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22. Relativity

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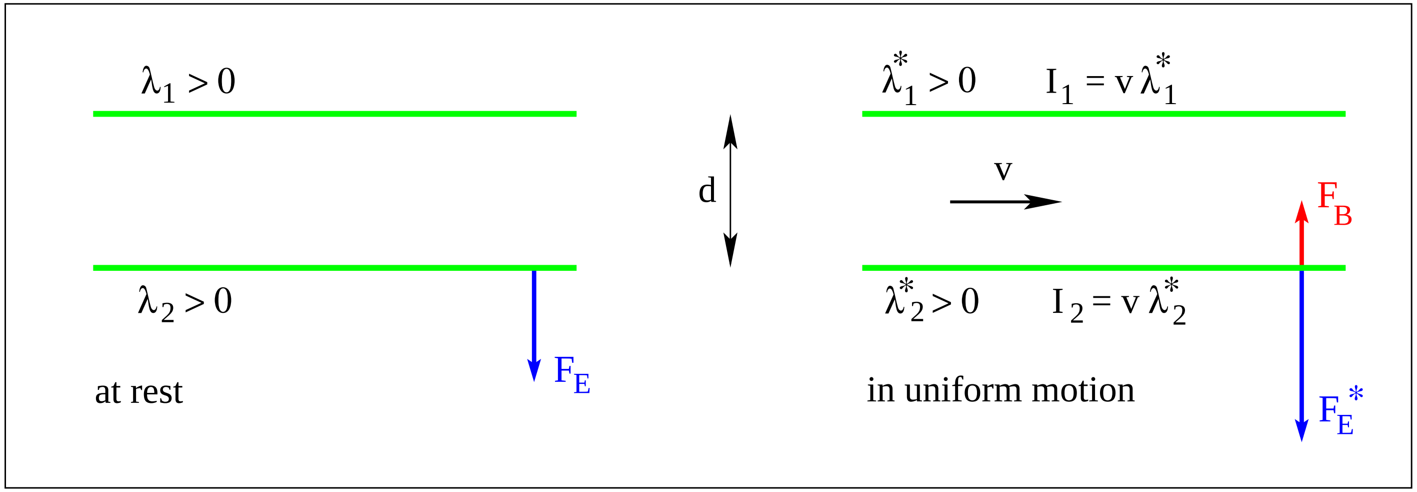
Abstract
Lecture slides 22 for Elementary Physics II (PHY 204), taught by Gerhard Müller at the University of Rhode Island.
Some of the slides contain figures from the textbook, Paul A. Tipler and Gene Mosca. *Physics for Scientists and Engineers*, $5^{th}/6^{th}$ editions. The copyright to these figures is owned by W.H. Freeman. We acknowledge permission from W.H. Freeman to use them on this course web page. The textbook figures are not to be used or copied for any purpose outside this class without direct permission from W.H. Freeman.

Is There Absolute Motion?

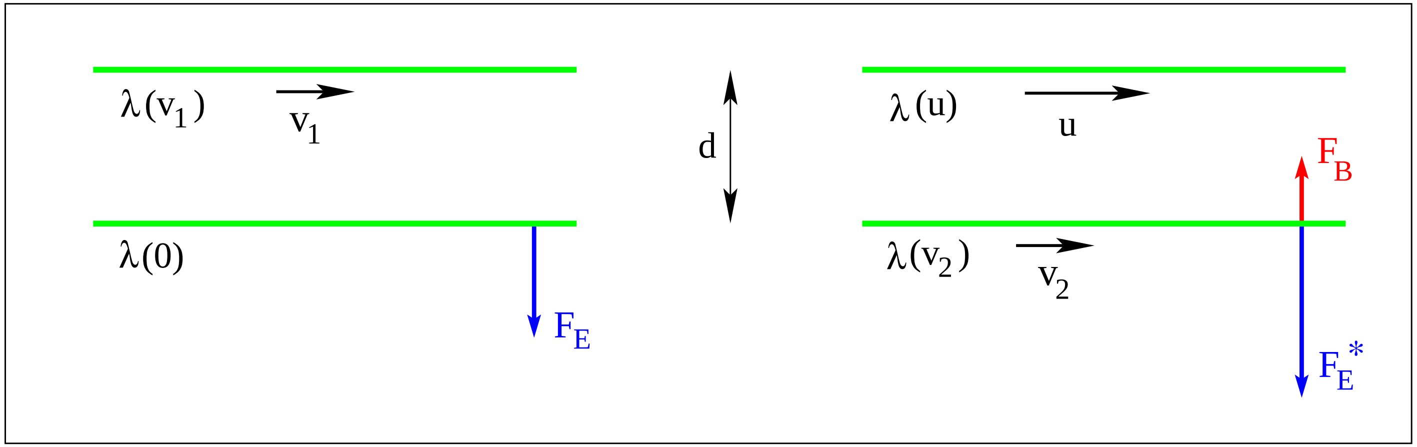
Forces between two long, parallel, charged rods



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

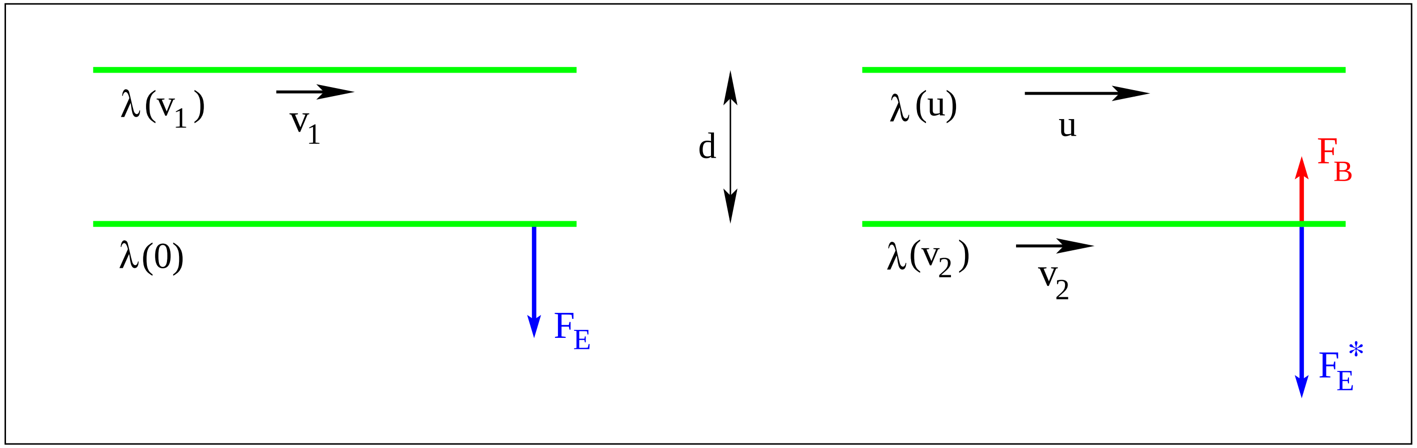
Catching Up with a Photon? (1)

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)



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