Homework No. 02 (Spring 2026)

PHYS 520B: ELECTROMAGNETIC THEORY

Department of Physics, Southern Illinois University–Carbondale

Due date: Tuesday, 2026 Jan 27, 4.30pm

1. (**20 points.**) Let two conducting plates, with their inside faces occupying the $y = 0$ plane and $y = a$, consist of uniform positive and negative charge density σ flowing in opposite directions of $\hat{\mathbf{z}}$, respectively, described by drift velocity v_d such that the electric and magnetic field for this configuration is given by

$$\mathbf{E} = \begin{cases} \hat{\mathbf{y}}\,\dfrac{\sigma}{\varepsilon_0}, & \text{if} \quad 0 < y < a, \\ 0, & \text{otherwise}, \end{cases} \tag{1a}$$

$$\mathbf{B} = \begin{cases} \hat{\mathbf{z}}\,\mu_0\sigma v_d, & \text{if} \quad 0 < y < a, \\ 0, & \text{otherwise}. \end{cases} \tag{1b}$$

Note,

$$cB = \beta_d E, \tag{2}$$

where $\beta_d = v_d/c$.

(a) Derive the expressions in Eqs. (1) using Gauss's law and Ampère's law, respectively.

(b) Explore the configuration in the rest frame of the flow associated with the drift velocity.

(c) Evaluate the electromagnetic stress (force per unit area) on the plate at $y = 0$. Consider the limiting case of $v_d = 0$ and match it with the results in the lecture of 2023 February 7.

(d) (This Item is not for assessment.) Discuss the relativistic transformation of the stress. Recall that $L' = L/\gamma$ and $E' = \gamma E$.

Refer the paper titled 'A simple relativistic paradox about electrostatic energy,' by W. Rindler and J. Denur, in Am. J. Phys. **56**, 795 (1988).