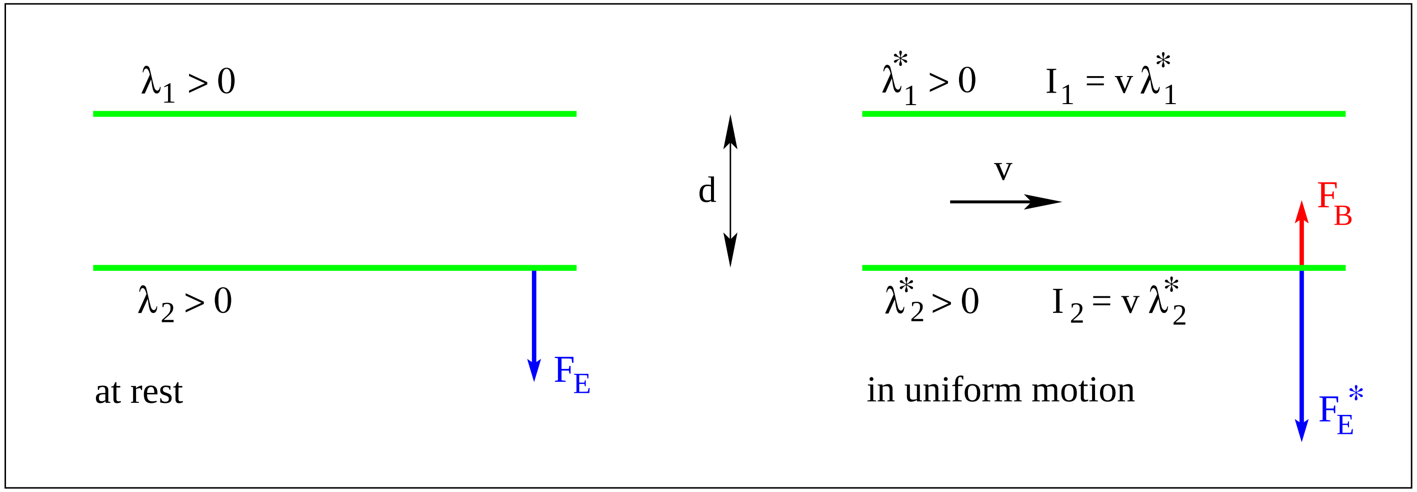
Is There Absolute Motion?

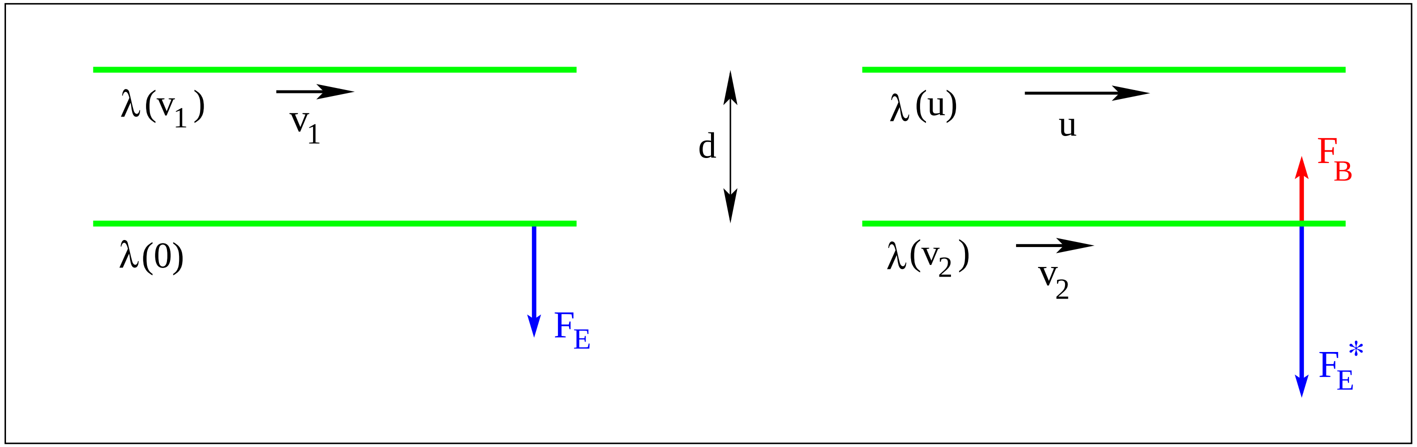
Forces between two long, parallel, charged rods



- $\frac{F_E}{L} = \frac{1}{2\pi\epsilon_0}\frac{\lambda_1\lambda_2}{d}$ (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)
- $\frac{F_E^* - F_B}{L} = \frac{1}{2\pi\epsilon_0}\frac{\lambda_1^*\lambda_2^*}{d}\left(1 - \frac{v^2}{c^2}\right) = \frac{1}{2\pi\epsilon_0}\frac{\lambda_1\lambda_2}{d}$
- $c = \frac{1}{\sqrt{\epsilon_0\mu_0}} = 2.998 \times 10^8 \mathrm{ms}^{-1}$ (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)

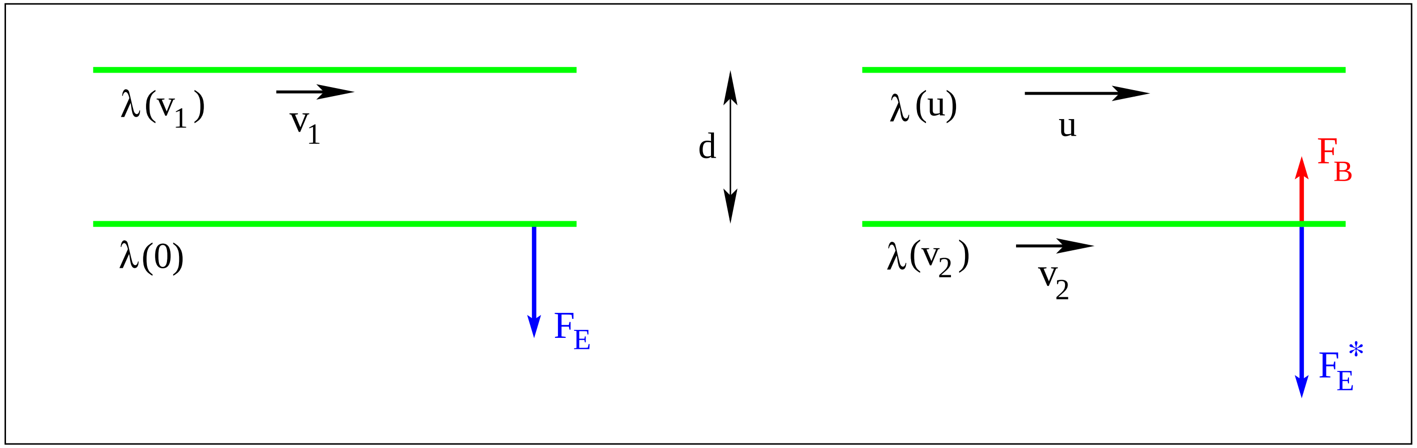
Catching Up with a Photon? (1)

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: $\lambda(v) = \dfrac{\lambda(0)}{\sqrt{1 - v^2/c^2}}$.
- Electric currents: $I(v) = \lambda(v)v$.

Catching Up with a Photon? (2)



- $$\frac{F_E}{L} = \frac{1}{2\pi\epsilon_0}\frac{\lambda(0)\lambda(v_1)}{d}, \qquad \frac{F_E^*}{L} = \frac{1}{2\pi\epsilon_0}\frac{\lambda(v_2)\lambda(u)}{d}.$$
- $$\frac{F_B}{L} = \frac{\mu_0}{2\pi}\frac{[\lambda(v_2)v_2][\lambda(u)u]}{d} = \frac{1}{2\pi\epsilon_0}\frac{\lambda(v_2)\lambda(u)}{d}\frac{v_2u}{c^2}.$$
- $$\frac{F_E^* - F_B}{L} = \frac{F_E}{L} \quad \Rightarrow \quad \frac{1}{2\pi\epsilon_0}\frac{\lambda(v_2)\lambda(u)}{d}\left(1 - \frac{v_2u}{c^2}\right) = \frac{1}{2\pi\epsilon_0}\frac{\lambda(0)\lambda(v_1)}{d}$$
- $$\Rightarrow \quad \frac{1}{\sqrt{1 - v_2^2c^2}}\frac{1}{\sqrt{1 - u^2/c^2}}\left(1 - \frac{v_2u}{c^2}\right) = \frac{1}{\sqrt{1 - v_1^2/c^2}}$$ to be solved for u.
- Relativistic kinematic predicts $u = \dfrac{v_1 + v_2}{1 + v_1v_2/c^2} < c$.