Notes for ECE 30500 - Semiconductor Devices

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These are lecture notes for Fall 2025 ECE 30500 by professor Elliott at Purdue. Modify, use, and distribute as you please.

Contents

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:

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

Cylindrical:

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

Spherical:

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

Divergence

Describes the rate of change of a vector function.

Rectangular:

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

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.