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## 22. Relativity

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### Abstract

Lecture slides 22 for Elementary Physics II (PHY 204), taught by Gerhard Müller at the University of Rhode Island.

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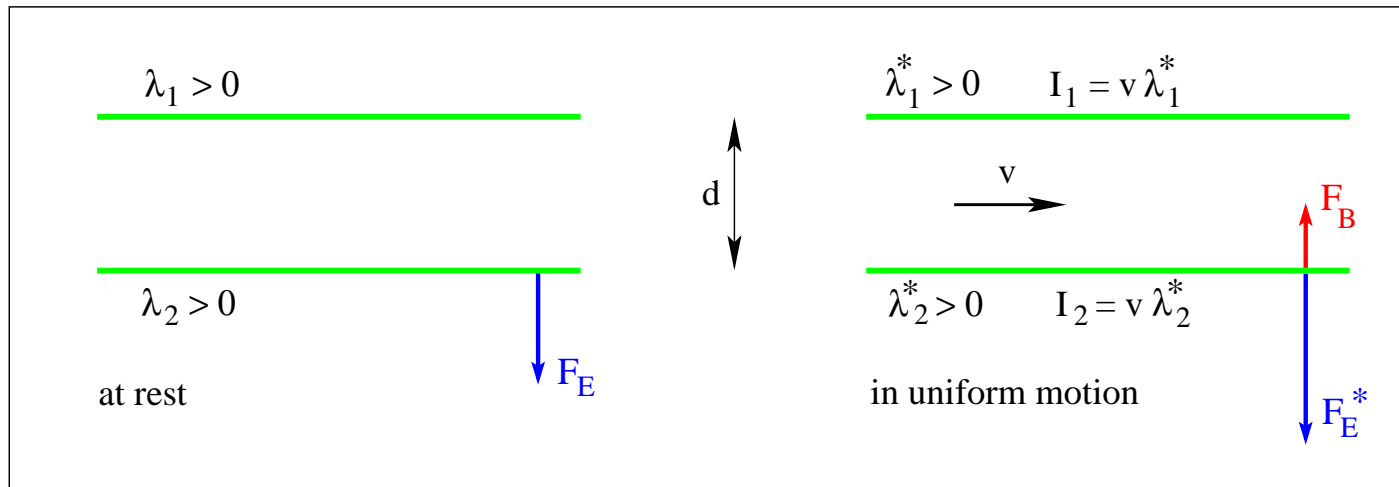
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# Is There Absolute Motion?



Forces between two long, parallel, charged rods

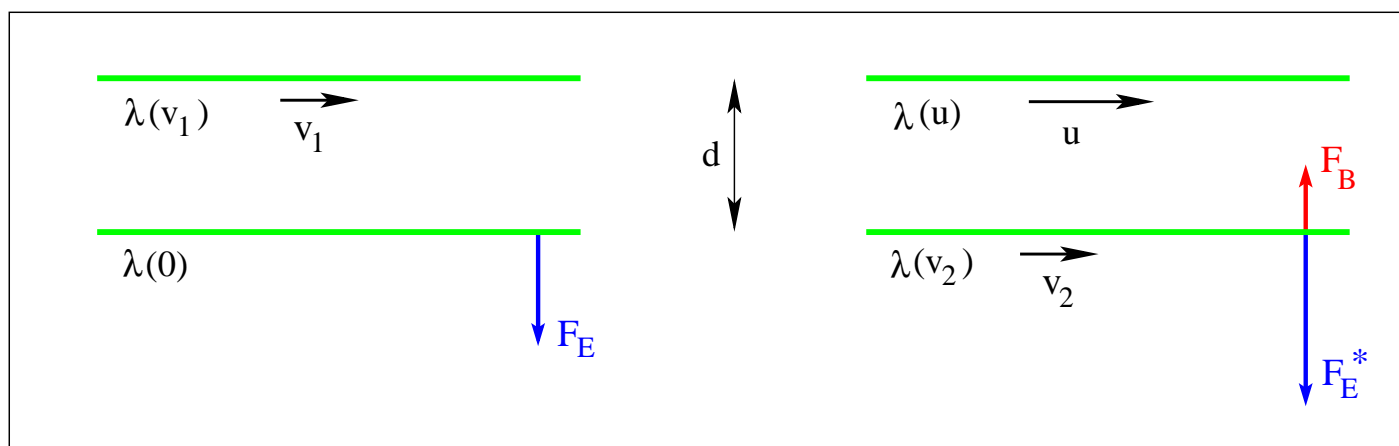


- $\frac{F_E}{L} = \frac{1}{2\pi\epsilon_0} \frac{\lambda_1 \lambda_2}{d}$  (left),  $\frac{F_E^*}{L} = \frac{1}{2\pi\epsilon_0} \frac{\lambda_1^* \lambda_2^*}{d}$ ,  $\frac{F_B}{L} = \frac{\mu_0}{2\pi} \frac{I_1 I_2}{d}$ , (right)
- $\frac{F_E^* - F_B}{L} = \frac{1}{2\pi\epsilon_0} \frac{\lambda_1^* \lambda_2^*}{d} \left(1 - \frac{v^2}{c^2}\right) = \frac{1}{2\pi\epsilon_0} \frac{\lambda_1 \lambda_2}{d}$
- $c = \frac{1}{\sqrt{\epsilon_0 \mu_0}} = 2.998 \times 10^8 \text{ ms}^{-1}$  (speed of light)
- $\lambda_1^* = \frac{\lambda_1}{\sqrt{1 - v^2/c^2}}$ ,  $\lambda_2^* = \frac{\lambda_2}{\sqrt{1 - v^2/c^2}}$  (due to length contraction)

# Catching Up with a Photon? (1)

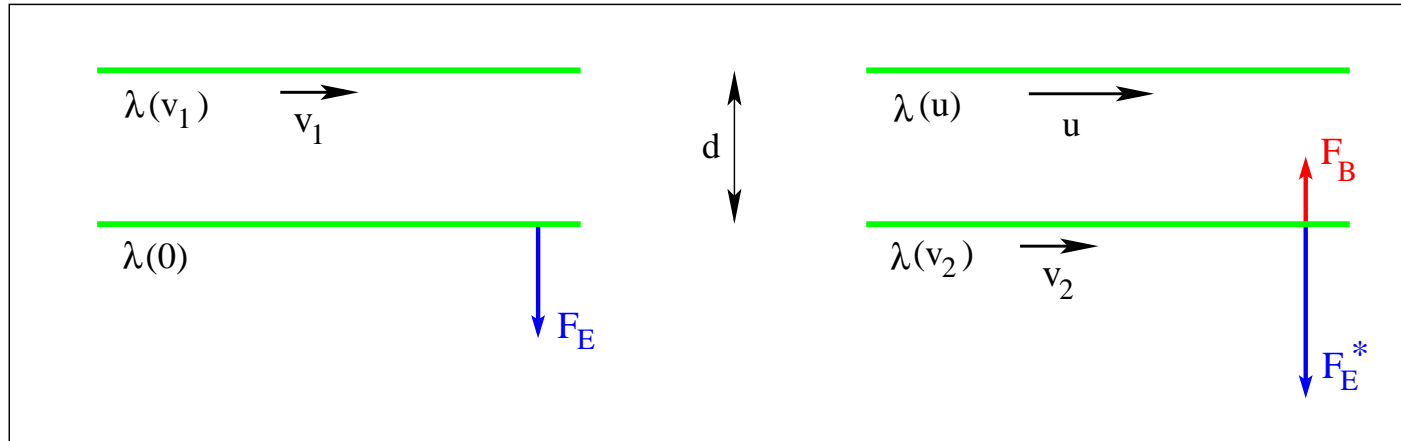


Forces between two long, parallel, charged rods in relative motion.



- Galilean kinematics predicts  $u = v_1 + v_2$ .
- Relativistic kinematics requires  $v_1 < c$ ,  $v_2 < c$ ,  $u < c$ .
- Relativistic dynamics requires  $F_E^* - F_B = F_E$ .
- Length-contracted charge densities:  $\lambda(v) = \frac{\lambda(0)}{\sqrt{1 - v^2/c^2}}$ .
- Electric currents:  $I(v) = \lambda(v)v$ .

# Catching Up with a Photon? (2)



- $\frac{F_E}{L} = \frac{1}{2\pi\epsilon_0} \frac{\lambda(0)\lambda(v_1)}{d}, \quad \frac{F_E^*}{L} = \frac{1}{2\pi\epsilon_0} \frac{\lambda(v_2)\lambda(u)}{d}.$
- $\frac{F_B}{L} = \frac{\mu_0}{2\pi} \frac{[\lambda(v_2)v_2][\lambda(u)u]}{d} = \frac{1}{2\pi\epsilon_0} \frac{\lambda(v_2)\lambda(u)}{d} \frac{v_2 u}{c^2}.$
- $\frac{F_E^* - F_B}{L} = \frac{F_E}{L} \Rightarrow \frac{1}{2\pi\epsilon_0} \frac{\lambda(v_2)\lambda(u)}{d} \left(1 - \frac{v_2 u}{c^2}\right) = \frac{1}{2\pi\epsilon_0} \frac{\lambda(0)\lambda(v_1)}{d}$
- $\Rightarrow \frac{1}{\sqrt{1 - v_2^2/c^2}} \frac{1}{\sqrt{1 - u^2/c^2}} \left(1 - \frac{v_2 u}{c^2}\right) = \frac{1}{\sqrt{1 - v_1^2/c^2}}$  to be solved for  $u$ .
- Relativistic kinematic predicts  $u = \frac{v_1 + v_2}{1 + v_1 v_2 / c^2} < c.$