Quiz 5: Mach-Zender Adjacency Matrix
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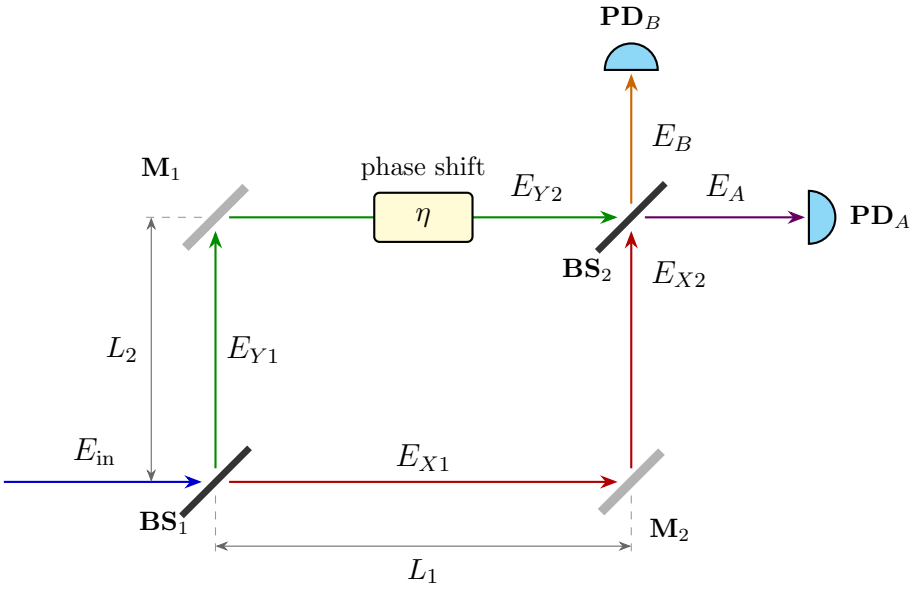
Lasers and Optomechanics

Name: _____

Mach-Zender Interferometer
Suppose we have a Mach-Zender interferometer as labeled below, sourced with a input field E_in with wavenumber k and with side lengths L_1 and L_2. In the Y-arm of the Mach-Zender is an optical element that applies a phase-shift η to the beam that passes through. Assume plane-waves for all fields in the interferometer.



For the below questions, use the following field vector $\vec{E}$ to represent the different seven labeled fields of the interferometer:

$$\vec{E} = \begin{bmatrix} E_{\text{in}} & E_{X1} & E_{Y1} & E_{X2} & E_{Y2} & E_A & E_B \end{bmatrix}^T \tag{1}$$

You may also want to use

$$\cos\alpha = \frac{e^{i\alpha} + e^{-i\alpha}}{2}, \qquad \sin\alpha = \frac{e^{i\alpha} - e^{-i\alpha}}{2i} \tag{2}$$

1. Write six equations relating the seven fields of the Mach-Zender interferometer.
   Use parameters $L_1, L_2, \eta, r_{BS1}, t_{BS1}, r_{BS2}, t_{BS2}, r_{M1}, r_{M2}$.
2. Find expressions for field transfer functions $\frac{E_A}{E_{\text{in}}}$ and $\frac{E_B}{E_{\text{in}}}$.
   Assume that $r_{BS1} = t_{BS1} = r_{BS2} = t_{BS2} = \frac{1}{\sqrt{2}}$, and that $r_{M1} = r_{M2} = 1$.
3. Using your result from (2), calculate the power relationships $\frac{P_A}{P_{\text{in}}}$ and $\frac{P_B}{P_{\text{in}}}$.
4. What would a change in L_1 or L_2 do to E_A and E_B? What about the power expressions P_A and P_B?
5. What about a change in η? Would this impact E_A and E_B or P_A and P_B?
6. Using your equations from (1), put together an adjacency matrix for the Mach-Zender interferometer.