$$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$$

$$\vec{F} = \iiint_R (\vec{E} + \vec{v} \times \vec{B})\,\rho\, d\tau$$

$$= \iiint_R (\rho\vec{E} + \rho\vec{v} \times \vec{B})\, d\tau$$

令 $\vec{f} = \rho\vec{E} + \rho\vec{v} \times \vec{B}$

$$= \rho\vec{E} + \vec{J} \times \vec{B}$$

$$= \epsilon(\nabla\cdot\vec{E})\vec{E} + \left[\frac{1}{\mu}\nabla\times\vec{B} - \epsilon\frac{\partial\vec{E}}{\partial t}\right]\times\vec{B}$$

$$= \epsilon(\nabla\cdot\vec{E})\vec{E} + \frac{1}{\mu}(\nabla\times\vec{B})\times\vec{B} - \epsilon\frac{\partial\vec{E}}{\partial t}\times\vec{B}$$

$$= \epsilon(\nabla\cdot\vec{E})\vec{E} + \frac{1}{\mu}(\nabla\times\vec{B})\times\vec{B} - \epsilon\frac{\partial}{\partial t}(\vec{E}\times\vec{B}) + \epsilon\vec{E}\times\frac{\partial\vec{B}}{\partial t}$$

$$= \epsilon(\nabla\cdot\vec{E})\vec{E} + \frac{1}{\mu}(\nabla\times\vec{B})\times\vec{B} + \epsilon(\nabla\times\vec{E})\times\vec{E} - \mu\epsilon\frac{\partial}{\partial t}(\vec{E}\times\vec{H})$$
$$+ \frac{1}{\mu}(\nabla\cdot\vec{B})\vec{B}$$

$$= \epsilon\left[(\nabla\cdot\vec{E})\vec{E} + (\vec{E}\cdot\nabla)\vec{E}\right] - \frac{1}{2}\nabla(\epsilon E^2) + \frac{1}{\mu}\left[(\nabla\cdot\vec{B})\vec{B} + (\vec{B}\cdot\nabla)\vec{B}\right] - \frac{1}{2}\nabla\left(\frac{B^2}{\mu}\right) - \mu\epsilon\frac{\partial}{\partial t}(\vec{E}\times\vec{H})$$

$$\frac{\partial}{\partial t}(\vec{E}\times\vec{B}) = \frac{\partial\vec{E}}{\partial t}\times\vec{B} + \vec{E}\times\frac{\partial\vec{B}}{\partial t}$$

$$\frac{\partial\vec{E}}{\partial t}\times\vec{B} = \frac{\partial}{\partial t}(\vec{E}\times\vec{B}) - \vec{E}\times\frac{\partial\vec{B}}{\partial t}$$

$$\nabla\times\vec{E} = -\frac{\partial\vec{B}}{\partial t}$$

$$\nabla(\vec{A}\cdot\vec{B}) = \vec{A}\times(\nabla\times\vec{B}) + \vec{B}\times(\nabla\times\vec{A}) + (\vec{A}\cdot\nabla)\vec{B} + (\vec{B}\cdot\nabla)\vec{A}$$

$$\nabla(\vec{E}\cdot\vec{E}) = \nabla(E^2) = 2\left[\vec{E}\times(\nabla\times\vec{E}) + (\vec{E}\cdot\nabla)\vec{E}\right]$$

$$\frac{1}{2}\nabla(\epsilon E^2) = \epsilon\vec{E}\times(\nabla\times\vec{E}) + \epsilon(\vec{E}\cdot\nabla)\vec{E}$$

$$\left\{\begin{array}{l} \epsilon(\nabla\times\vec{E})\times\vec{E} = \epsilon(\vec{E}\cdot\nabla)\vec{E} - \frac{1}{2}\nabla(\epsilon E^2) \\ \frac{1}{\mu}(\nabla\times\vec{B})\times\vec{B} = \frac{1}{\mu}(\vec{B}\cdot\nabla)\vec{B} - \frac{1}{2}\nabla\left(\frac{B^2}{\mu}\right) \end{array}\right.$$