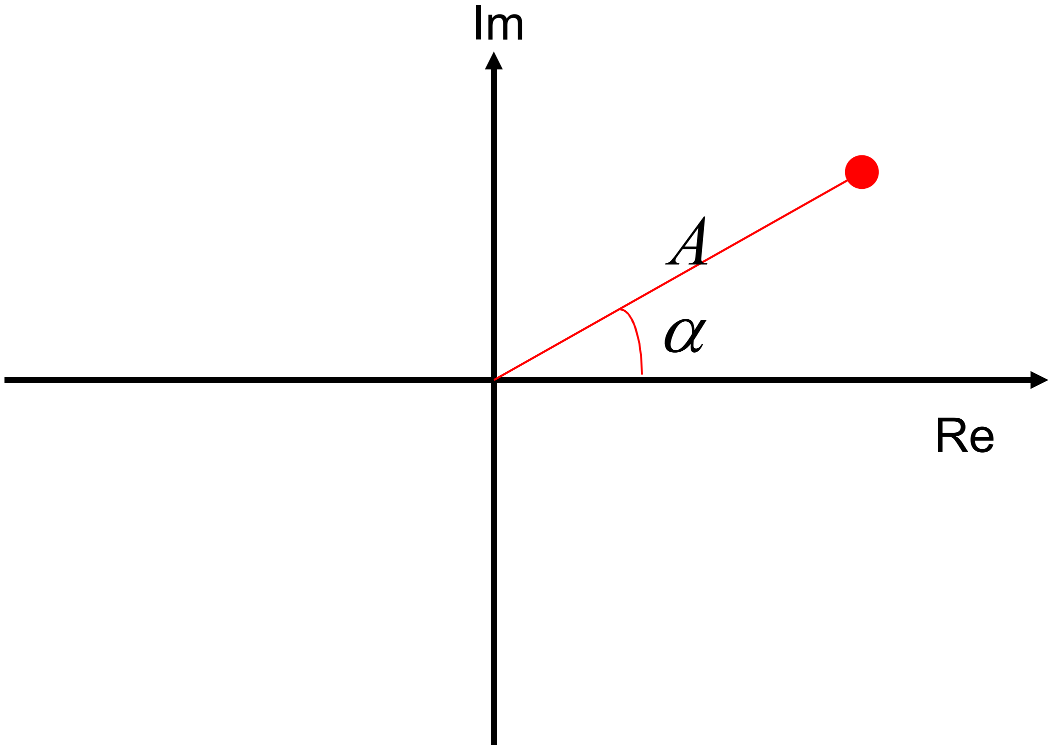
$$z_2 = -1 = e^{j\pi}$$

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



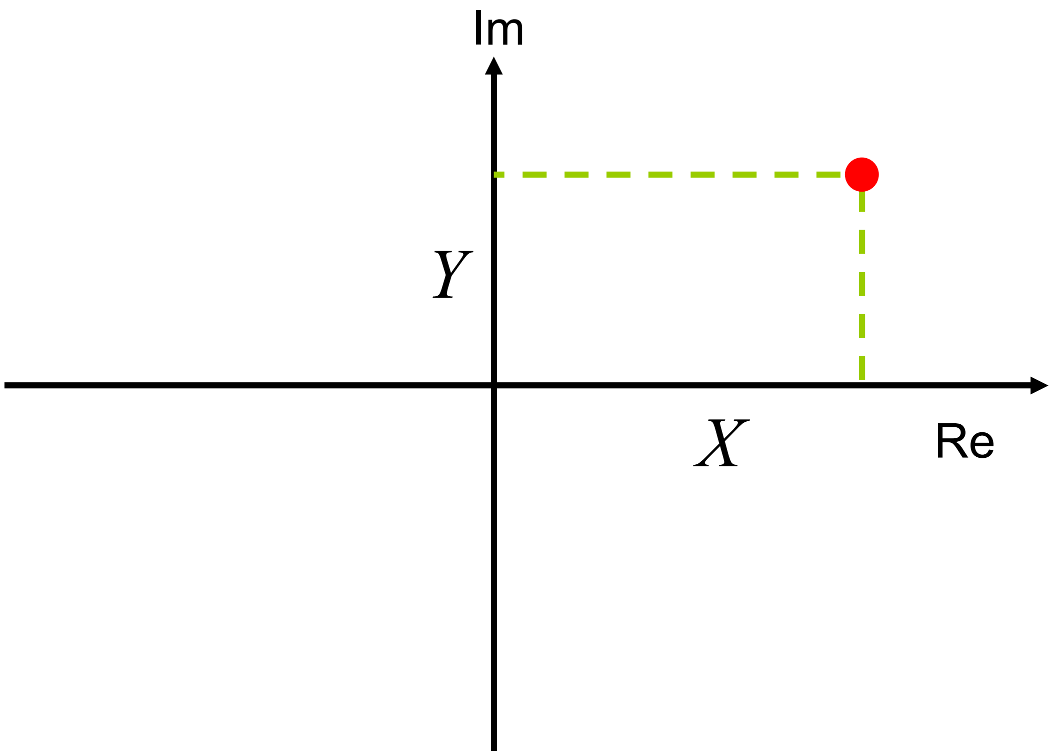
Complex numbers

$$Ae^{j\alpha}$$



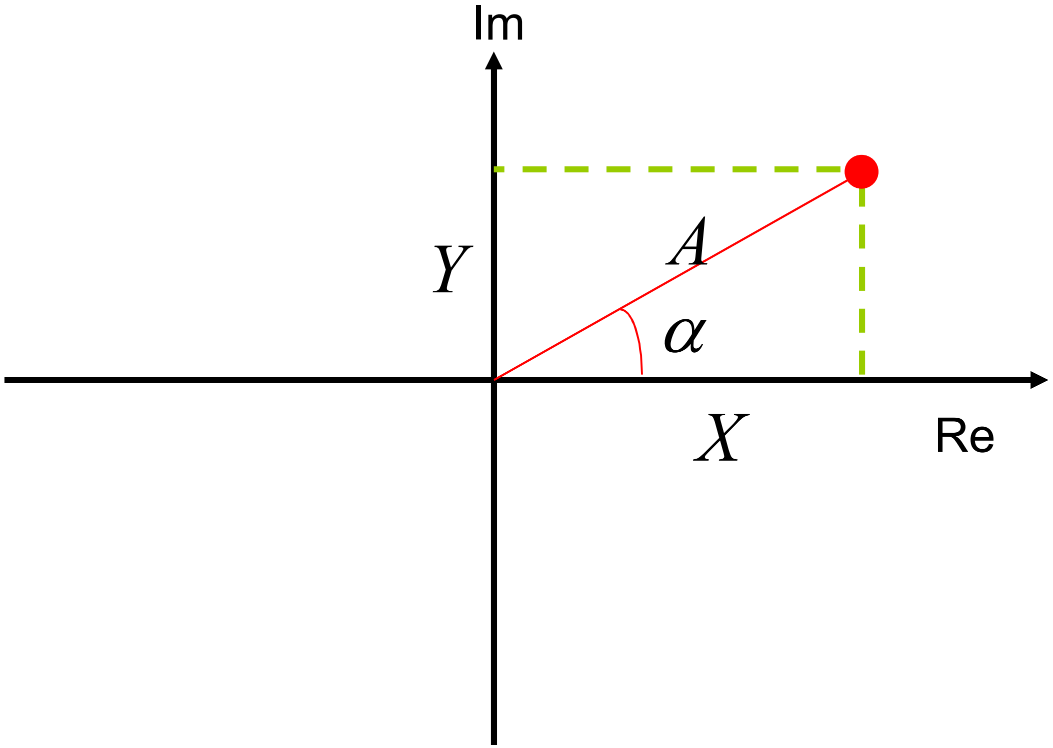
Complex numbers

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



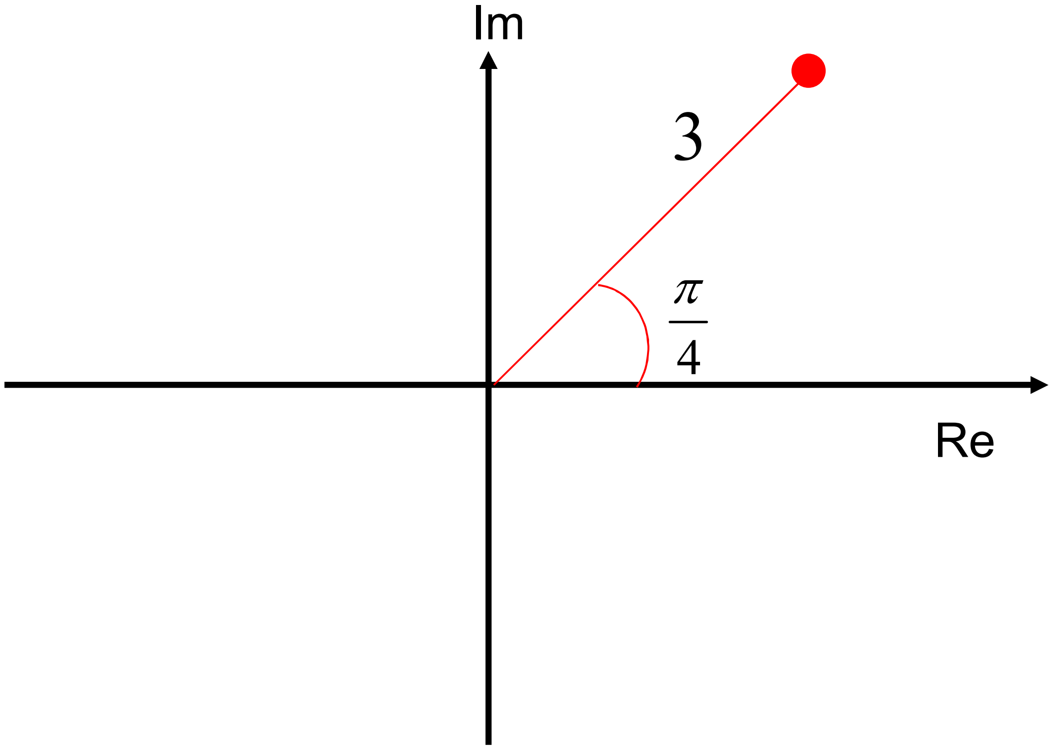
Complex numbers

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



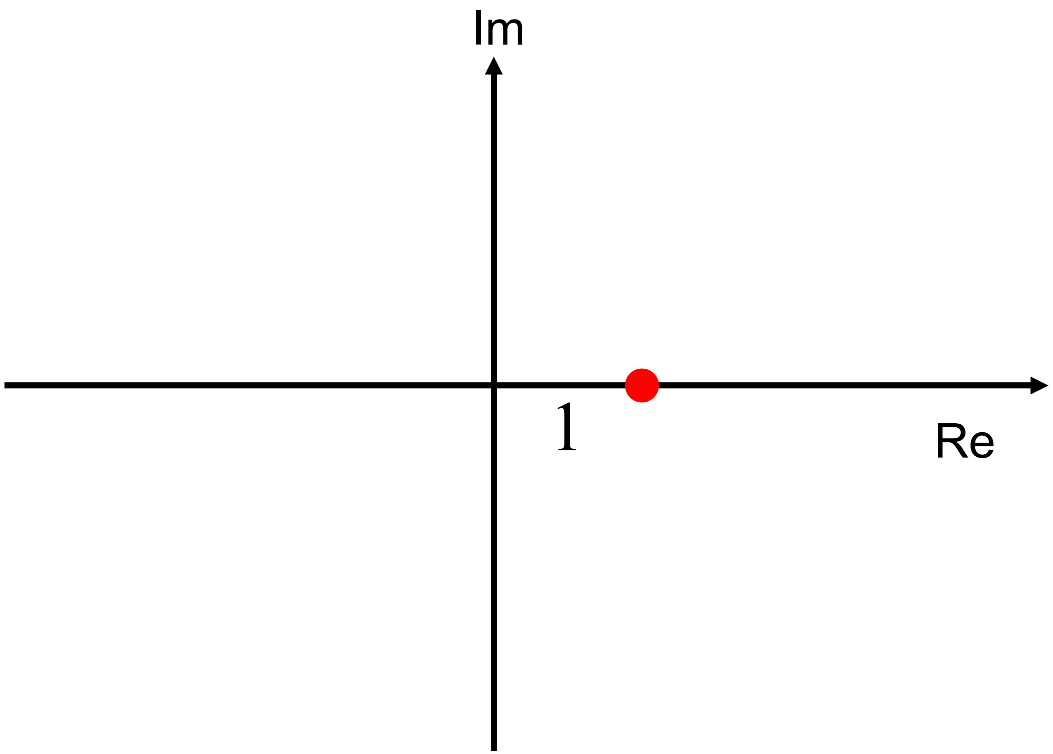
Complex numbers: some examples

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



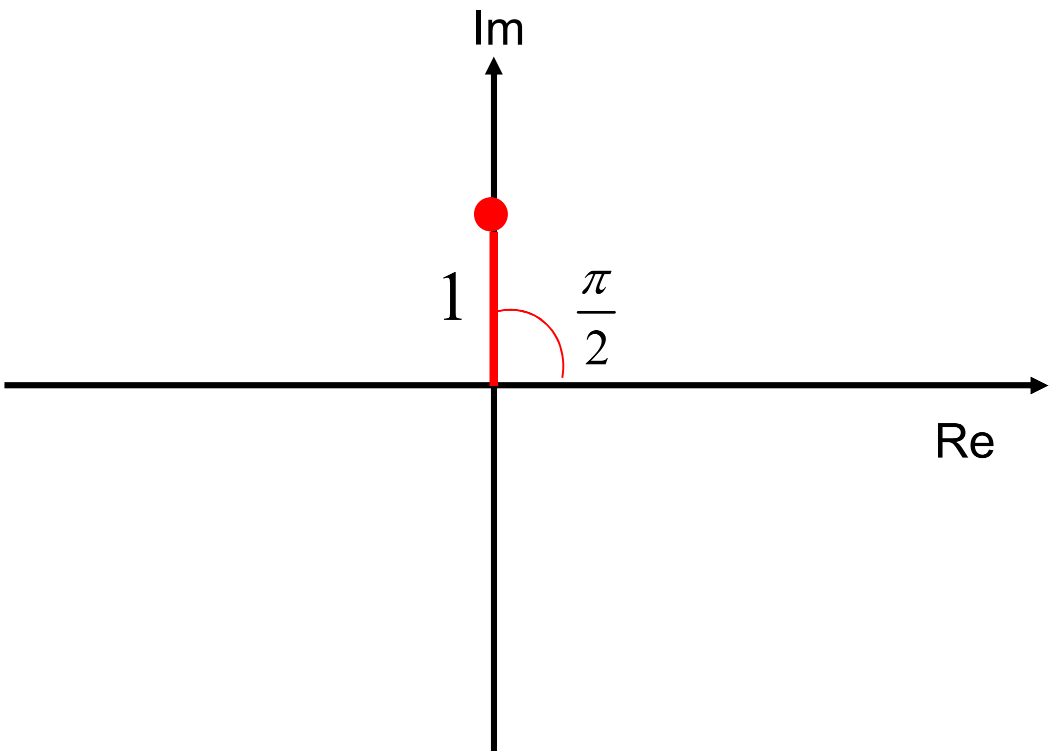
Complex numbers: some examples

$$1$$



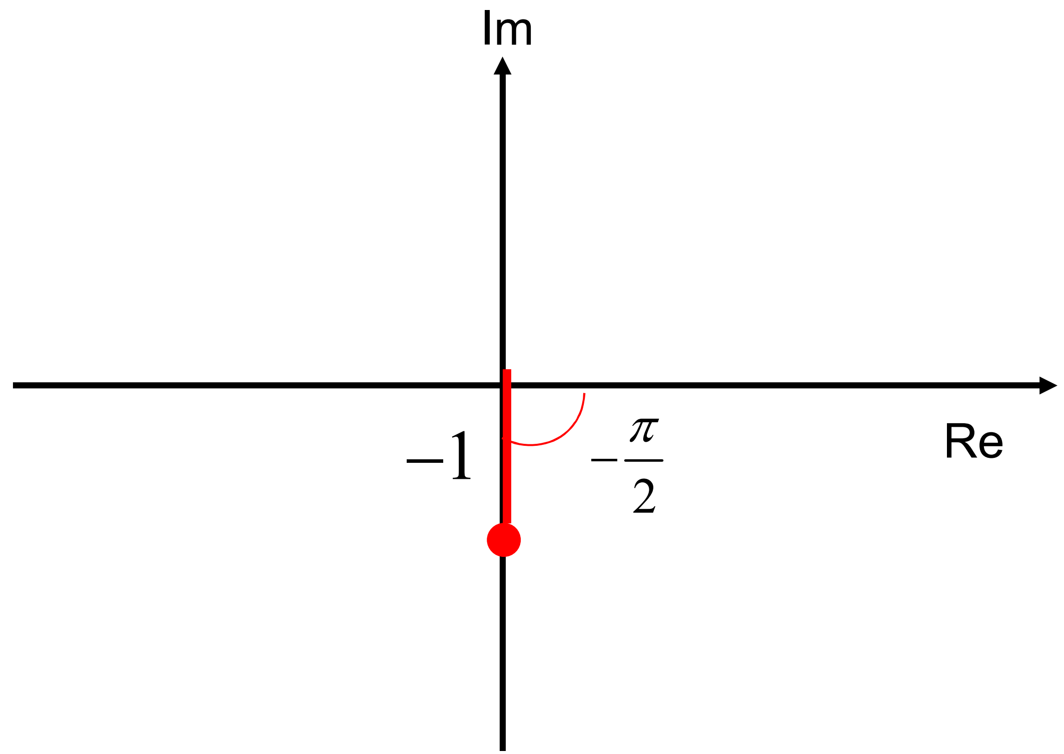
Complex numbers: some examples

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



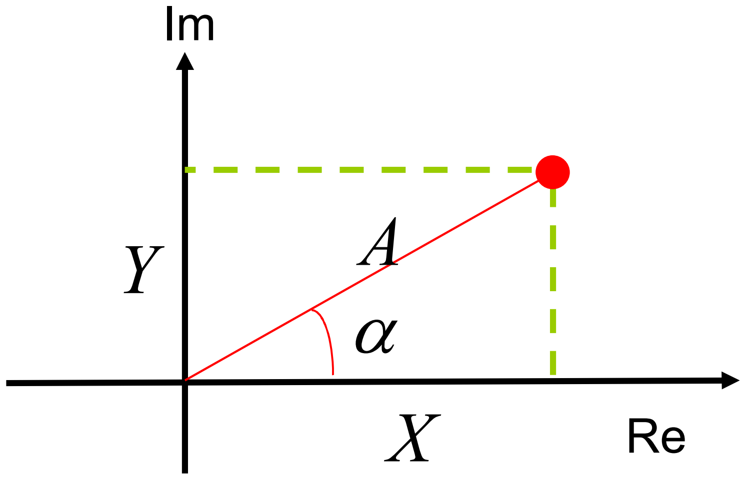
Complex numbers: some examples

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



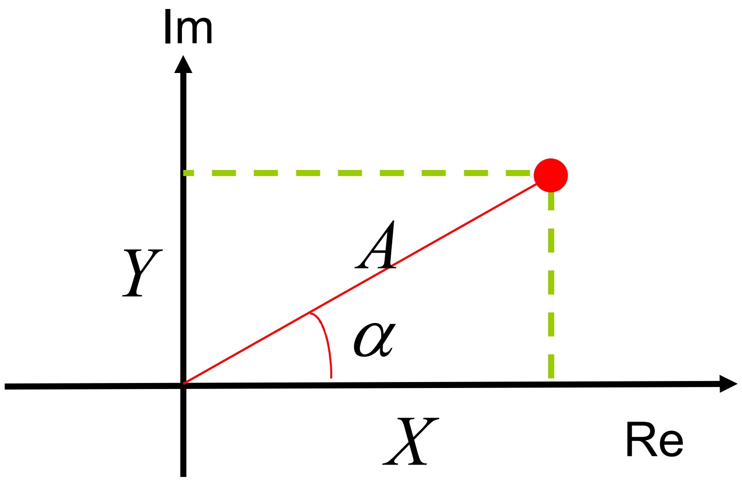
Complex numbers: conversion formulas

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



Complex numbers: conversion formulas

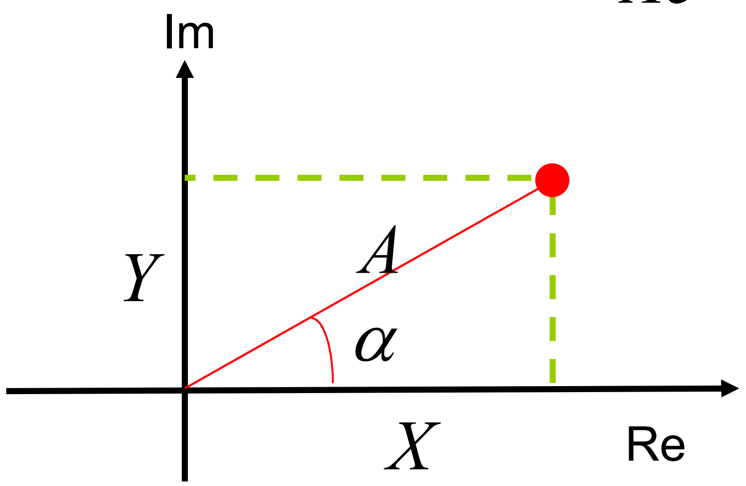
$$Ae^{j\alpha} = X + jY$$



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

Complex numbers: conversion formulas

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



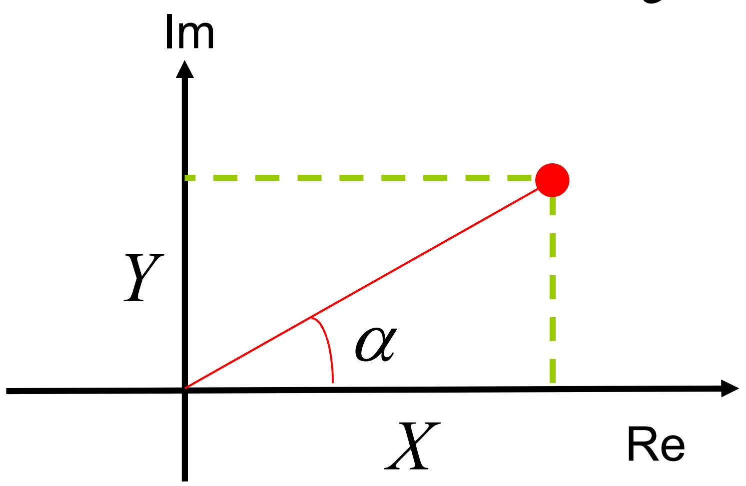
$$Ae^{j\alpha} \longrightarrow X + jY$$

$$X = A\cos\alpha$$

$$Y = A\sin\alpha$$

Complex numbers: conversion formulas

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



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

$$X = A\cos\alpha$$

$$Y = A\sin\alpha$$

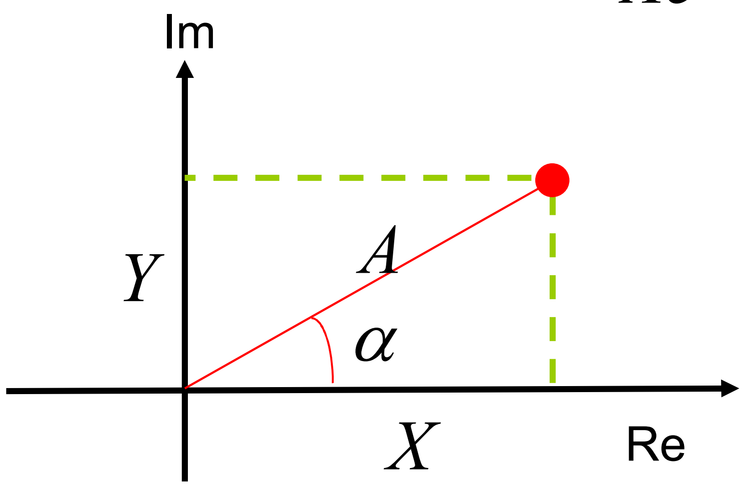
Eulero's formulas

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

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

Complex numbers: conversion formulas

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



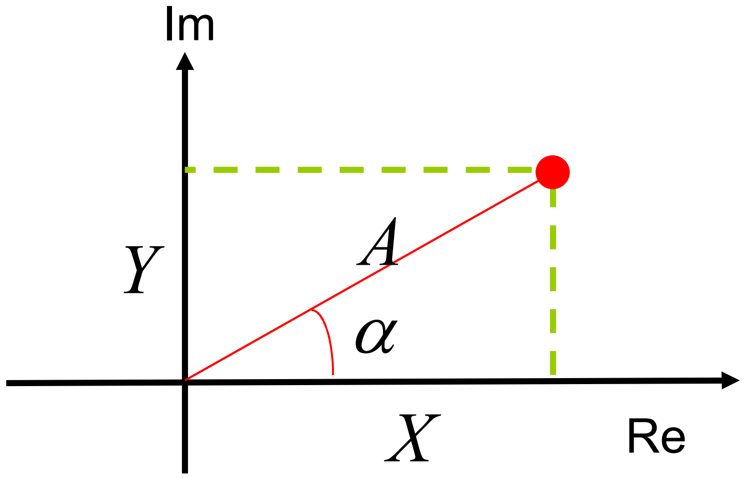
$$Ae^{j\alpha} \longrightarrow X + jY$$

$$X = A\cos\alpha$$

$$Y = A\sin\alpha$$

Complex numbers: conversion formulas

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



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

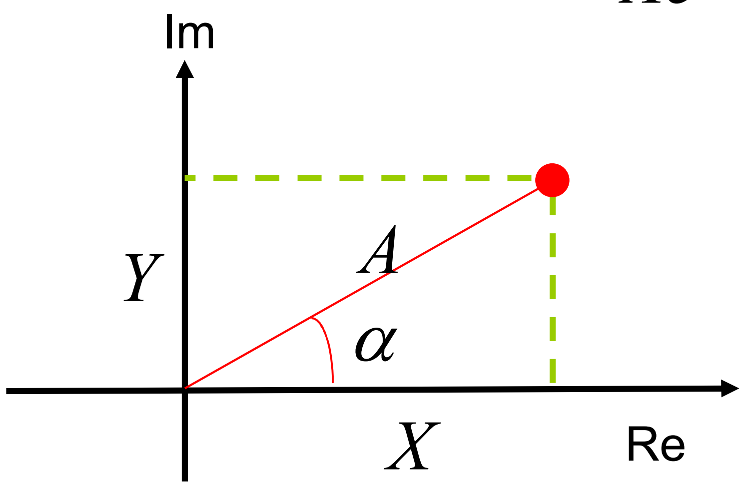
$$X = A\cos\alpha$$

$$Y = A\sin\alpha$$

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

Complex numbers: conversion formulas

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



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

$$X = A\cos\alpha$$

$$Y = A\sin\alpha$$

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

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

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

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

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

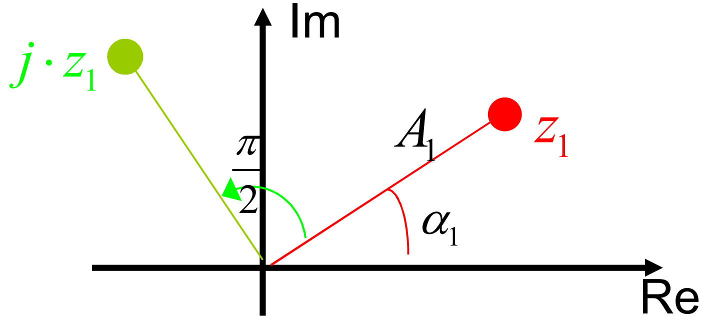
$$Z_2 = A_2 e^{j\alpha_2} = X_2 + jY_2$$

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

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

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

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



Complex numbers: product

Some examples

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

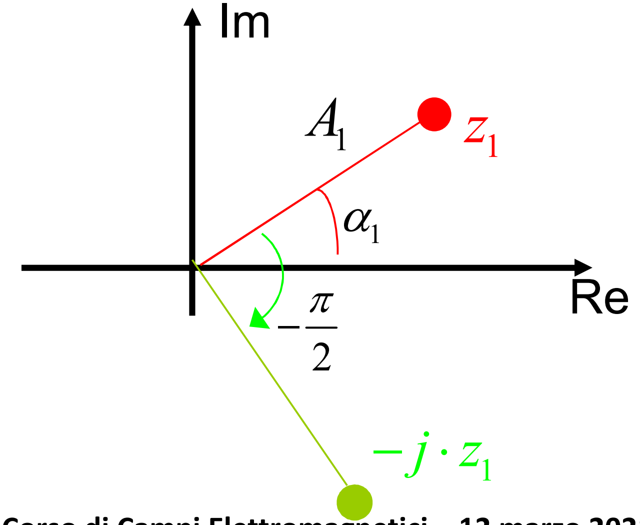
$$Z_2 = A_2 e^{j\alpha_2} = X_2 + jY_2$$

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

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

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

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



Complex numbers: product

Some examples

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

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

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

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

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

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