

Notes for ECE 30500 - Semiconductor Devices

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Gradient, Divergence, and Curl

Gradient

The gradient describes the spatial slope of a 3-dimensional function. It can only be applied to a scalar field.

Rectangular:

$$\nabla f = a_x \frac{\delta f}{\delta x} + a_y \frac{\delta f}{\delta y} + a_z \frac{\delta f}{\delta z}$$

Cylindrical:

$$\nabla f = a_\rho \frac{\delta f}{\delta \rho} + a_\phi \frac{1}{\rho} \frac{\delta f}{\delta \phi} + a_z \frac{\delta f}{\delta z}$$

Spherical:

$$\nabla f = a_R \frac{\delta f}{\delta R} + a_\theta \frac{1}{R} \frac{\delta f}{\delta \theta} + a_z \frac{1}{R \sin(\theta)} \frac{\delta f}{\delta z}$$

Divergence

Describes the rate of change of a vector function.

Rectangular:

$$\nabla \cdot D = \left(a_x \frac{\delta}{\delta x} + a_y \frac{\delta}{\delta y} + a_z \frac{\delta}{\delta z} \right) \cdot (a_x D_x + a_y D_y + a_z D_z) = \frac{\delta D_x}{\delta x} + \frac{\delta D_y}{\delta y} + \frac{\delta D_z}{\delta z}$$

Curl

Describes the rotation of a vector function.

Rectangular:

$$\nabla \times D = a_x \left(\frac{\delta D_z}{\delta y} - \frac{\delta D_y}{\delta z} \right) + a_y \left(\frac{\delta D_x}{\delta z} - \frac{\delta D_z}{\delta x} \right) + a_z \left(\frac{\delta D_y}{\delta x} - \frac{\delta D_x}{\delta y} \right)$$

Cylindrical:

$$\nabla \times D = a_\rho \left(\frac{\delta D_z}{\delta \phi} - \frac{\delta \rho D_\phi}{\delta z} \right) + \rho a_\phi \left(\frac{\delta D_\rho}{\delta z} - \frac{\delta D_z}{\delta \rho} \right) + a_z \left(\frac{\delta \rho D_\phi}{\delta \rho} - \frac{\delta D_\rho}{\delta \phi} \right)$$

Identities

1. $\nabla \times \nabla V = 0$: the gradient does not rotate.
2. $\nabla \cdot (\nabla \times A) = 0$: the curl of a vector function does not diverge (grow).
3. A vector field whose divergence and curl are known is completely determined.