ECE343 Spring 2025

Objective 5.3: Electric Field from Scalar Potential



UNITED STATES
AIR FORCE
ACADEMY

Lesson	Topics	Reading	Notes
24	BVP (Capacitor, Coax), Electric Potential	5.16	LO 5.3
25	Electric Boundary Conditions	5.18-5.22	LO 5.4
26	BC's/Capacitance	5.23-5.24	
27	Electrostatic Lab	Lab packet	
Chapter 6: Steady Current & Conductivity			
28	Current density, Conductivity, Resistance	Ch. 6	
Chapter 7: Magnetostatics			
29	Magnetic Fields, Gauss' Law for Magnetism	7.1-7.3	LO 7.1-7.2 **GR 2**
30	Ampere's Law	7.4-7.5, 7.9	LO 7.3
31	Ampere's Law Applied	7.6-7.8	LO 7.3
32	Magnetic Boundary Conditions	7.10-7.14	LO 7.4
33	Magnetostatics Lab	Lab packet	
Chapter 8: Time-Varying Fields			
34	Faraday's Law, Displacement Current, Maxwell Eqns	8.3, 8.8, 8.9	LO 8.1
35	Faraday's Law, Displacement Current, Maxwell Eqns	8.3, 8.8, 8.9	LO 8.2-8.3
Chapter 9: Plane Waves in Lossless Media			
36	Maxwell's Equations in lossless, source-free region	9.1-9.2	LO 9.1
37	Maxwell's Equations in lossless, source-free region	9.1-9.2	LO 9.1
38	Uniform Plane Waves & Polarization	9.4-9.6	LO 9.2-9.3
39	Normal Incidence	Vol 2, 5.6-5.7	LO 9.4-9.5
40	Oblique Incidence	Vol 2, 5.6-5.7	LO 9.5
41	Oblique Incidence	Vol 2, 5.6-5.7	LO 9.5
42	Incidence Lab	TBD	LO 9.5

Ch 5 Learning Objectives

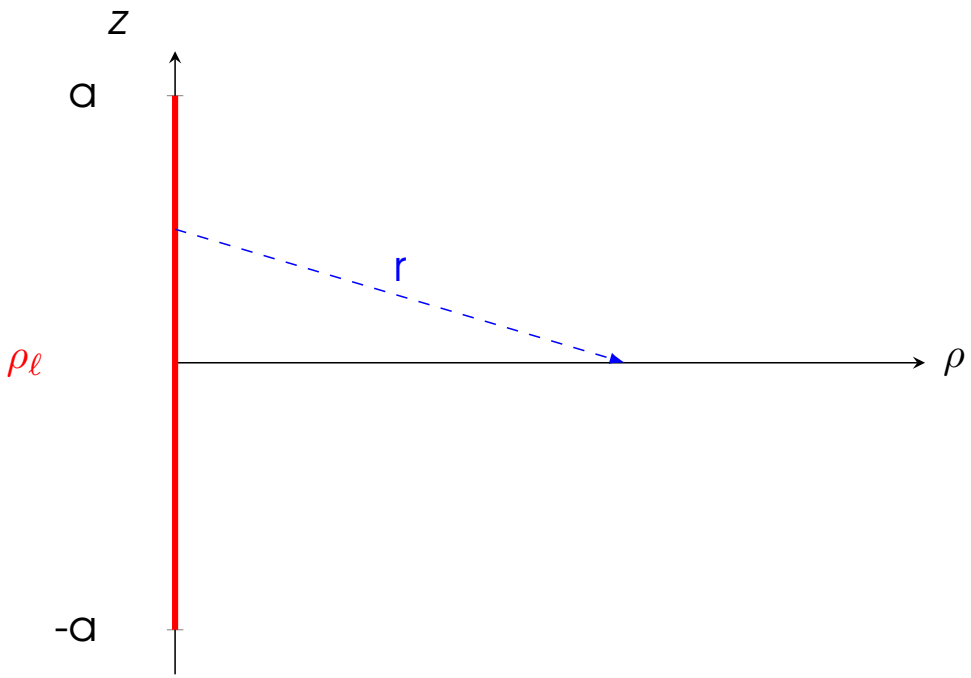
5.1 I can apply Coloumb's Law to use direct integration to calculate the electric field due to charge density in varoius geometries, including rectangular, cylindrical, and spherical coordinate systems.

5.2 I can apply the integral and differential forms of Gauss' Law to calculate the electric field due to charge density in various geometries, including rectangular, cylindrical, and spherical coordinate systems.

5.3 I can calculate the electric field from the scalar electric potential in a variety of geometries.

5.4 I can apply the electric field boundary conditions to calculate electric fields on both sides of a material boundary.

Scalar Potential: Line Charge



$$V = \int \frac{dQ}{4\pi\varepsilon r}$$

$$dQ = \rho_\ell d\ell = \rho_\ell dz$$

$$r = \sqrt{z^2 + \rho^2}$$

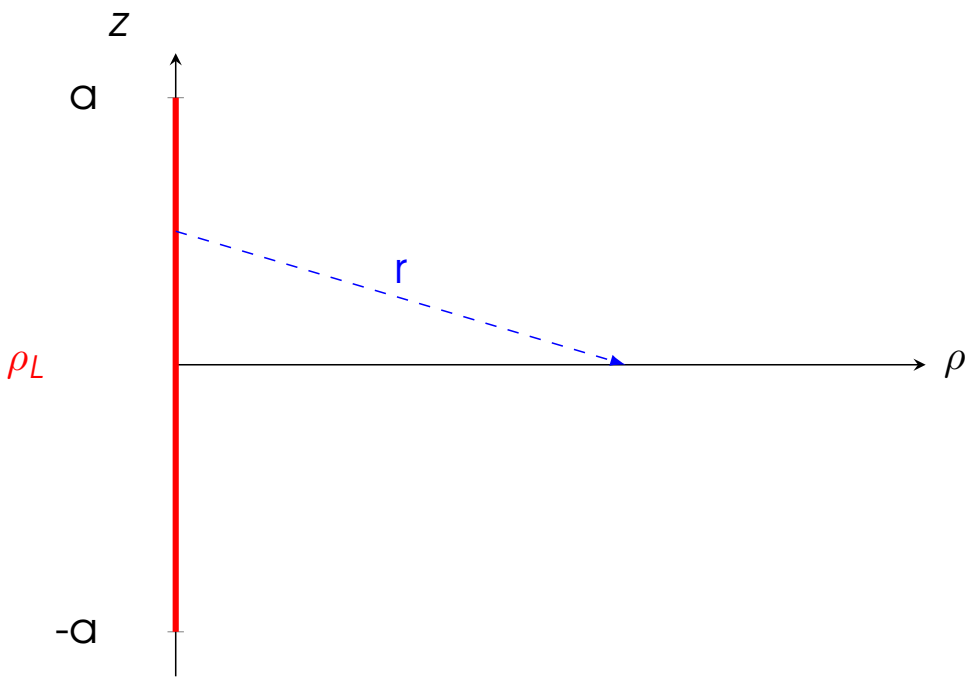
$$\Longrightarrow \int \frac{\rho_\ell dz}{4\pi\varepsilon\sqrt{z^2 + \rho^2}}$$

$$= \frac{\rho_\ell}{4\pi\varepsilon} \int \frac{1}{\sqrt{z^2 + \rho^2}} dz$$

$$= \frac{2\rho_\ell}{4\pi\varepsilon} \left[\ln\left(z + \sqrt{z^2 + \rho^2}\right) \right] \Bigg|_0^a$$

$$V = \frac{\rho_\ell}{2\pi\varepsilon} \left[\ln\left(\frac{a + \sqrt{a^2 + \rho^2}}{\rho} \right) \right]$$

Scalar Potential: Line Charge



$$V = \frac{\rho_\ell}{2\pi\varepsilon}\left[\ln\left(\frac{a+\sqrt{a^2+\rho^2}}{\rho}\right)\right]$$

$$\Longrightarrow \vec{E} = -\nabla V = -\hat{\boldsymbol{\rho}}\frac{\partial V}{\partial \rho}$$

for $a >> \rho$:

$$\Longrightarrow \vec{E} = -\hat{\boldsymbol{\rho}}\frac{\partial}{\partial \rho}\frac{\rho_\ell}{2\pi\varepsilon}\left[\ln\left(\frac{2a}{\rho}\right)\right]$$

$$= -\hat{\boldsymbol{\rho}}\frac{\partial}{\partial \rho}\frac{\rho_\ell}{2\pi\varepsilon}\left[\ln(2a) - \ln(\rho)\right]$$

$$\Longrightarrow \vec{E} = \hat{\boldsymbol{\rho}}\frac{\rho_L}{2\pi\varepsilon\rho}$$