

Pseudo Scalar  $I = \gamma_t \wedge \gamma_x \wedge \gamma_y \wedge \gamma_z$

Magnetic Field Bi-Vector  $B = \mathbf{B}\gamma_t = -B^x\gamma_t \wedge \gamma_x - B^y\gamma_t \wedge \gamma_y - B^z\gamma_t \wedge \gamma_z$

Electric Field Bi-Vector  $E = \mathbf{E}\gamma_t = -E^x\gamma_t \wedge \gamma_x - E^y\gamma_t \wedge \gamma_y - E^z\gamma_t \wedge \gamma_z$

Electromagnetic Field Bi-Vector  $F = E + IB = -E^x\gamma_t \wedge \gamma_x - E^y\gamma_t \wedge \gamma_y - E^z\gamma_t \wedge \gamma_z - B^z\gamma_x \wedge \gamma_y + B^y\gamma_x \wedge \gamma_z - B^x\gamma_y \wedge \gamma_z$

Four Current Density  $J = J^t\gamma_t + J^x\gamma_x + J^y\gamma_y + J^z\gamma_z$

Geom Derivative of Electromagnetic Field Bi-Vector

$$\begin{aligned}\nabla F = & (\partial_x E^x + \partial_y E^y + \partial_z E^z) \gamma_t \\ & + (-\partial_z B^y + \partial_y B^z - \partial_t E^x) \gamma_x \\ & + (\partial_z B^x - \partial_x B^z - \partial_t E^y) \gamma_y \\ & + (-\partial_y B^x + \partial_x B^y - \partial_t E^z) \gamma_z \\ & + (-\partial_t B^z + \partial_y E^x - \partial_x E^y) \gamma_t \wedge \gamma_x \wedge \gamma_y \\ & + (\partial_t B^y + \partial_z E^x - \partial_x E^z) \gamma_t \wedge \gamma_x \wedge \gamma_z \\ & + (-\partial_t B^x + \partial_z E^y - \partial_y E^z) \gamma_t \wedge \gamma_y \wedge \gamma_z \\ & + (\partial_x B^x + \partial_y B^y + \partial_z B^z) \gamma_x \wedge \gamma_y \wedge \gamma_z\end{aligned}$$

Maxwell Equations

$$\nabla F = J$$

Div  $E$  and Curl  $H$  Equations

$$\begin{aligned}\langle \nabla F \rangle_1 - J = 0 = & (-J^t + \partial_x E^x + \partial_y E^y + \partial_z E^z) \gamma_t \\ & + (-J^x - \partial_z B^y + \partial_y B^z - \partial_t E^x) \gamma_x \\ & + (-J^y + \partial_z B^x - \partial_x B^z - \partial_t E^y) \gamma_y \\ & + (-J^z - \partial_y B^x + \partial_x B^y - \partial_t E^z) \gamma_z\end{aligned}$$

Curl  $E$  and Div  $B$  equations

$$\begin{aligned}\langle \nabla F \rangle_3 = 0 = & (-\partial_t B^z + \partial_y E^x - \partial_x E^y) \gamma_t \wedge \gamma_x \wedge \gamma_y \\ & + (\partial_t B^y + \partial_z E^x - \partial_x E^z) \gamma_t \wedge \gamma_x \wedge \gamma_z \\ & + (-\partial_t B^x + \partial_z E^y - \partial_y E^z) \gamma_t \wedge \gamma_y \wedge \gamma_z \\ & + (\partial_x B^x + \partial_y B^y + \partial_z B^z) \gamma_x \wedge \gamma_y \wedge \gamma_z\end{aligned}$$