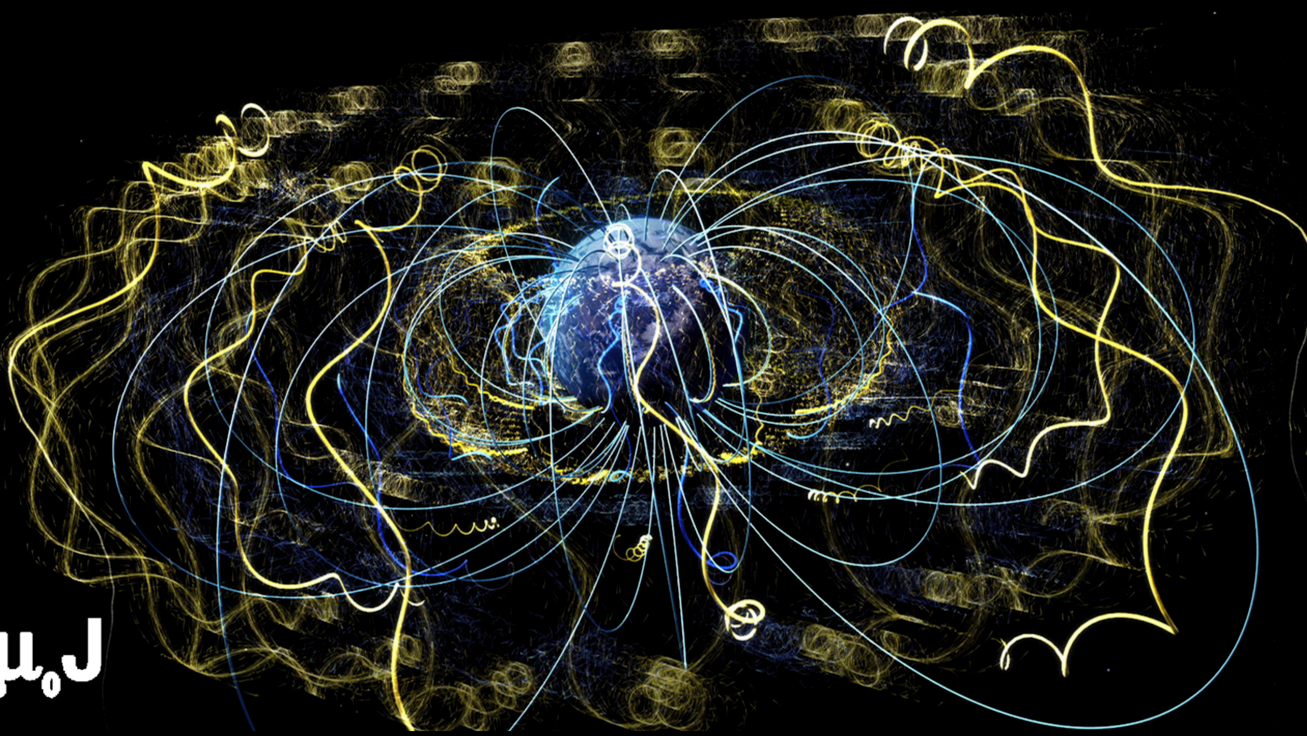
$$\nabla \cdot \mathbf{E} = \frac{\rho}{\varepsilon_0}$$

$$\nabla \cdot \mathbf{B} = 0$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

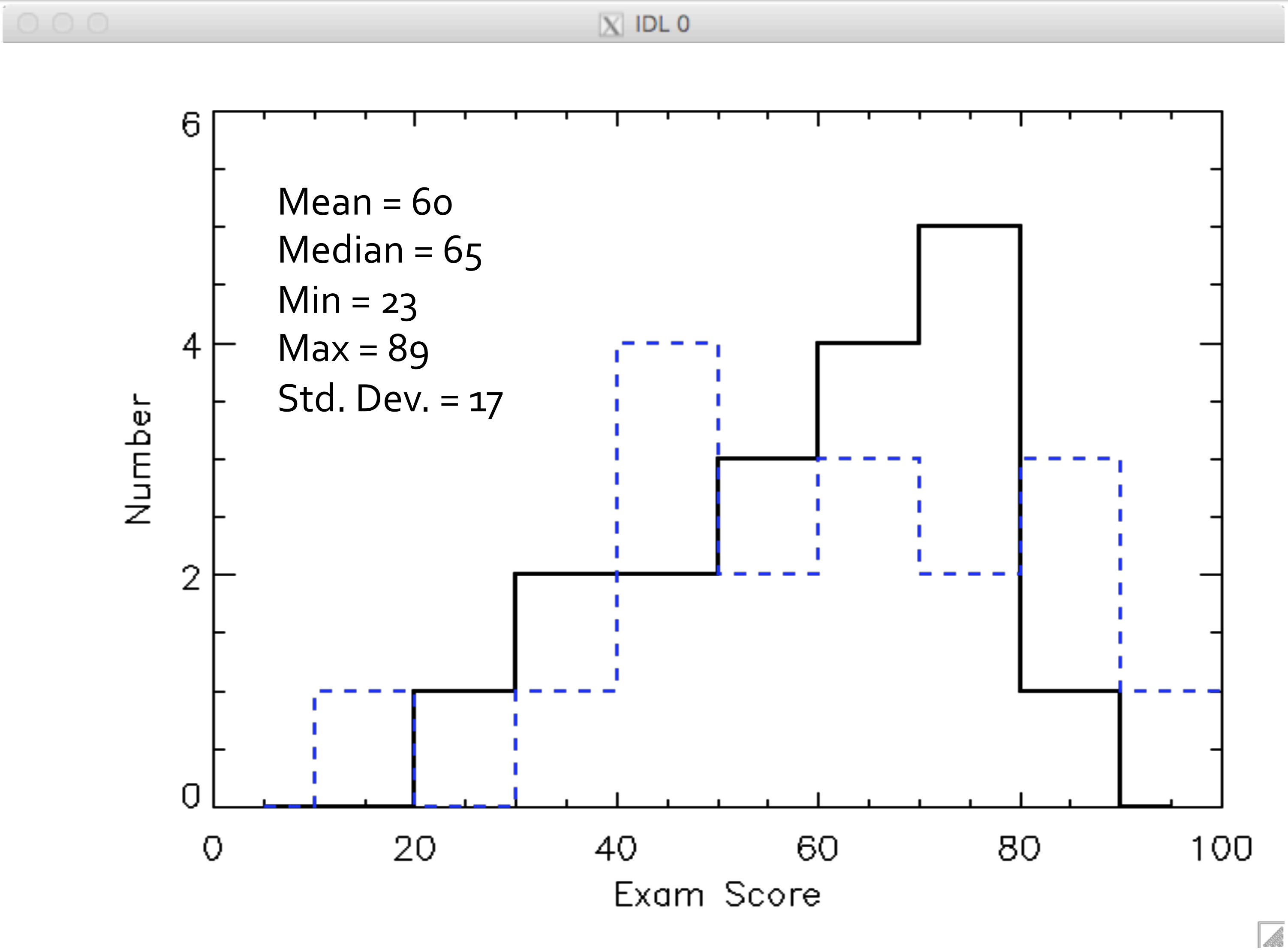
$$\nabla \times \mathbf{B} = \mu_0 \varepsilon_0 \frac{\partial \mathbf{E}}{\partial t} + \mu_0 \mathbf{J}$$



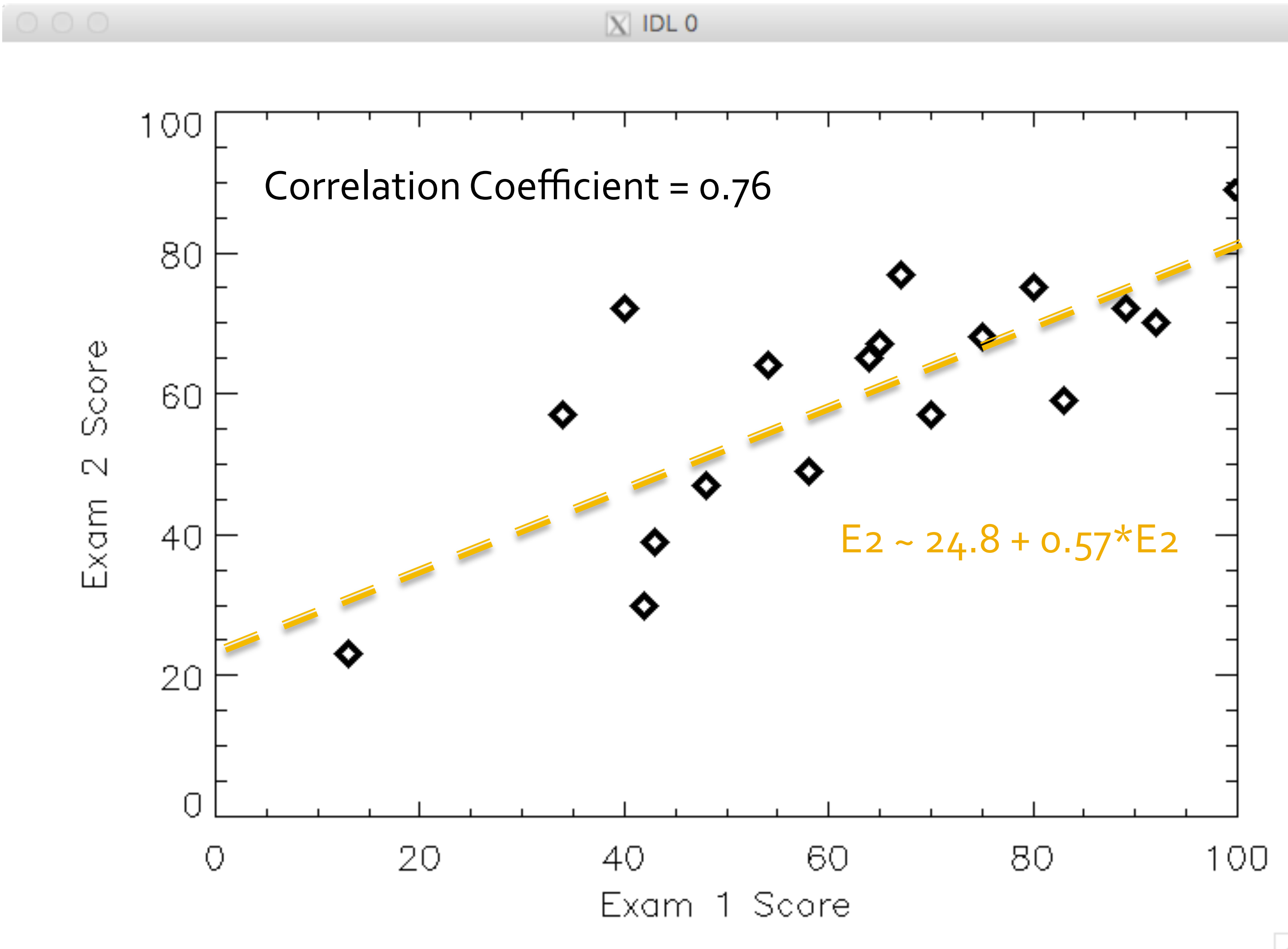
Electricity and Magnetism II: 3812

Professor Jasper Halekas
Virtual by Zoom!
MWF 9:30-10:20 Lecture

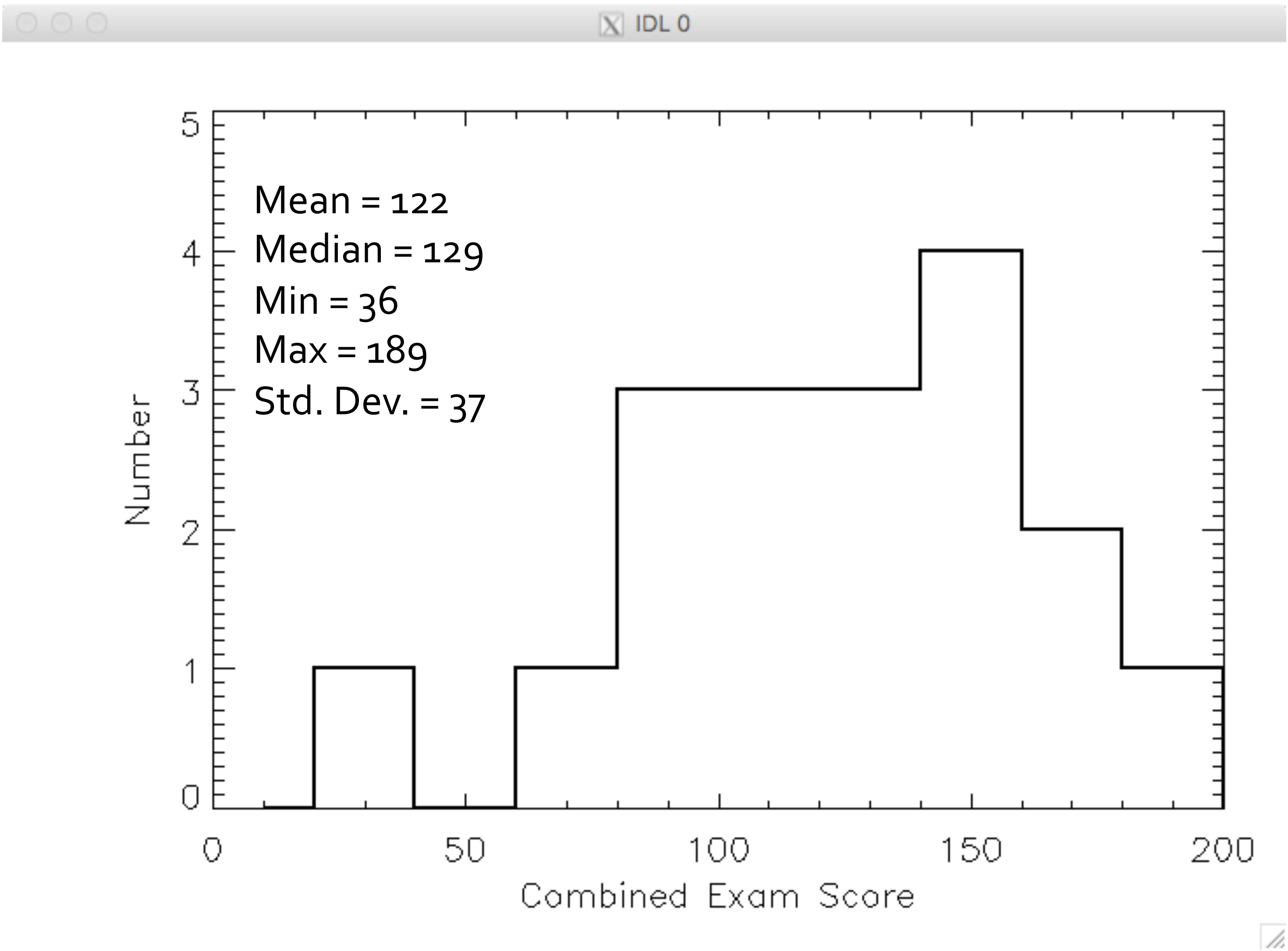
Exam 2 Scores



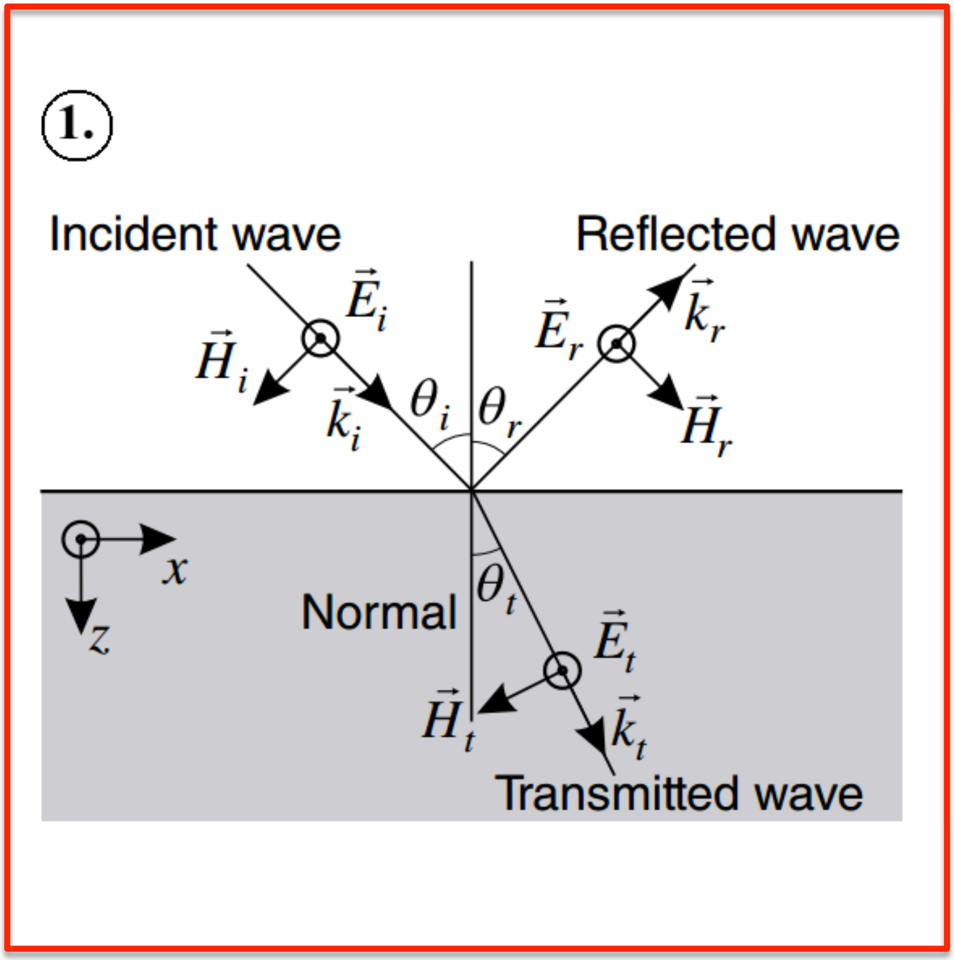
Exam 2 vs. Exam 1



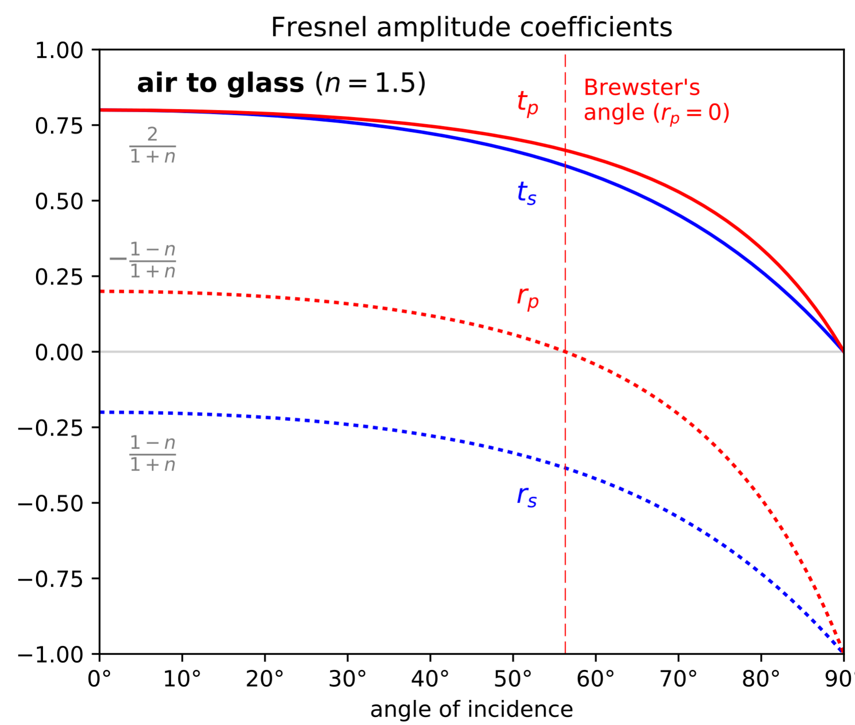
Combined Score Distribution



Problem 1

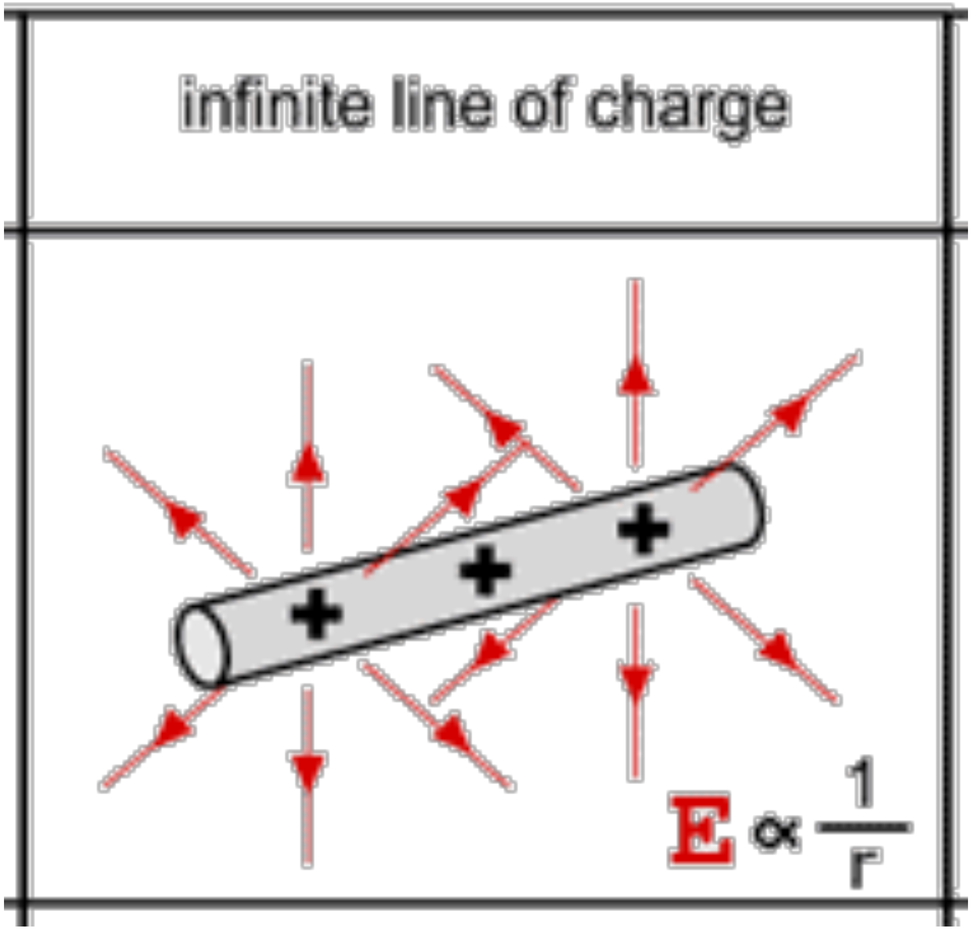


1.
Incident wave
Reflected wave
Normal
Transmitted wave
x
z

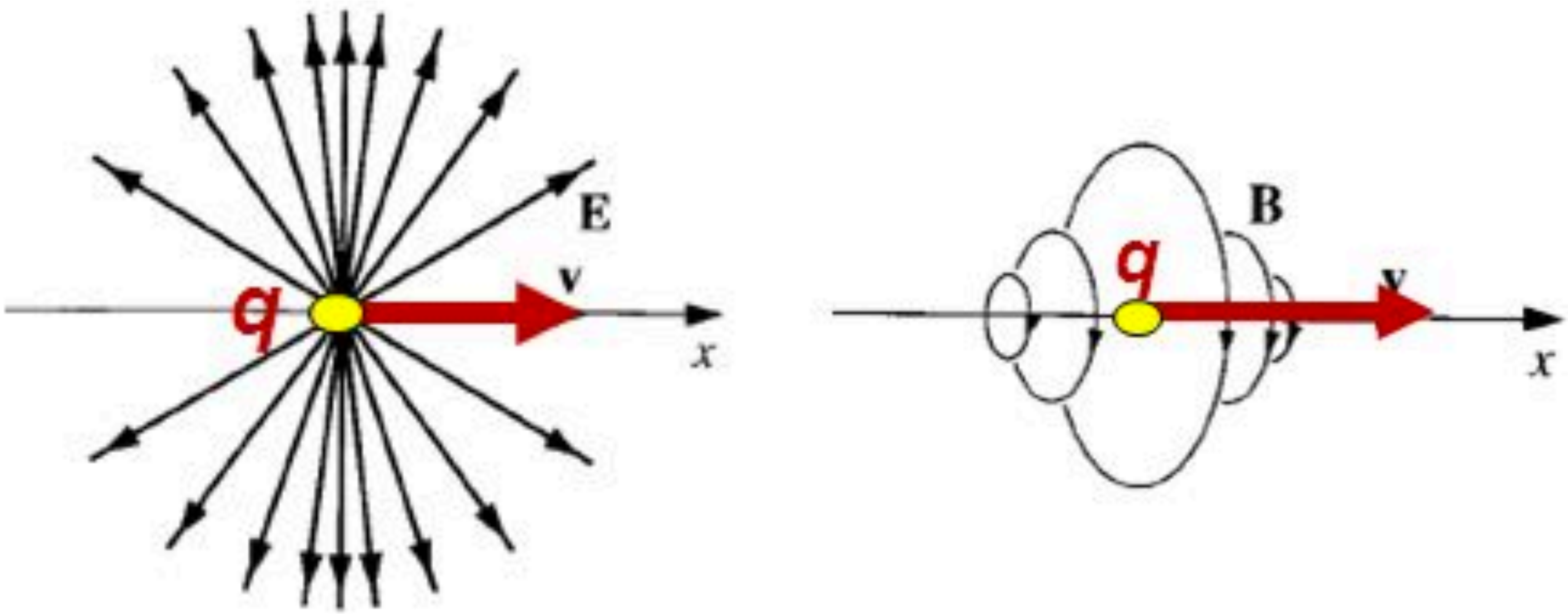


Fresnel amplitude coefficients
air to glass ($n = 1.5$)
Brewster's angle ($r_p = 0$)
t_p
t_s
r_p
r_s
$\frac{2}{1+n}$
$-\frac{1-n}{1+n}$
$\frac{1-n}{1+n}$
angle of incidence

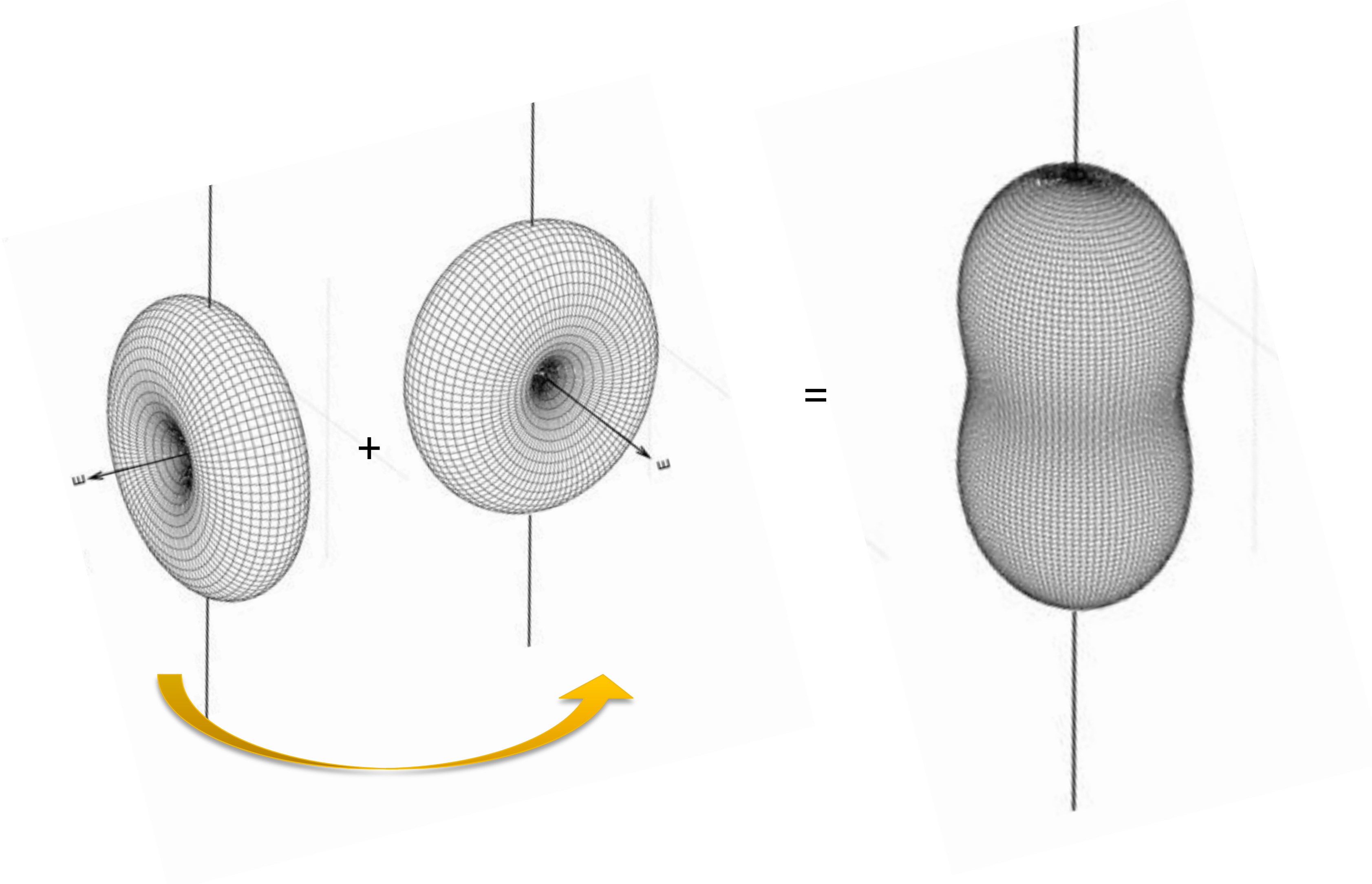
Problem 2



Problem 3



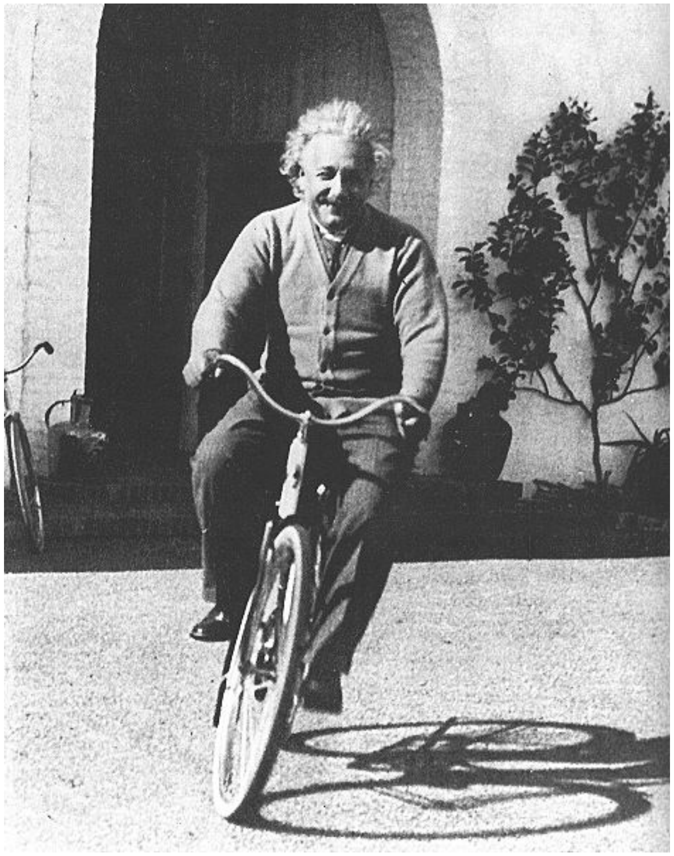
Problem 4



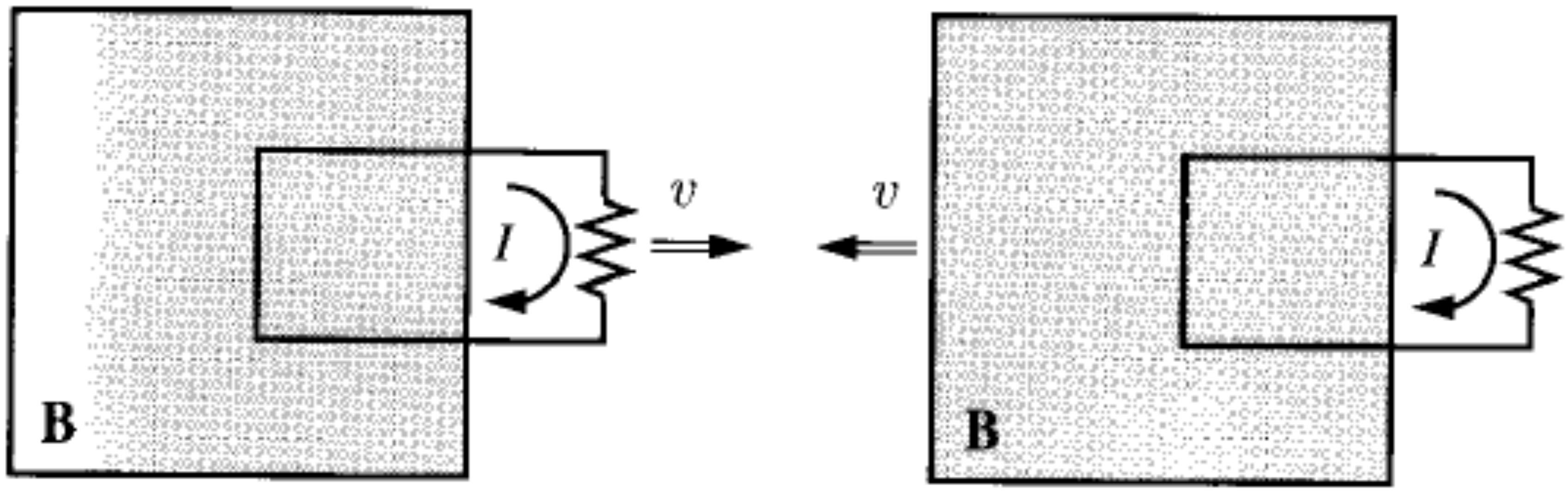
Einstein's Postulates

The laws of physics are the same in all inertial frames of reference.

The speed of light is the same in all inertial frames of reference.

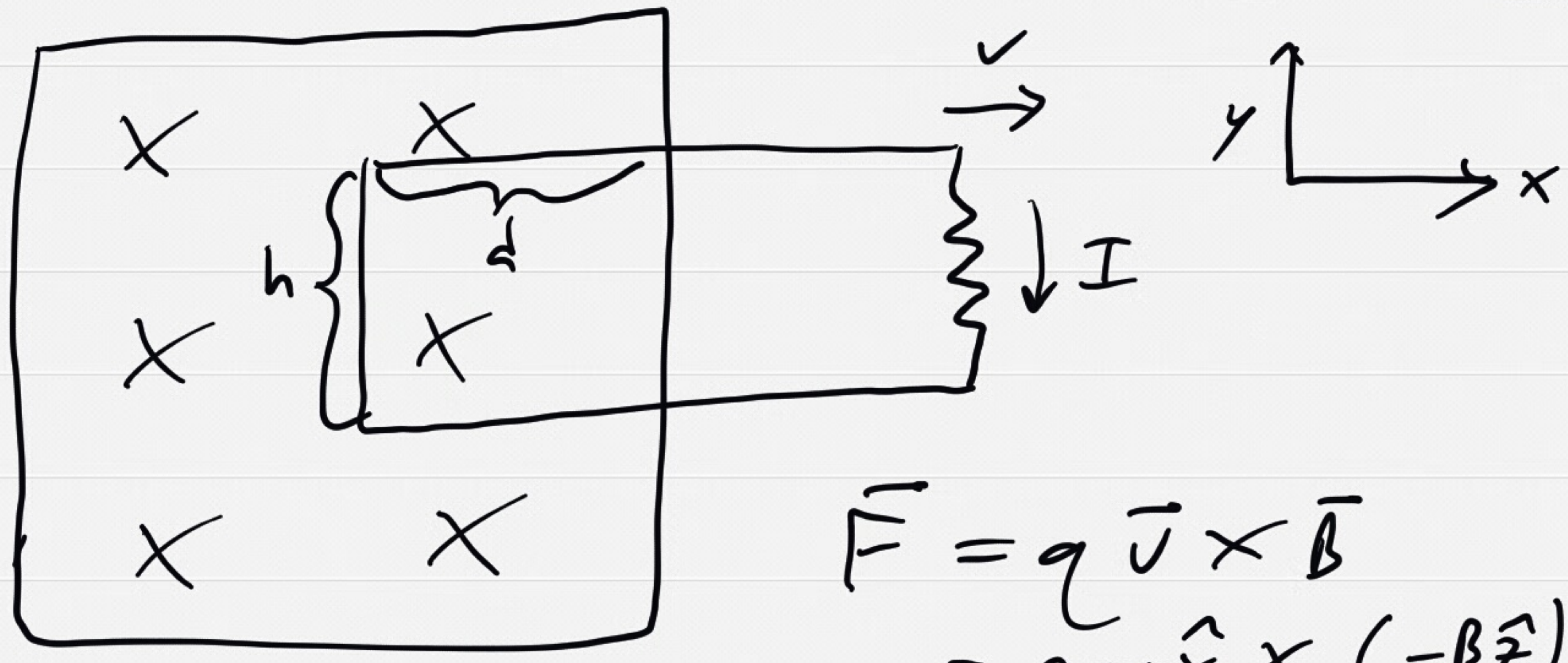


Does Relativity Apply to E&M?



(a) (b)

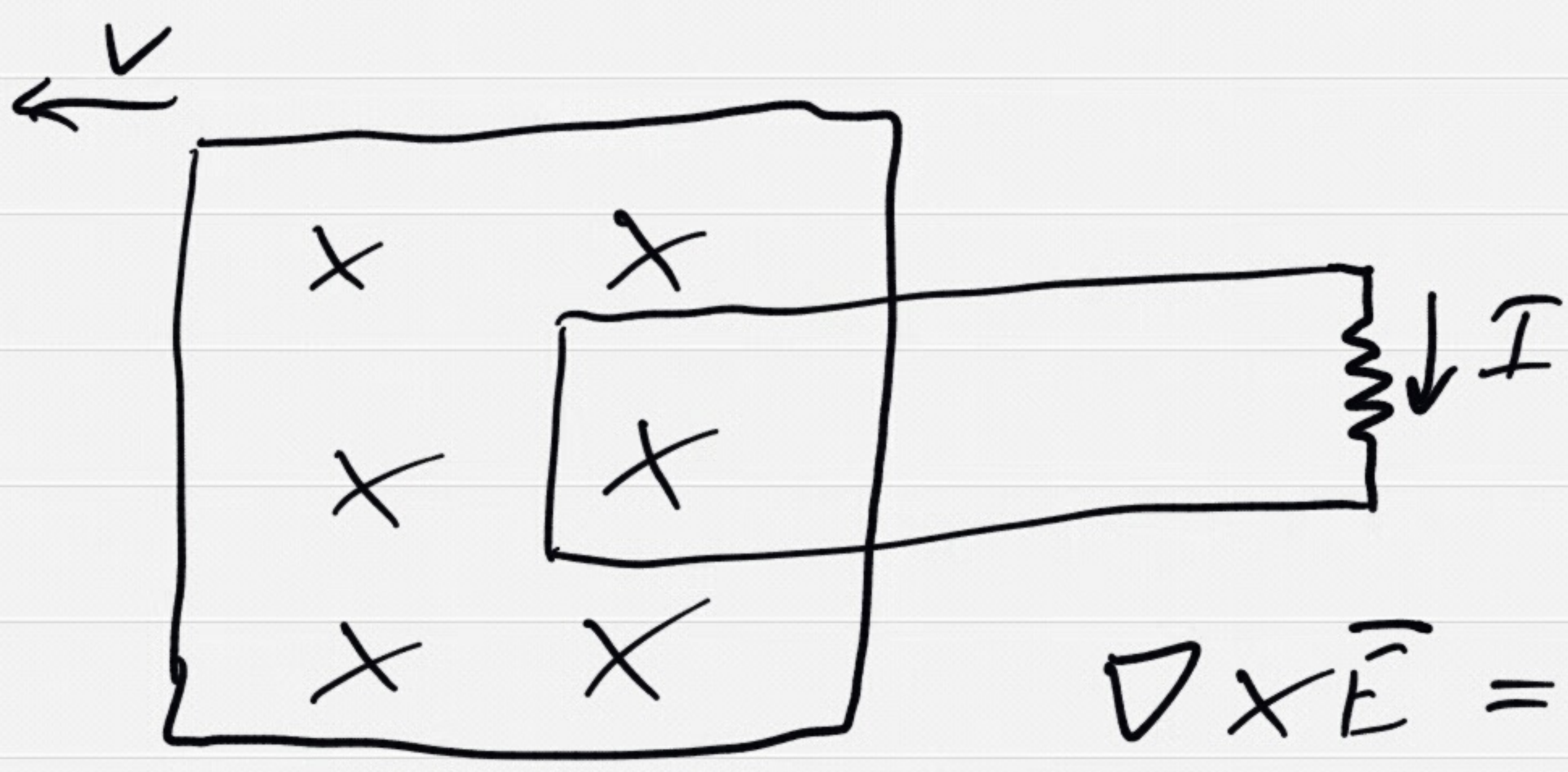
Ch. 12: Electrodynamics & Relativity



$$\vec{F} = q\vec{v}\times\vec{B}$$
$$= qv\hat{x}\times(-B\hat{z})$$
$$= qvB\hat{y}$$

$$\mathcal{E} = \oint \vec{f}\cdot d\vec{\ell} = \oint \frac{\vec{F}}{q}\cdot d\vec{\ell}$$
$$= \oint vB\hat{y}\cdot d\vec{\ell} = -vBh$$

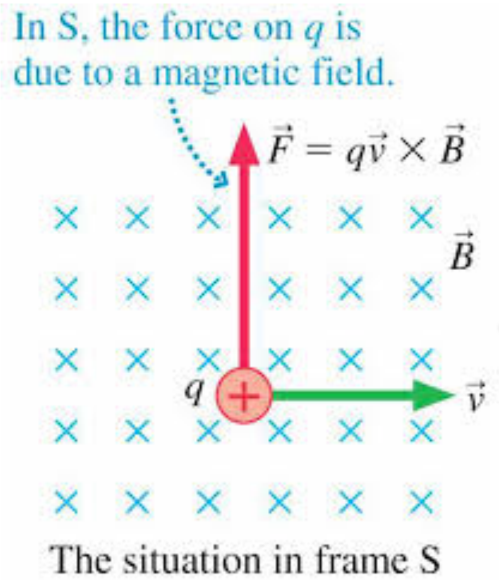
causes $I = \frac{vBh}{R}$ CW

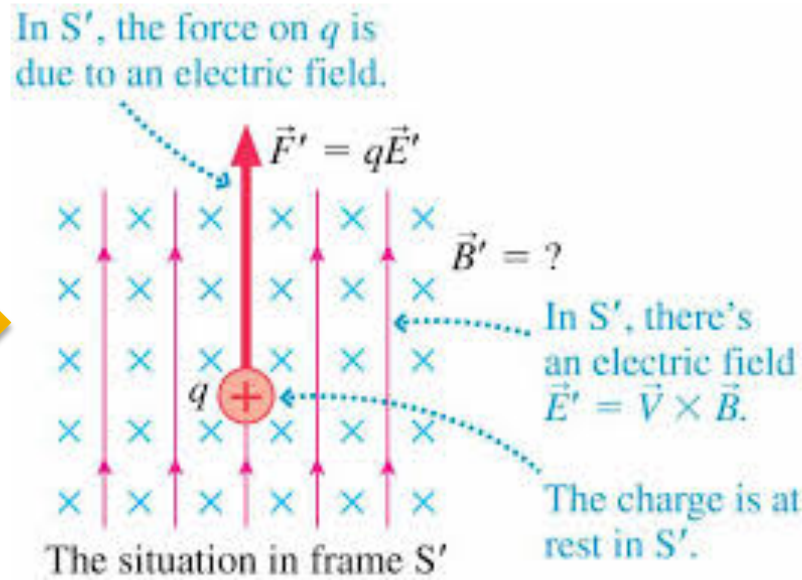


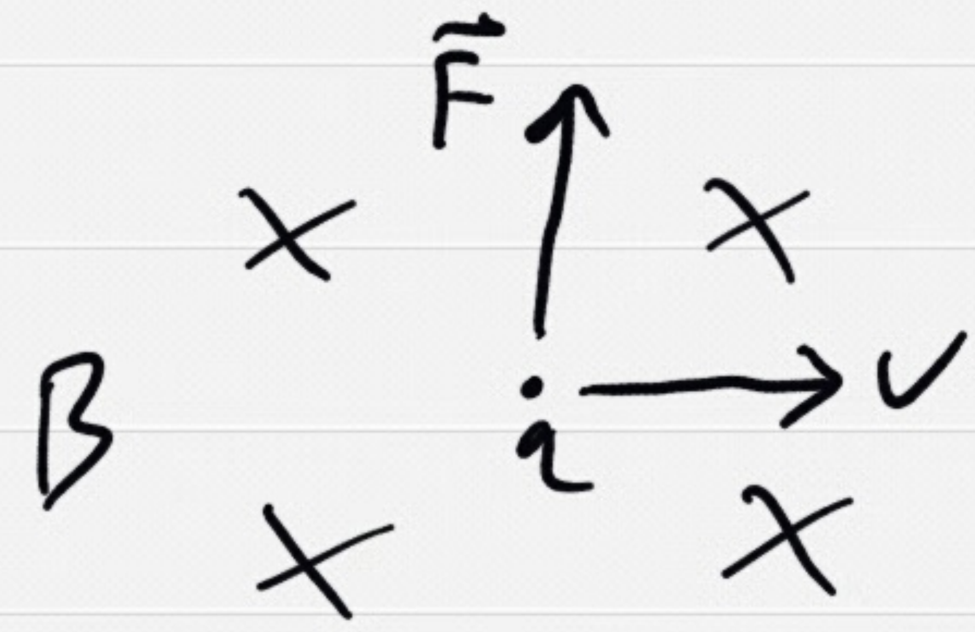
$$\nabla\times\vec{E} = -\partial\vec{B}/\partial t$$
$$\Rightarrow \oint \vec{E}\, d\vec{\ell} = -d/dt \int \vec{B}\cdot d\vec{a}$$
$$\mathcal{E} = -d/dt\,(-Bhd)$$
$$= -BhV$$
$$\Rightarrow I = BhV/R \quad \text{CW}$$

EMF from $\vec{B}$ in one frame, from $\vec{E}$ in the other!!

Does Relativity Apply to E&M?

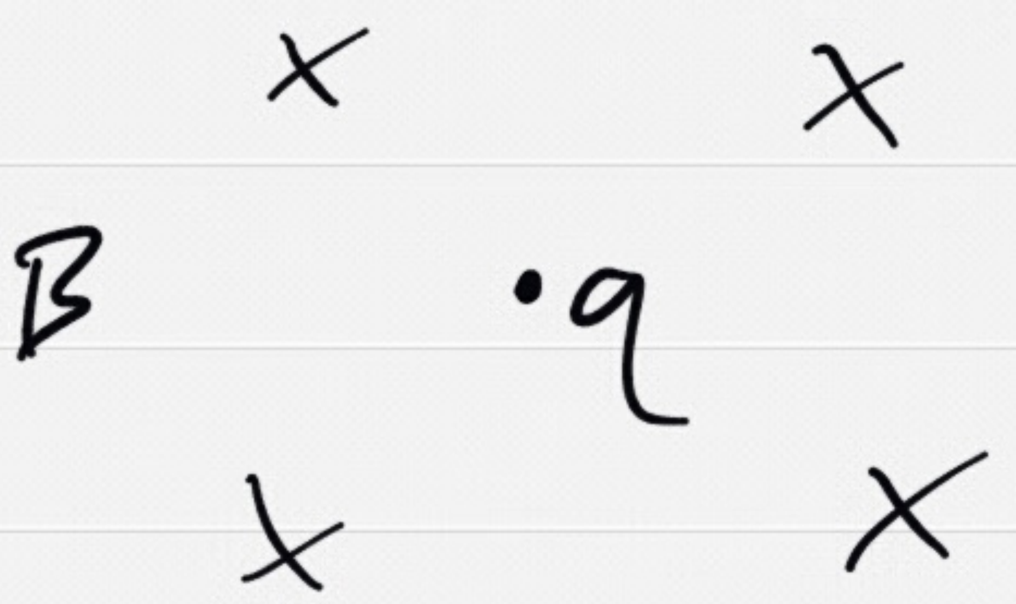






$$\vec{F} = \vec{F}_B = q\,\vec{v}\times\vec{B}$$
$$= q v \hat{x} \times (-B\hat{z})$$
$$= q v B \hat{y}$$

Frame S

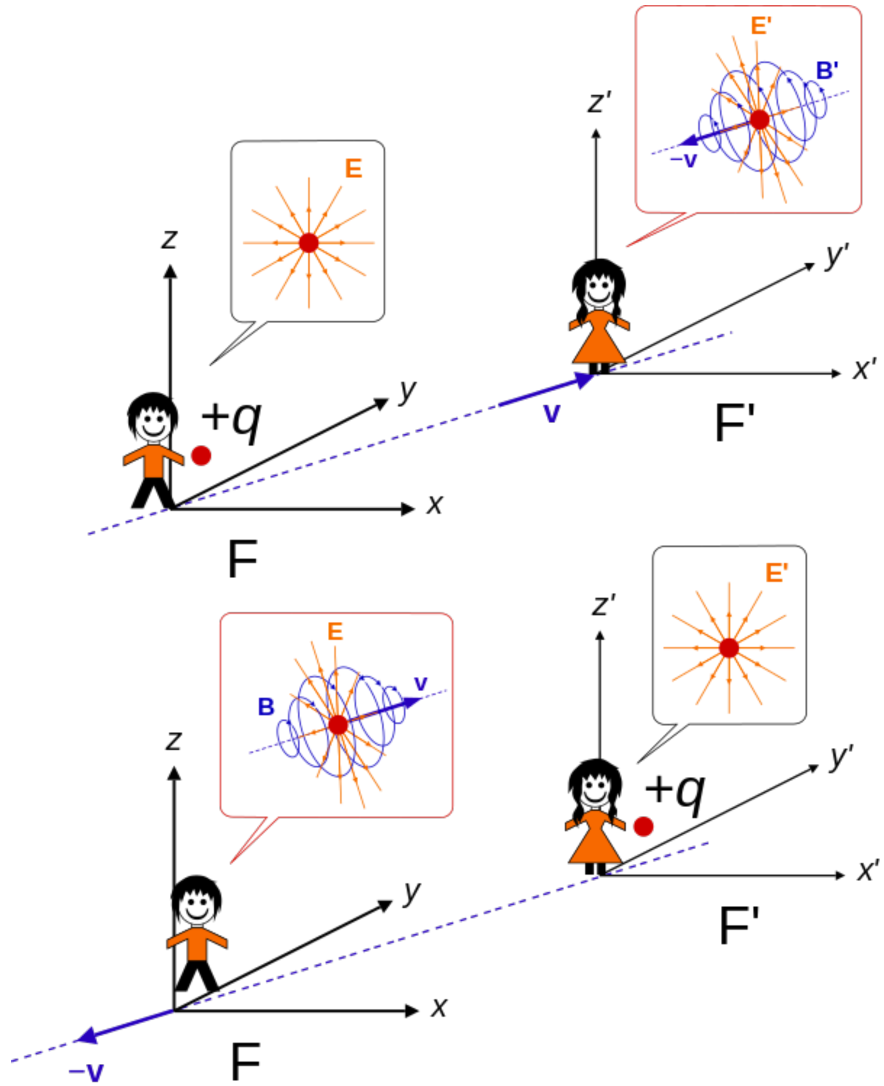


$$\vec{F}_B = q\,\vec{v}\times\vec{B}$$
$$= 0$$

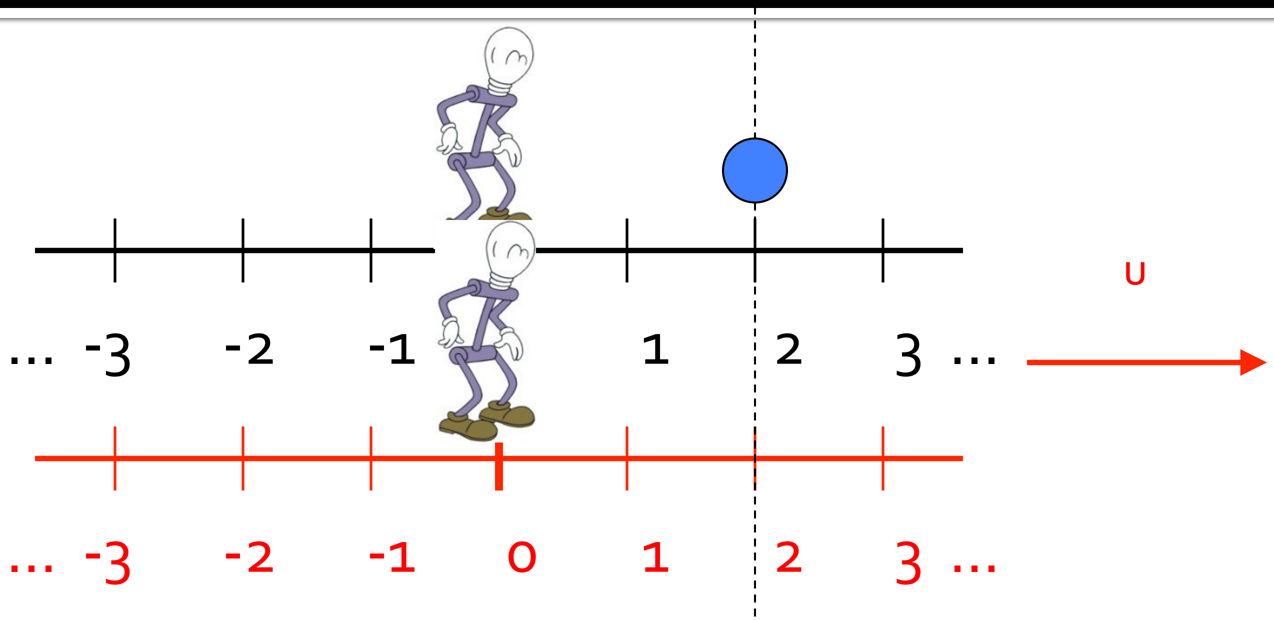
Frame S′

- In S′, no magnetic Lorentz force
- The only possibility is an electric Lorentz force
  - Must have:
    $$\vec{E}' = vB\hat{y} = \vec{v}\times\vec{B}$$
    so that $\vec{F}' = q\vec{E}' = \vec{F}$
  - Galilean transformation
    $$\vec{E}' = q\,\vec{v}\times\vec{B}, \quad \vec{B}' = \vec{B}$$

Relativity and E&M



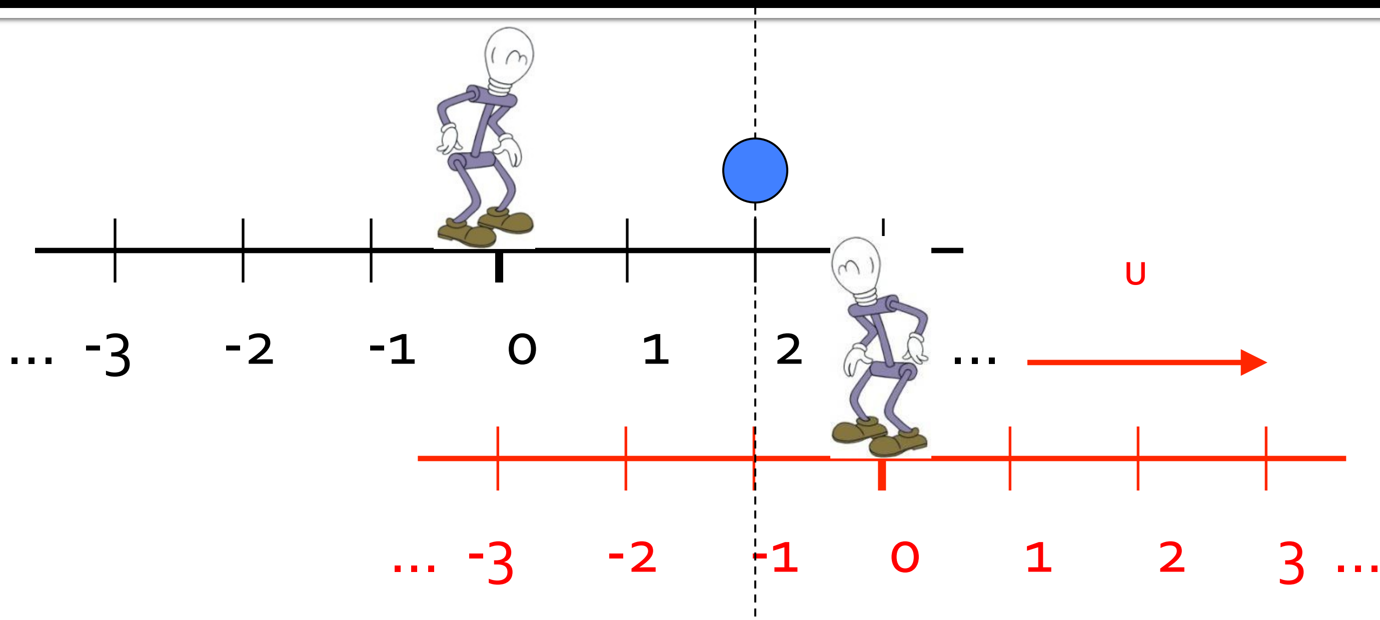
Comparing inertial frames



At time t = 0, the two frames coincide. A ball is at rest in frame S. Its position is

- $x = 2$ m in S
- $x' = 2$ m in S′

Comparing inertial frames



Frame S′ is moving to the right (relative to S) at u=1 m/s. At time t = 3 sec, the position of the ball is

- x = 2 m in S
- x′ = -1 m in S′

Galilean Transformation

$$x' = x - ut$$

$$y' = y$$

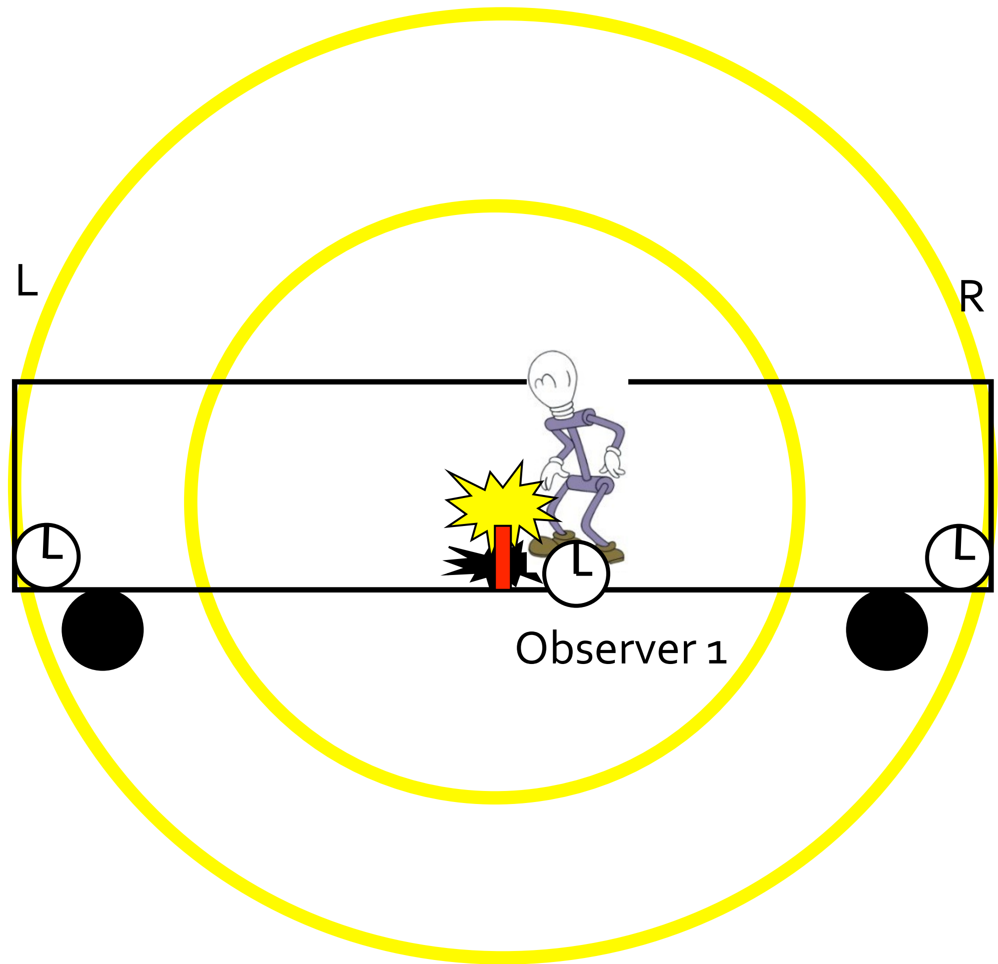
$$z' = z$$

$$t' = t$$

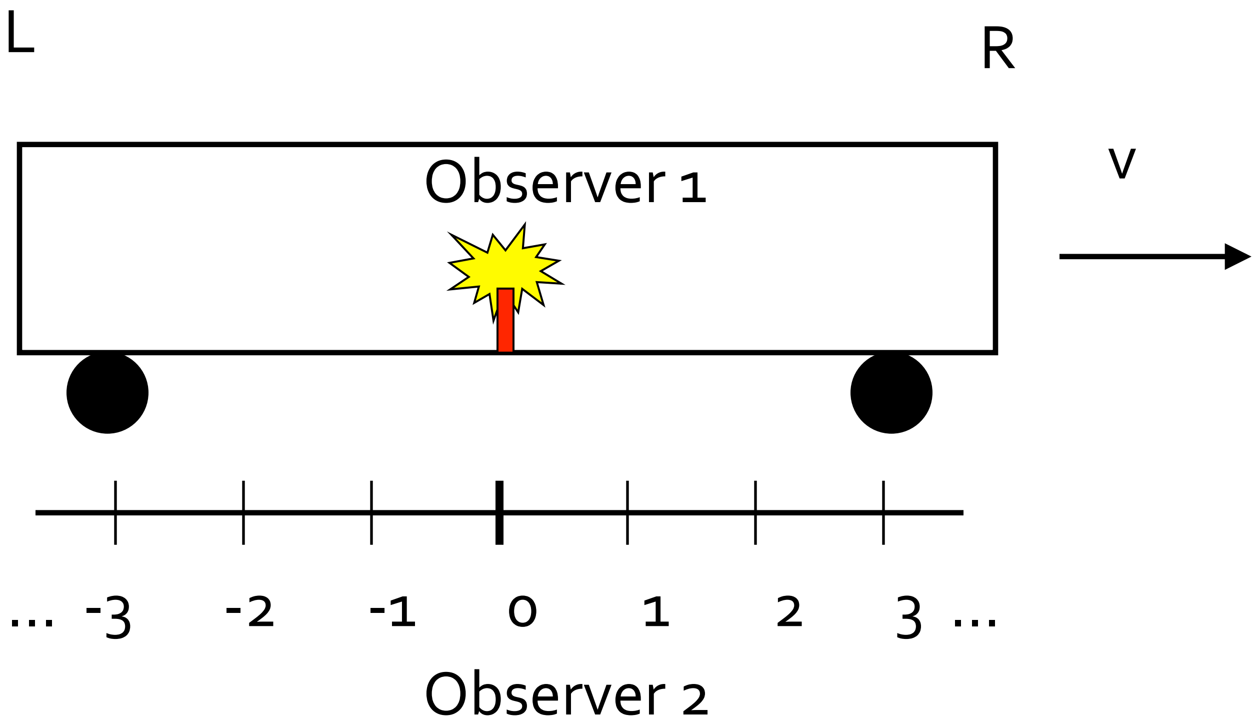
Note:
Assumes frames aligned at t = 0

$$v_x' = \frac{dx'(t)}{dt} = \frac{d}{dt}\left(x(t) - ut\right) = \frac{dx(t)}{dt} - u = v_x - u$$

Observer 1 Frame

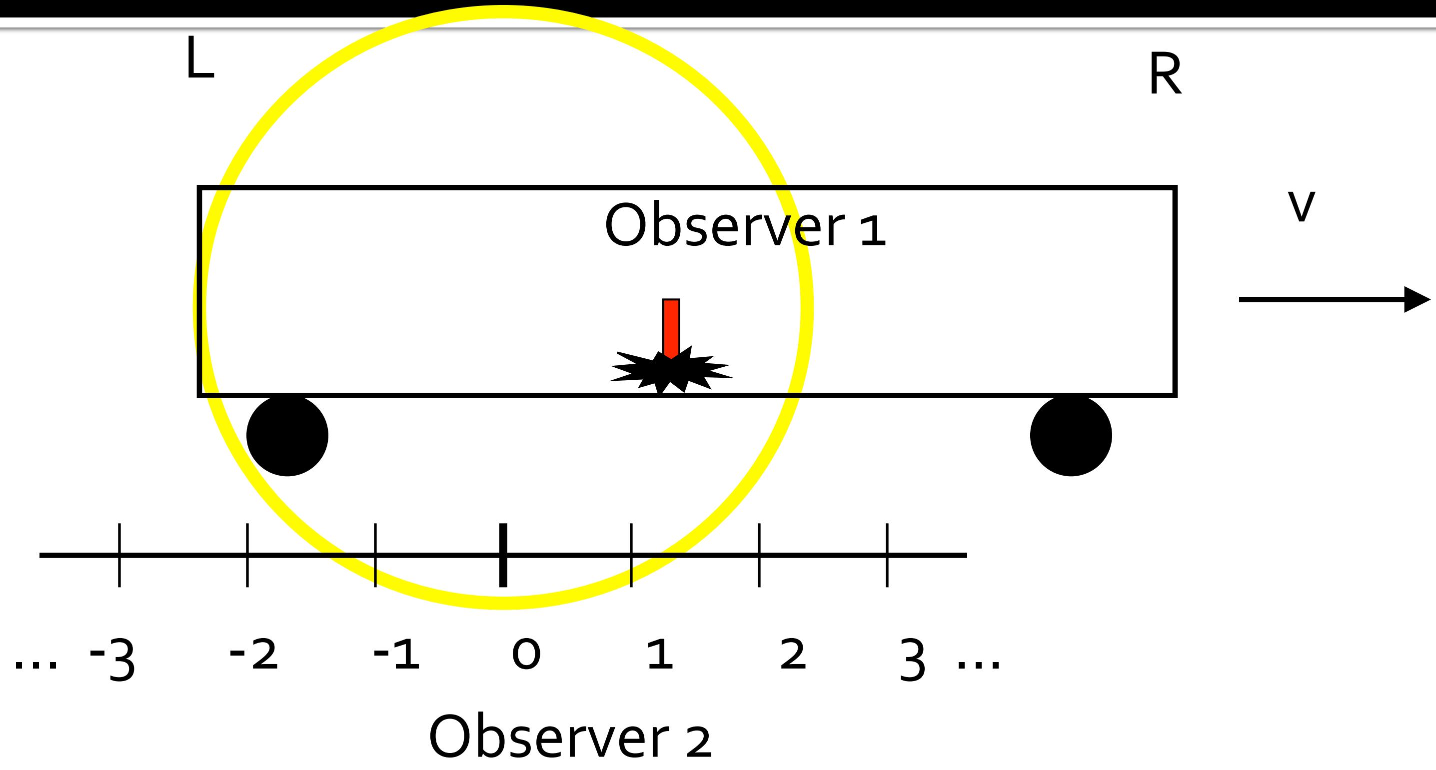


Observer 2 Frame



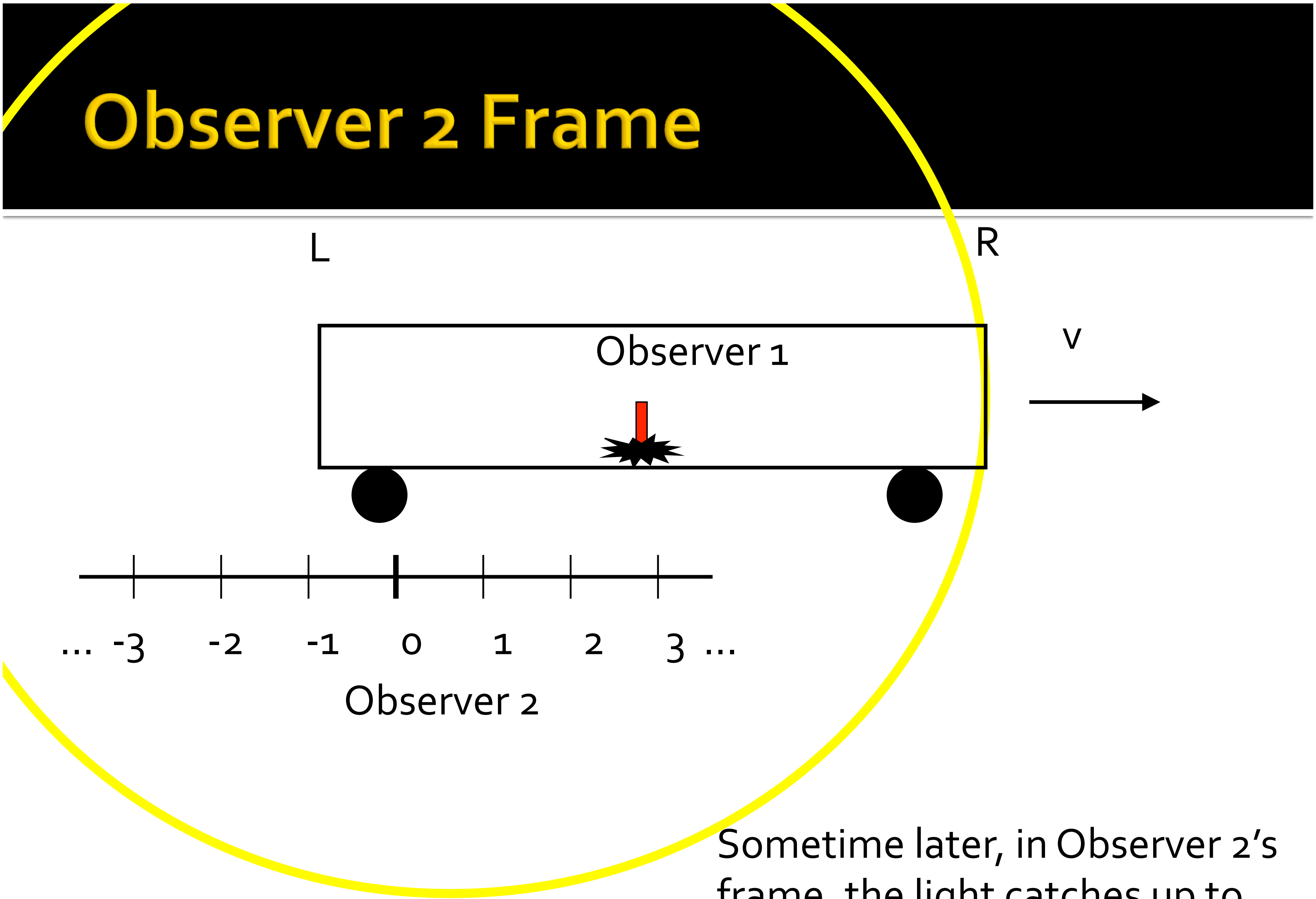
Suppose Observer 1's firecracker explodes at the origin of Observer 2's reference frame.

Observer 2 Frame



The light spreads out in Observer 2's frame from the point where they saw it explode. Because the train car is moving, the light in Observer 2's frame arrives at the left end first.

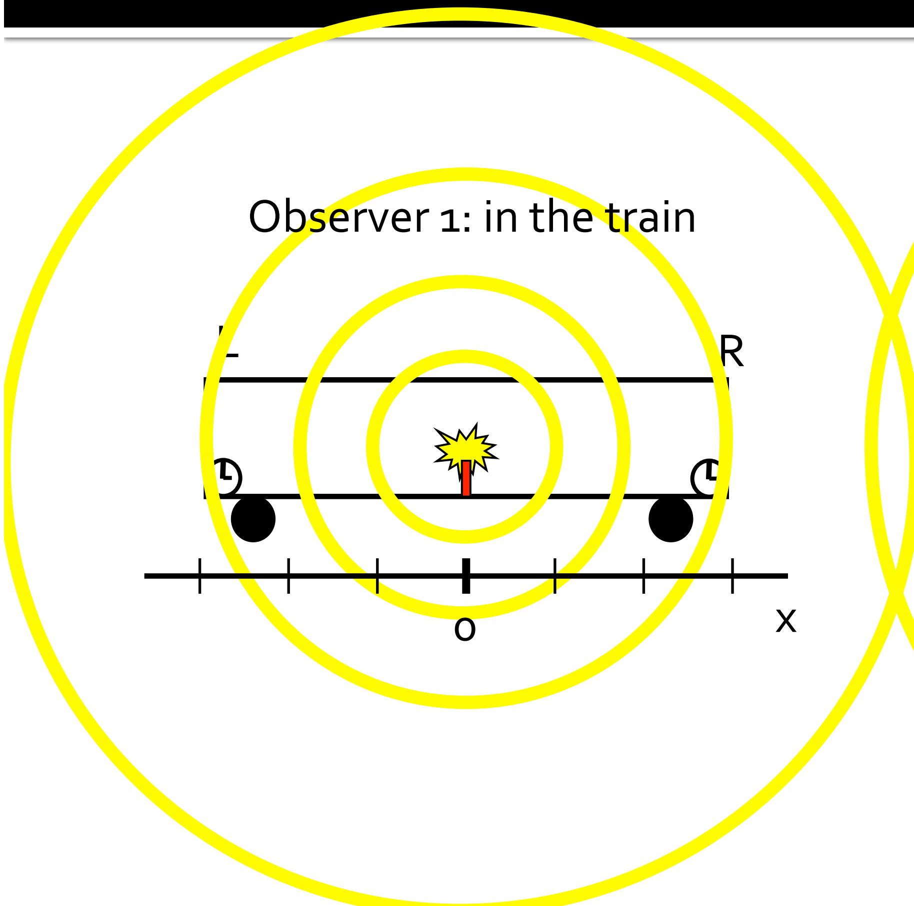
Observer 2 Frame



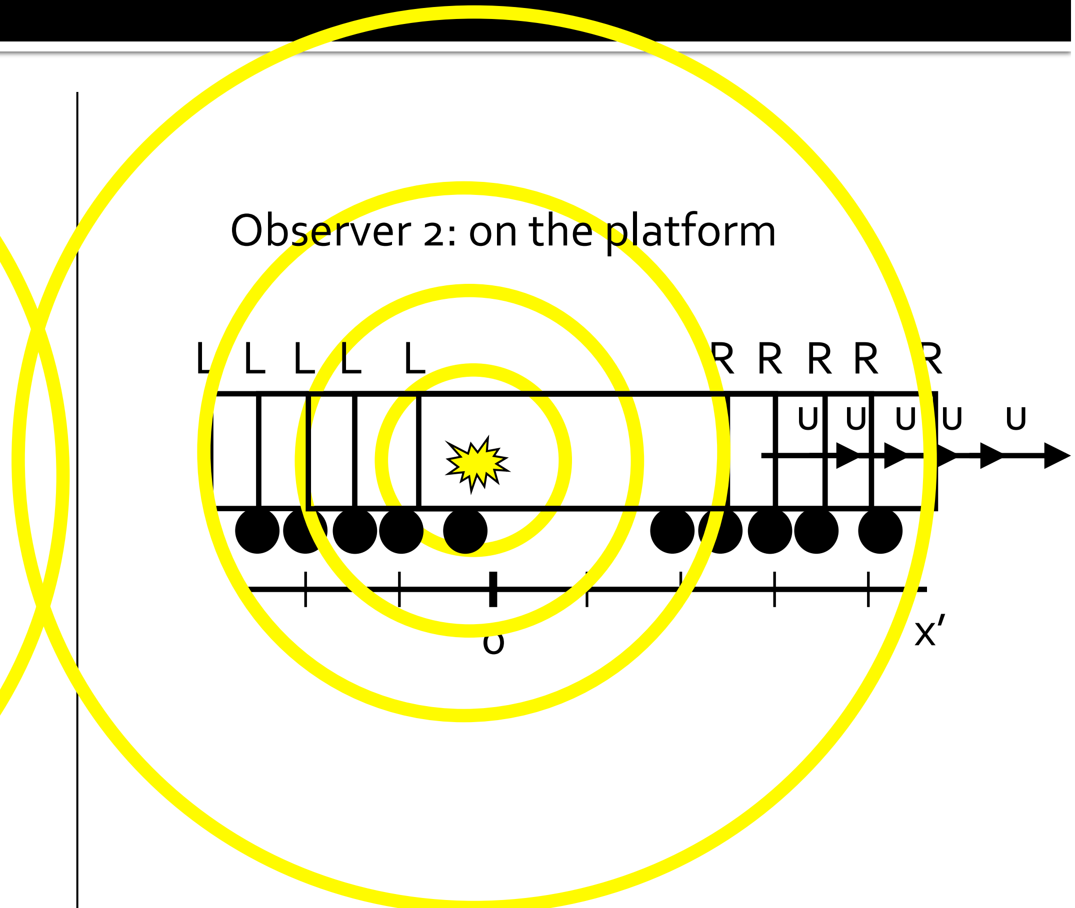
Sometime later, in Observer 2's frame, the light catches up to the right end of the train.

Simultaneity is Relative

Observer 1: in the train



Observer 2: on the platform



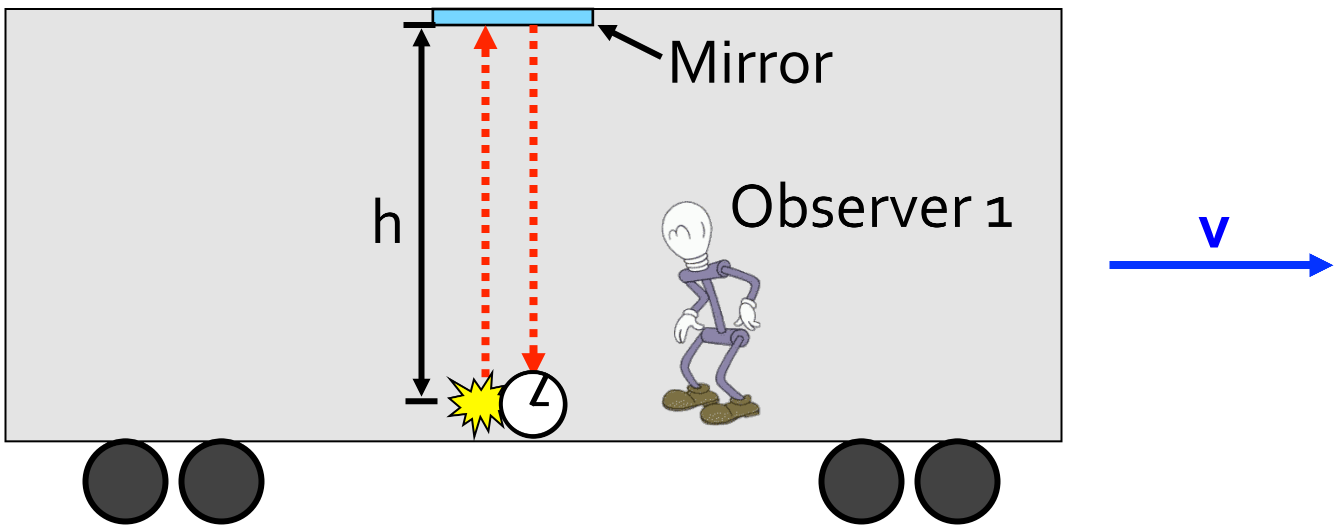
Event L: (x=-3, t=3s)	Event R: (x=+3, t=3s)

Observer 1 says: ‘Simultaneous!’

Event L′: (x′=-2, t′=2s)	Event R′: (x′=+5, t′=4s)

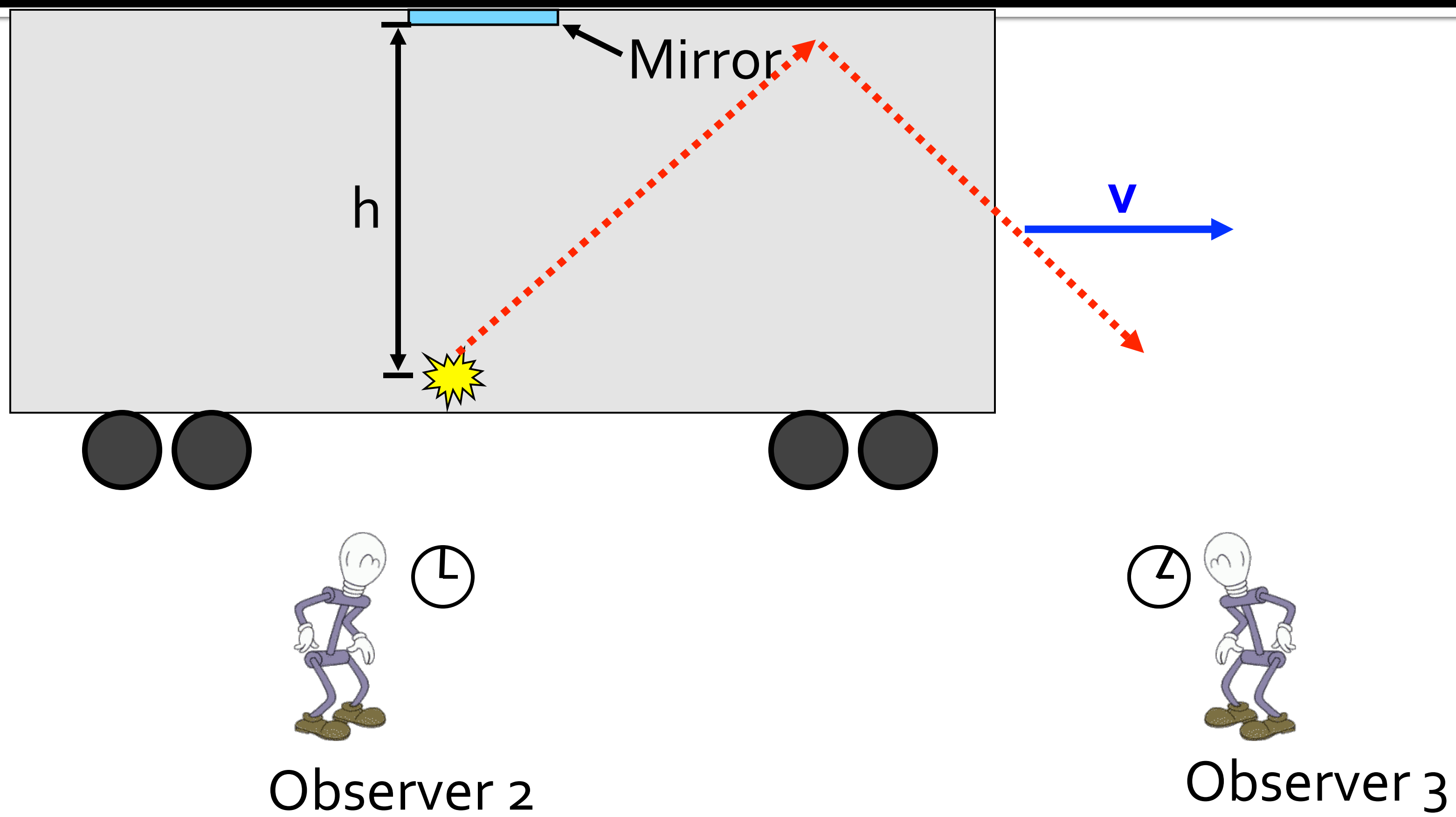
Observer 2 says: ‘Not simultaneous!’

Time Dilation



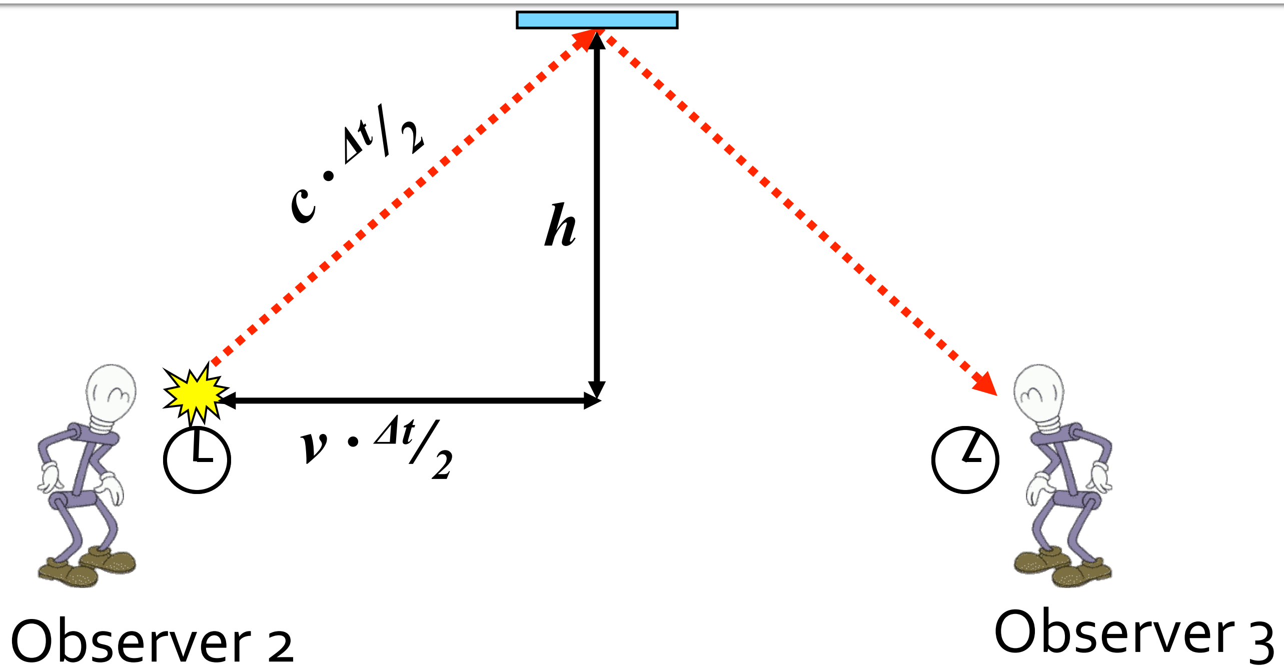
Observer 1 measures the time interval: $\Delta t' = \Delta t_0 = {}^{2h}/_{c}$

Time Dilation



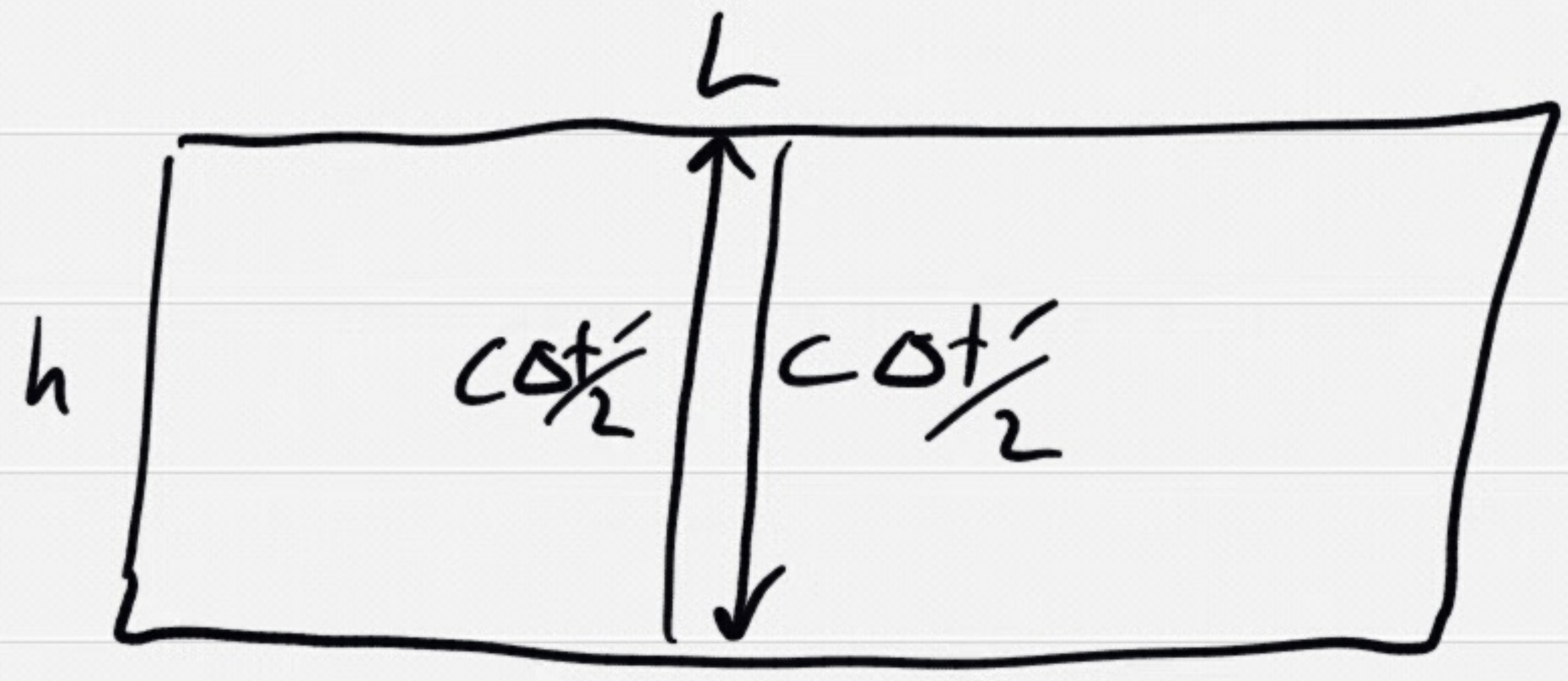
Note: This experiment requires two observers.

Time Dilation



12.1 | Special Relativity

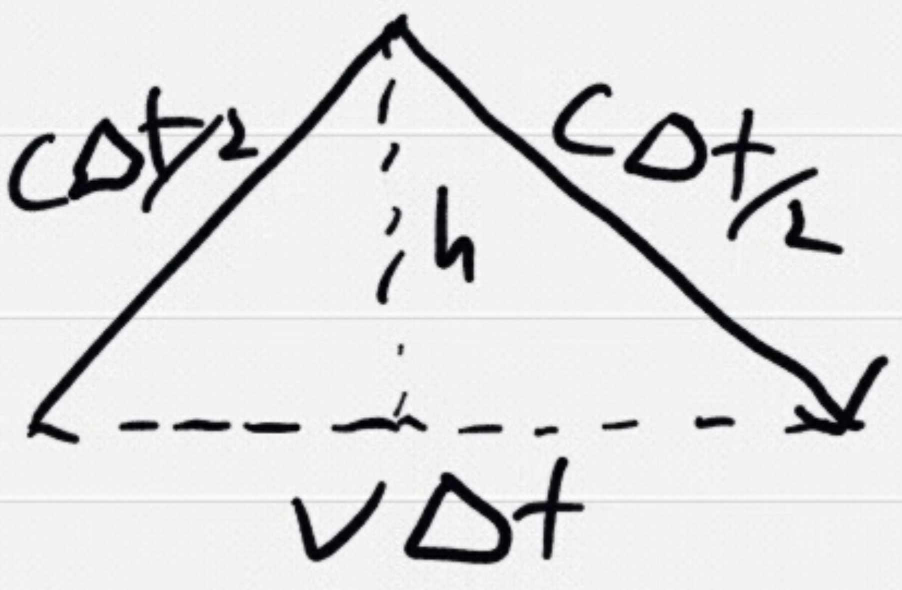
Time dilation



Frame S'

$$\Delta t' = 2h/c$$
$$= \Delta t_0$$
$$= \Delta\tau$$
= proper time interval

Frame S



$$\left(\frac{c\Delta t}{2}\right)^2 = \left(\frac{v\Delta t}{2}\right)^2 + h^2$$

$$\Rightarrow \Delta t = \frac{2h}{c} \cdot \frac{1}{\sqrt{1 - v^2/c^2}}$$

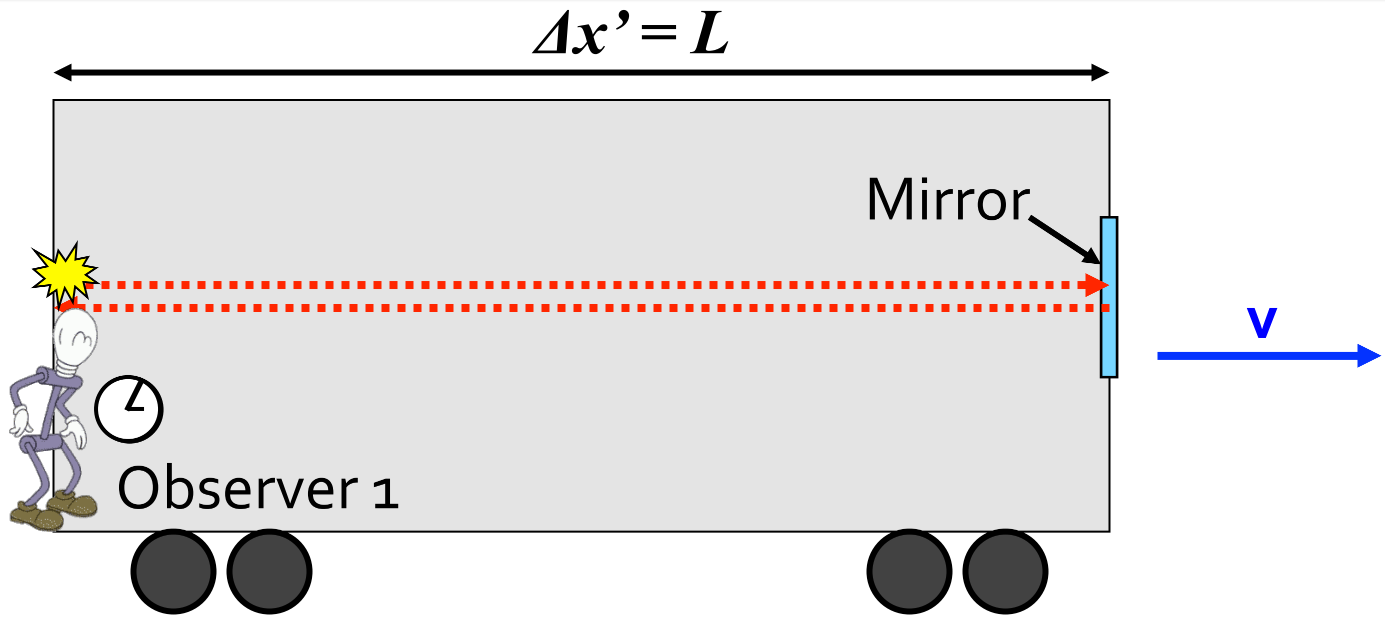
$$= \gamma \Delta t'$$

Proper Time

- "Proper Time" = $\Delta\tau = \Delta t_o$
  - The time interval measured in a frame where the two events occur at the same spatial coordinate – i.e. the frame moving with your clock

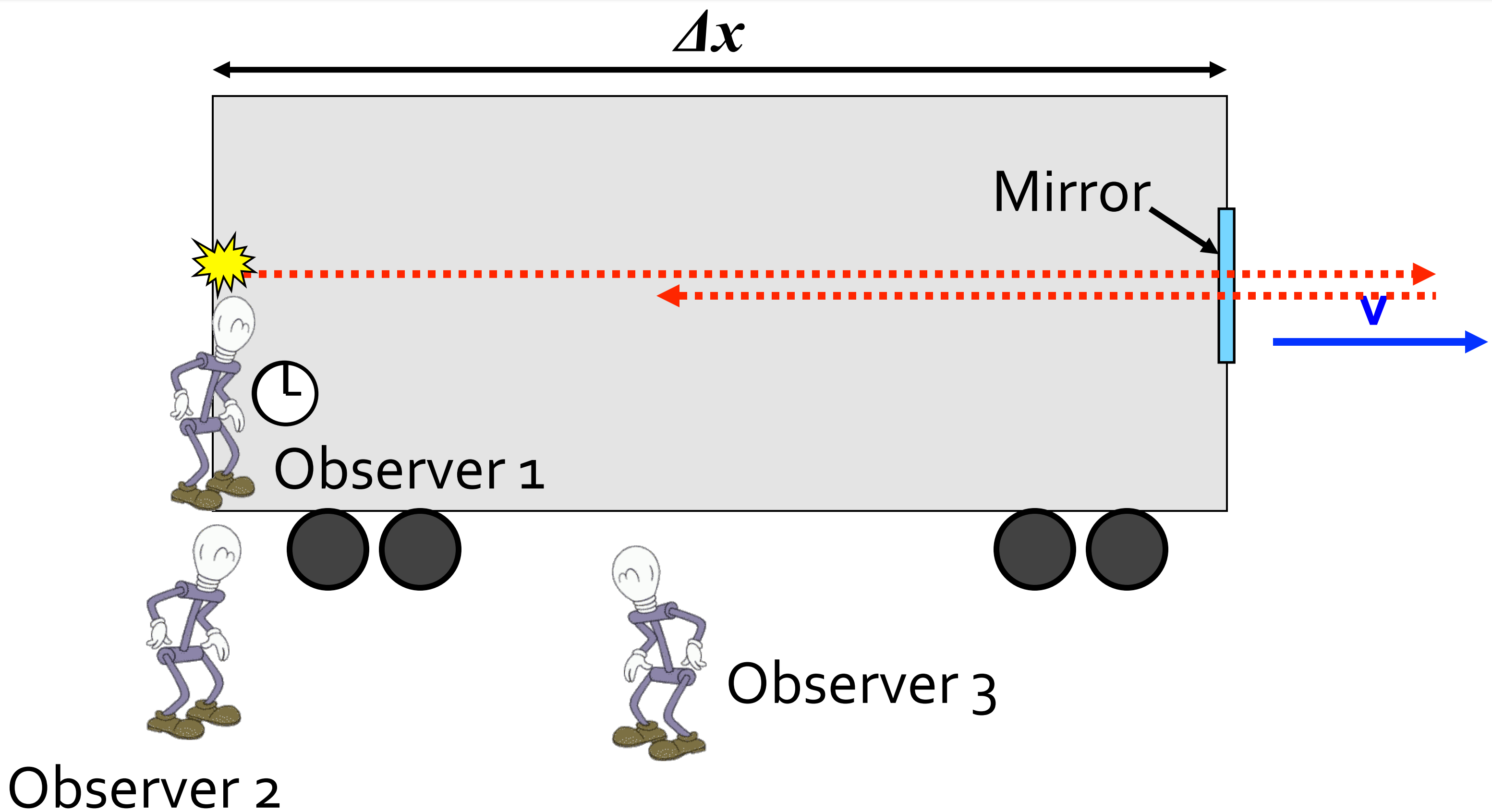
- The time interval Δt measured in **any** other frame moving with respect to this frame will be longer
  - $\Delta t = \gamma \Delta t_0$

Length Contraction



Observer 1 measures the time interval: $\Delta t' = \Delta t_0 = {}^{2L}/_{c}$

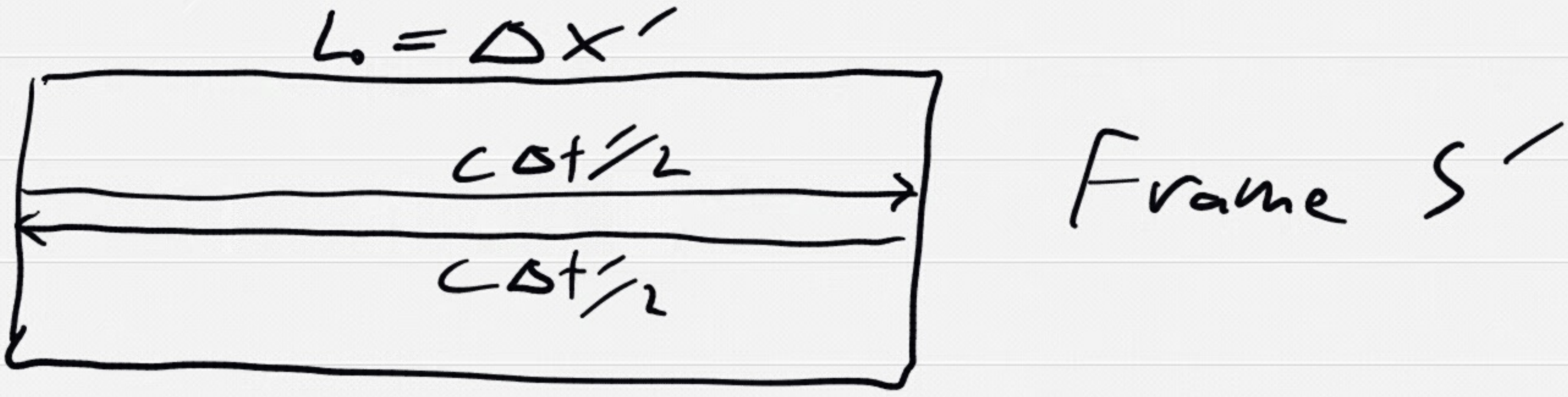
Length Contraction



Observers 2 and 3 measure the time interval:

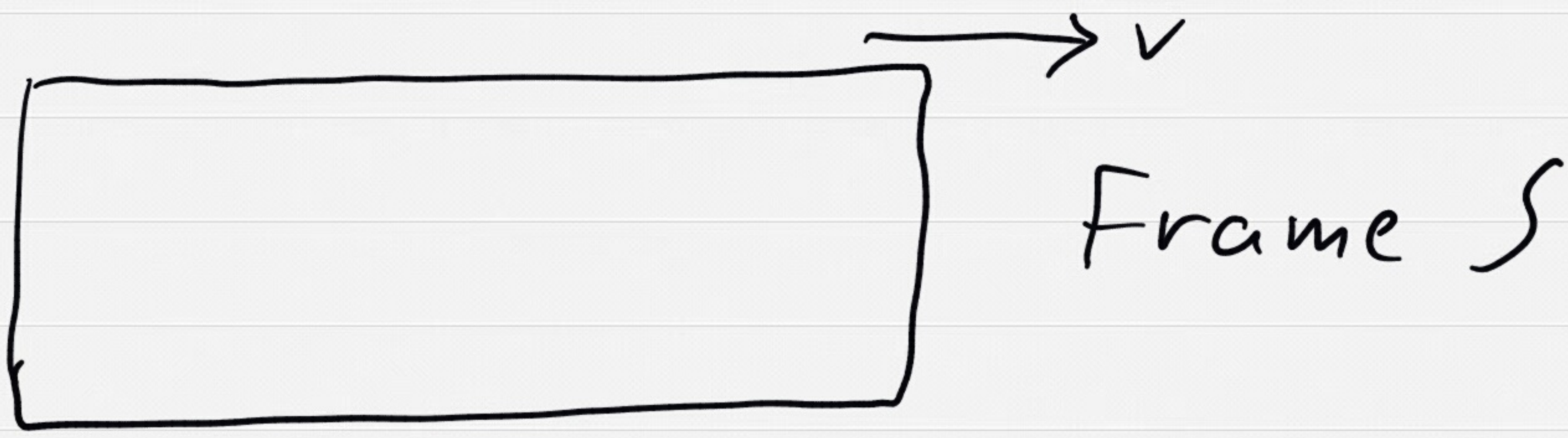
$\Delta t = \Delta x/(c-v) + \Delta x/(c+v) \Rightarrow \Delta x = \Delta x'/\gamma$

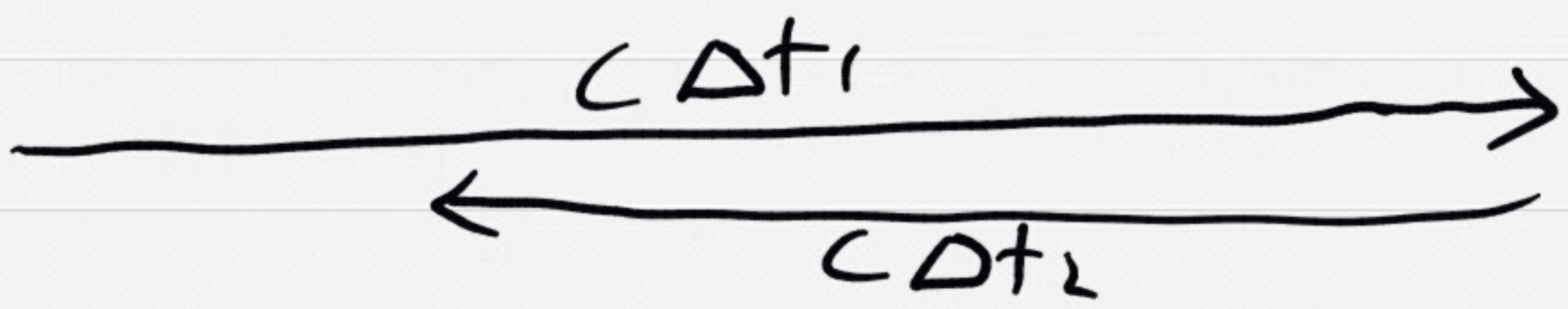
Length Contraction



$$\Delta t' = 2L_0/c = 2\Delta x'/c$$

$$\Rightarrow \Delta x' = c\Delta t'/2 = L_0$$





$$\Delta t_1 = (\Delta x + v\Delta t_1)/c$$

$$\Delta t_2 = (\Delta x - v\Delta t_2)/c$$

$$\Rightarrow \Delta t_1 = \frac{\Delta x}{c}\left(\frac{1}{1 - v/c}\right)$$

$$\Delta t_2 = \frac{\Delta x}{c}\left(\frac{1}{1 + v/c}\right)$$

$$\Delta t = \frac{\Delta x}{c}\,\frac{2}{1 - v^2/c^2}$$

$$\Delta x = \frac{c\Delta t}{2}\left(1 - v^2/c^2\right)$$

$$= \frac{c}{2}\,\frac{\Delta t'}{\sqrt{1 - v^2/c^2}}\left(1 - v^2/c^2\right)$$

$$= \Delta x'\sqrt{1 - v^2/c^2} = \frac{\Delta x'}{\gamma} = L_0/\gamma$$

Proper Length

- "Proper Length" = L_o
  - The length of an object measured in a frame where it is at rest

- The length L measured in **any** other frame moving with a velocity with respect to this frame that has a component along the length will be shorter
  - $L = L_0/\gamma$

Length Contraction