

PHYSICS 102

DR. LECLAIR

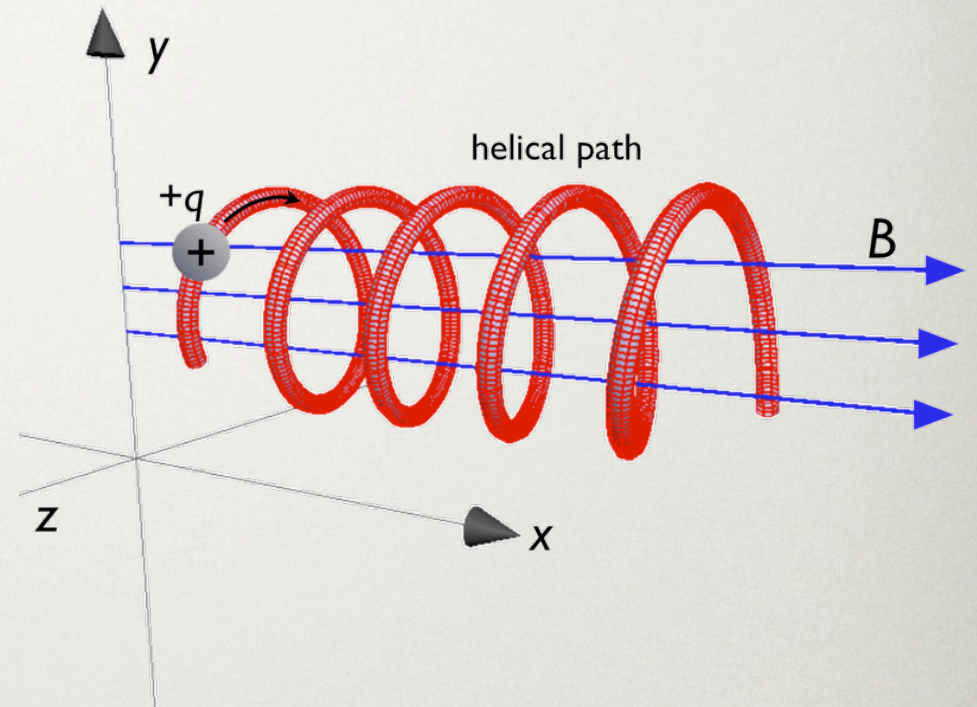
OFFICIAL THINGS

Lecture:

- 227 Gallalee
- every day!

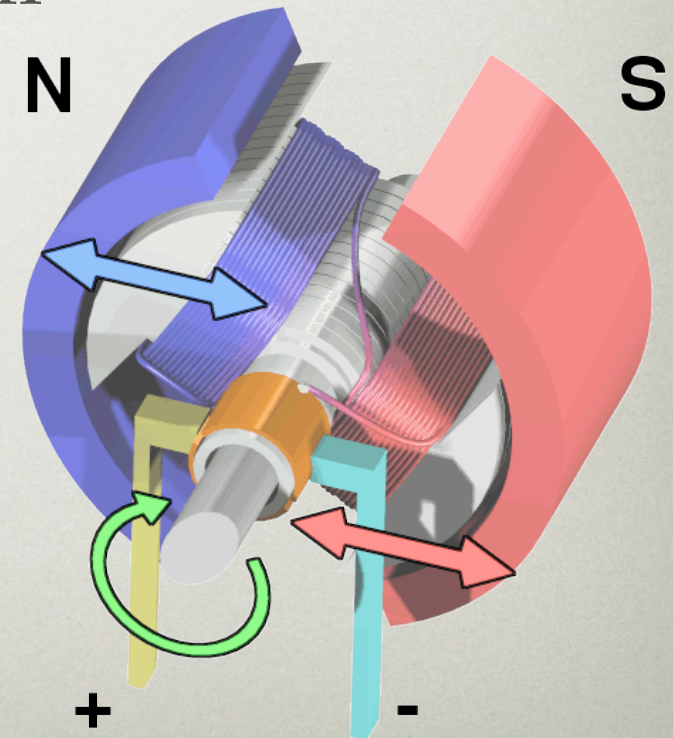
Lab:

- M-W-Th ~3 hr block
- will not usually need whole 3 hours



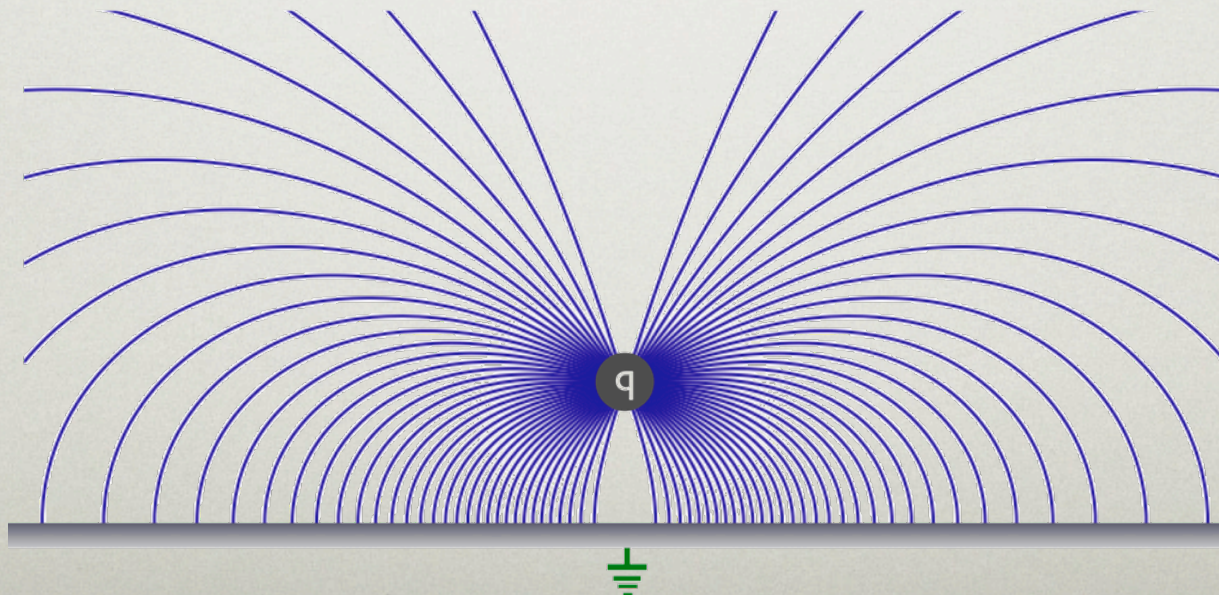
OFFICIAL THINGS

- Dr. Patrick LeClair
 - leclair.homework@gmail.com
 - office: 110 Gallalee / 2012 Bevill
 - lab: 180 Bevill
- Office hours:
 - *1-2pm in Gallalee*
- *other times by appointment*



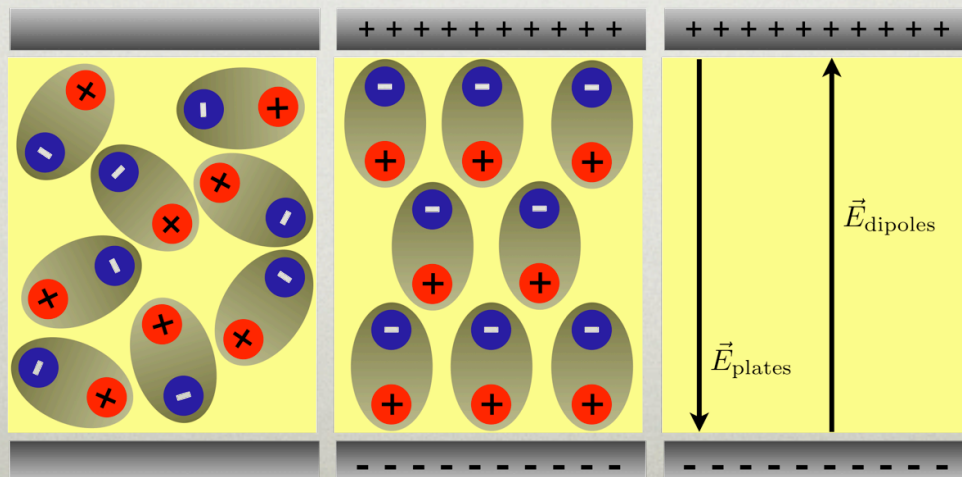
MISC. FORMAT ISSUES

- we will take a break during lectures ...
- lecture and labs will try to stay linked
- learn a concept, then demonstrate it
- working in groups is encouraged *for homework*



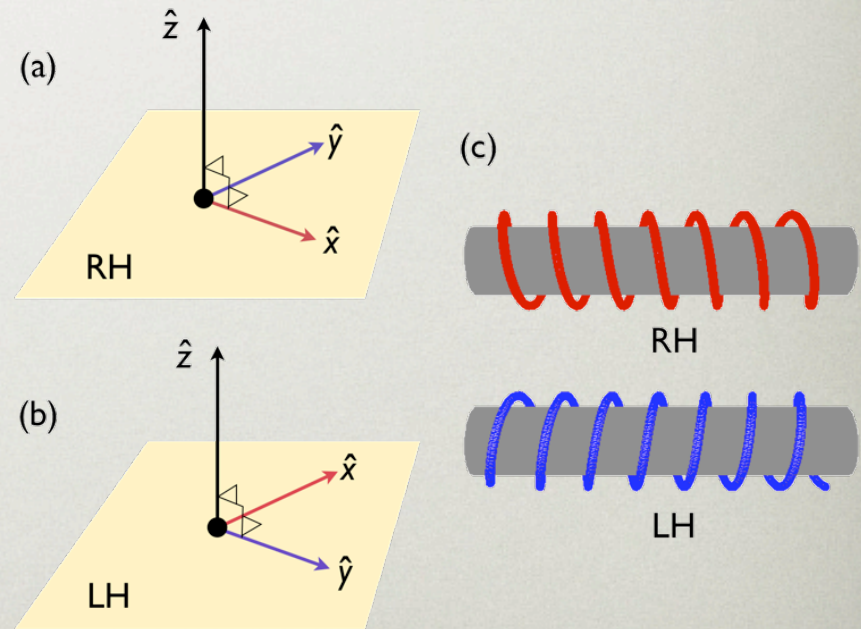
SOCIAL INTERACTION

- we need you in groups of 3-4 for labs
- groups are not assigned ...
 - ... so long as they remain functional relationships
 - even distribution of workload



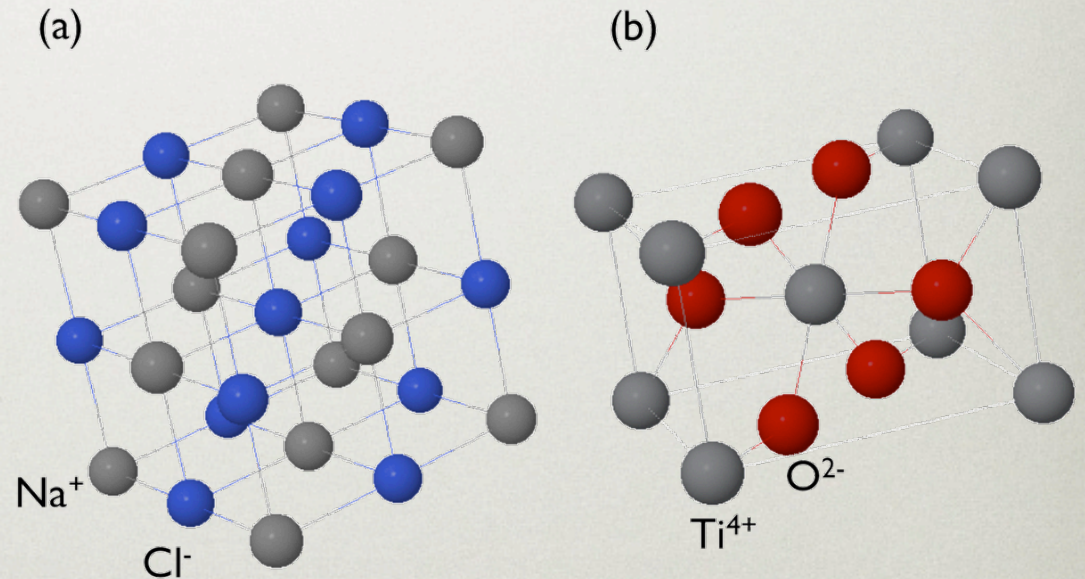
WHAT WILL WE COVER?

- relativity
- electric forces & fields
- electrical energy & capacitance
- current & resistance
- dc circuits
- magnetism
- electromagnetic induction
- ac circuits & EM waves



WHAT WILL WE COVER (CONT.)

- reflection and refraction
- mirrors & lenses
- wave optics
- quantum physics
- atomic physics
- nuclear physics



GRADING AND SO FORTH

- 20% labs / exercises
- 20% homework
 - every 2-3 days
- 20% each: 3 exams
 - during lab period
 - ~60-90 min
 - no final exam

HOMework

- MasteringPhysics (free)
- due date / time is rigid. drop lowest score.
- can collaborate, BUT turn in your own
- will go over @ start of lab sessions

QUIZZES

- sometimes.
- only a few questions!
- previous day's work
- 10-15 min anticipated
- count as a HW grade

LABS / EXERCISES

- try to be on time ...
- something due every day lab is held
- if not a “real” lab:
 - in-class exercises or simulations
- drop 1 lab
- USUALLY will not take 3 hours

SHOWING UP

- no make-up of in-class work or homework
“acceptable” + documented gets you a BYE
- missing an exam is seriously bad.
acceptable reason => makeup or weight final
- lowest 2 labs are dropped. I don't want to know.

DISTRACTIONS

- cell phones
 - keep it on a quiet mode.
 - take the call outside if it is urgent
- “no food / drink”
- at least one break during each lecture

OTHER

Academic misconduct

- do your own work on quizzes & exams
- suspected violations referred to A & S
- teamwork encouraged on labs / homework

Accessibility / disability accommodations

- for a request - 348-4285 Disabilities services
- after initial arrangements, contact me

INTERNETS

- we have our own intertubes:
 - <http://ph102.blogspot.com>
 - updated very frequently. often at odd hours.
 - comments (anonymous even) allowed
 - rss feed
- [google calendar](#)
- [Facebook group](#) ...
 - can add RSS feed of blog to facebook
- check blog & calendar before class

LET'S GET AT IT

The pace will have to be brutal.

Today & tomorrow

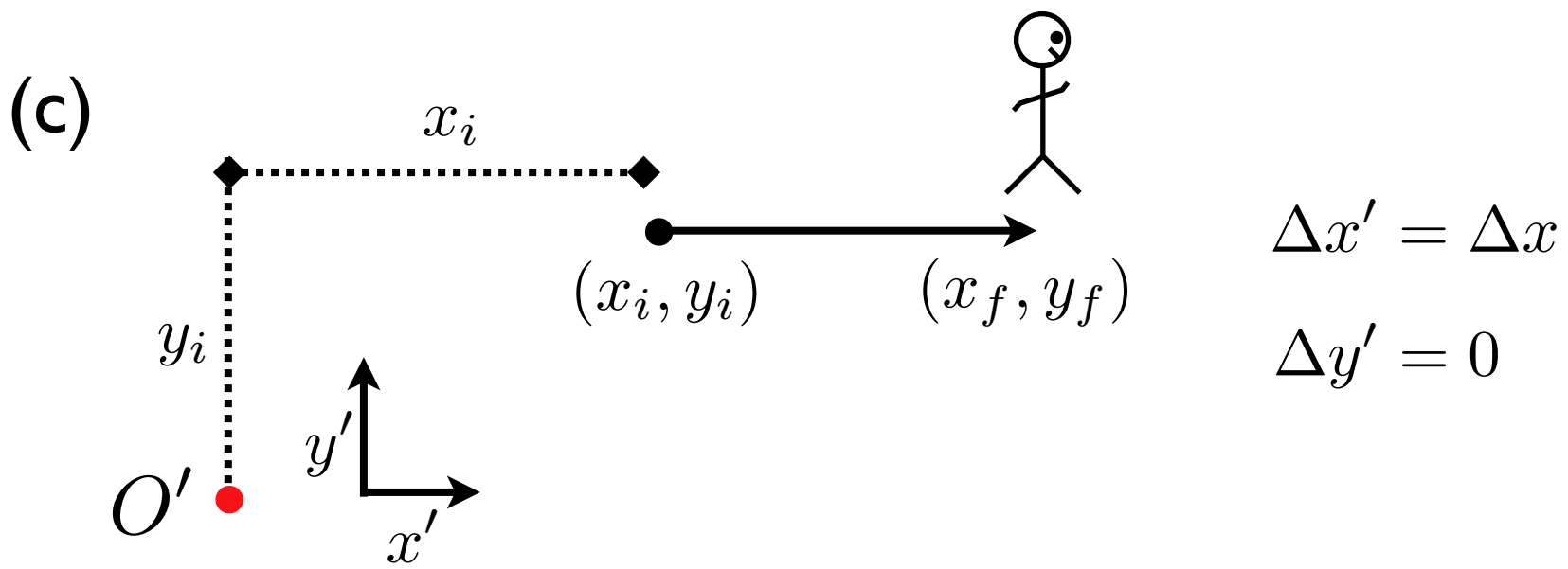
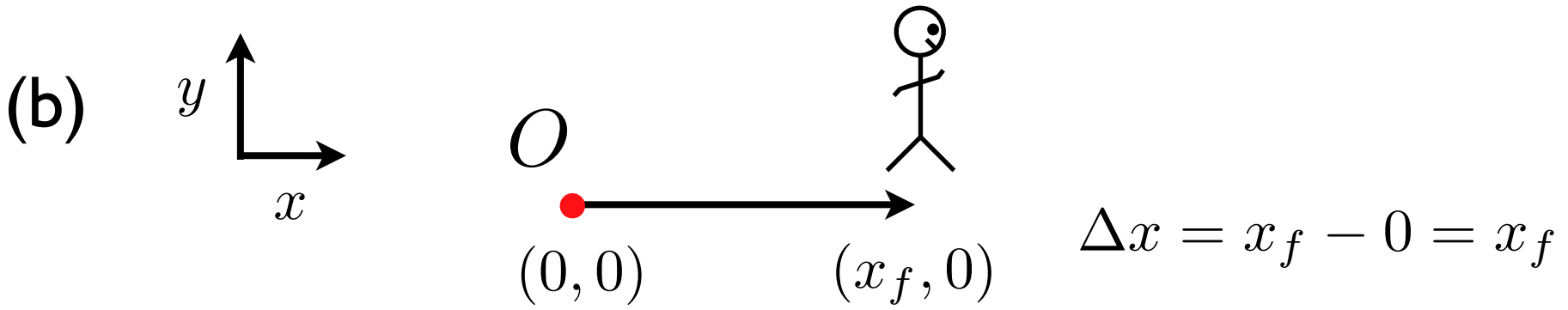
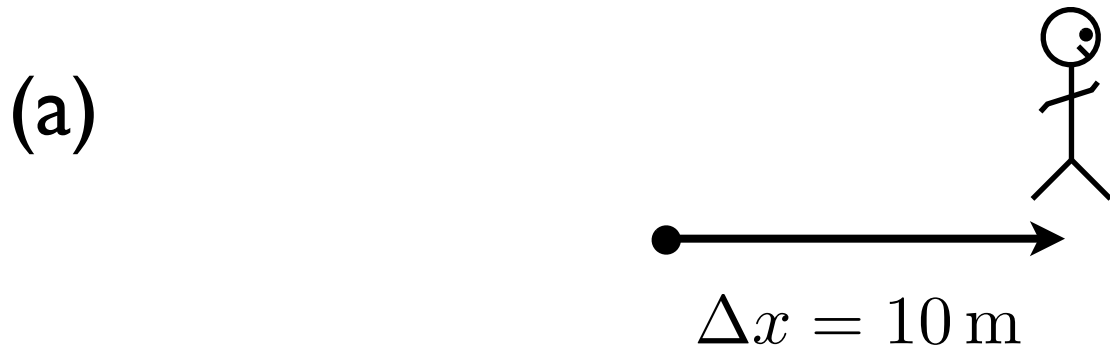
- Relativity

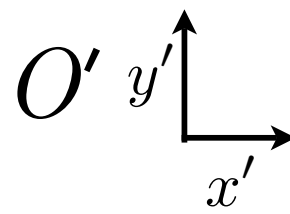
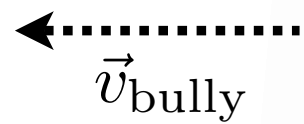
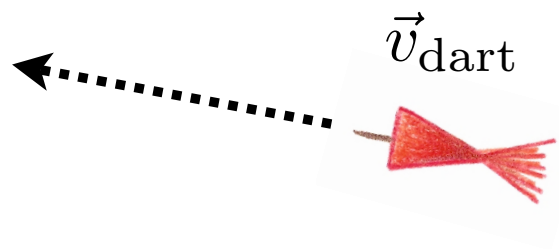
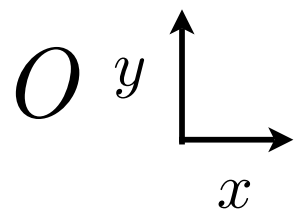
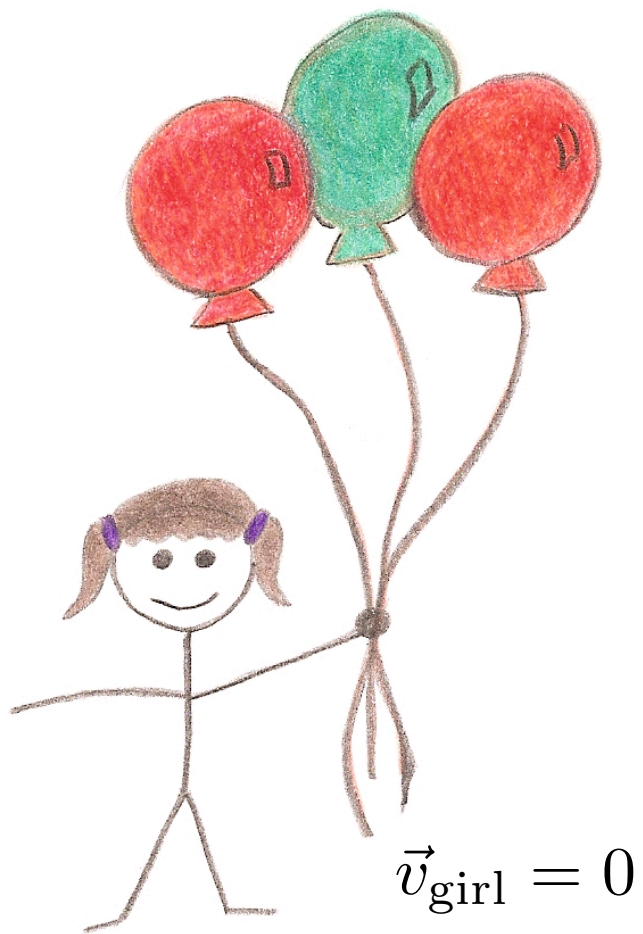
Friday

- electric fields & forces

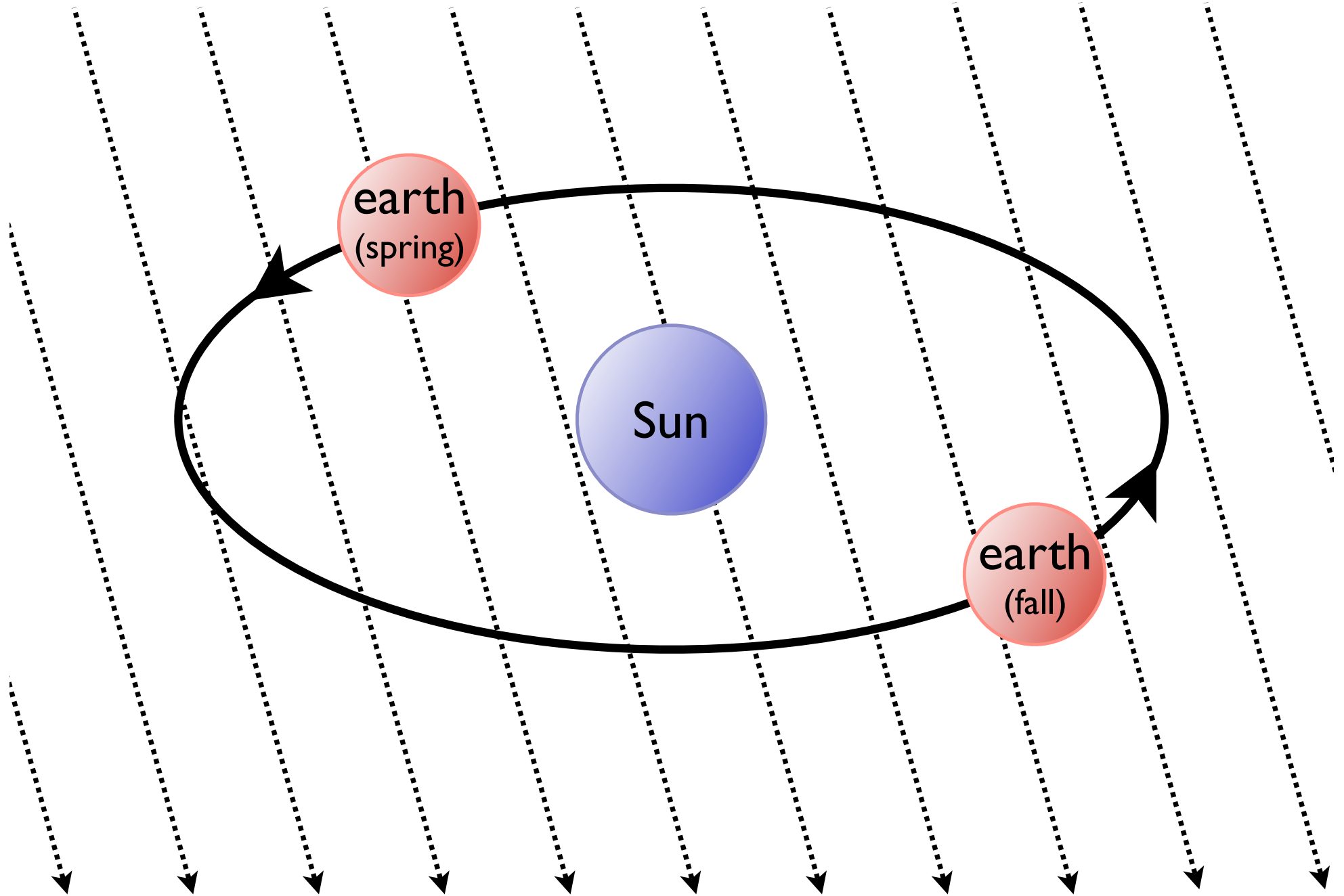
Tomorrow's lab

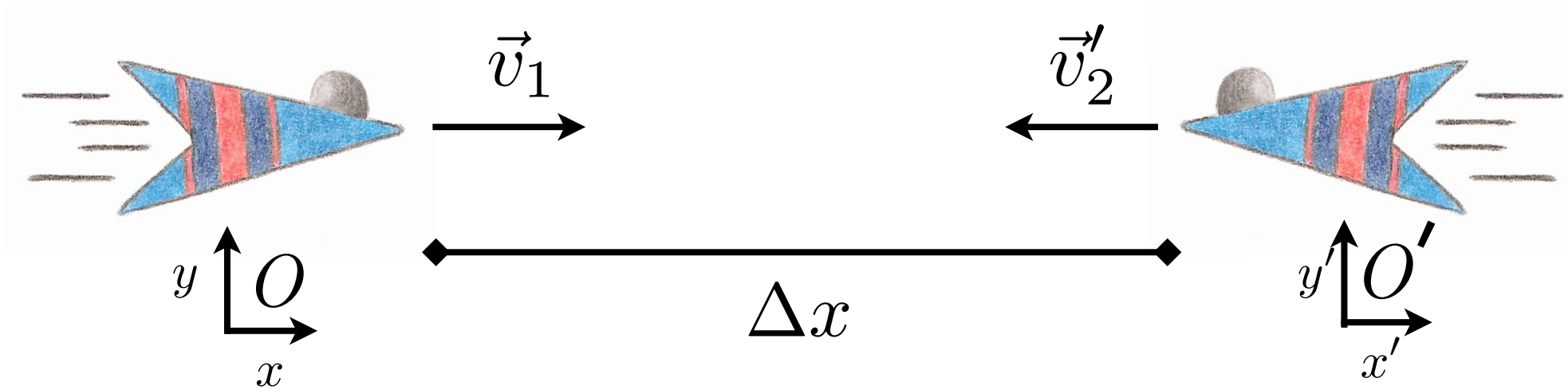
- research & writing assignment (yes really)

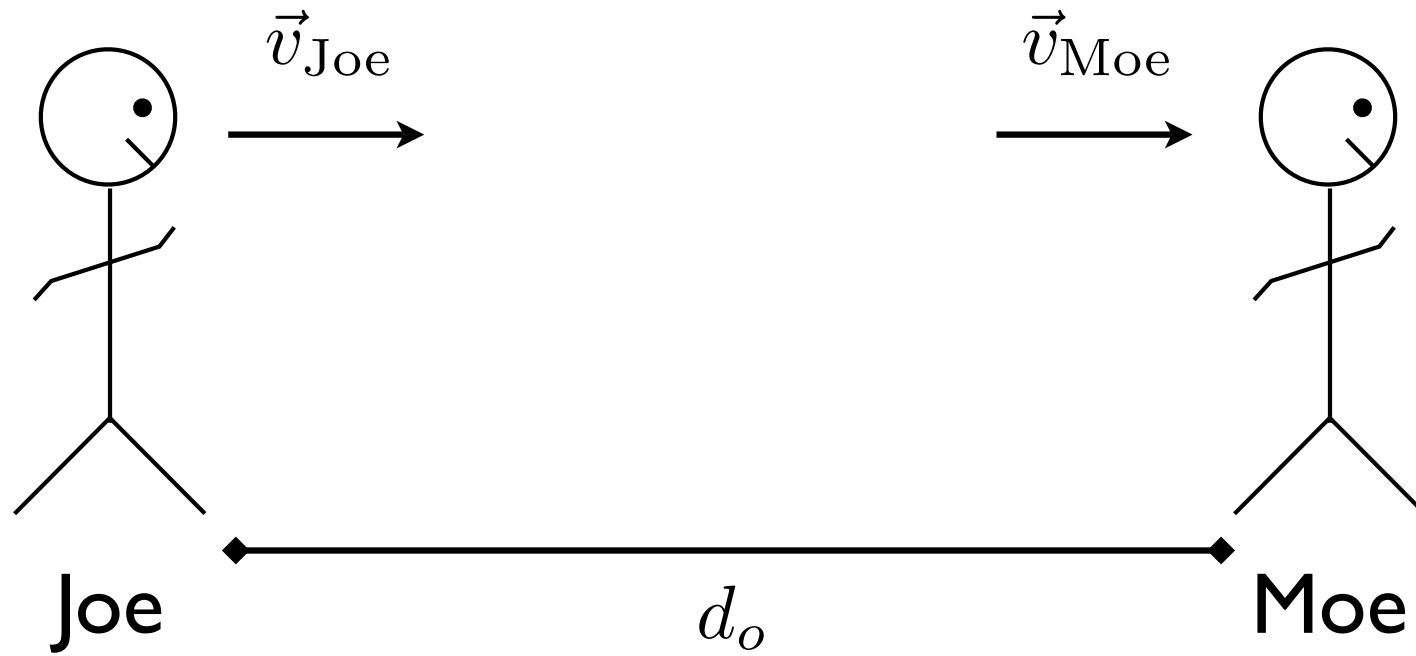




Luminiferous æther

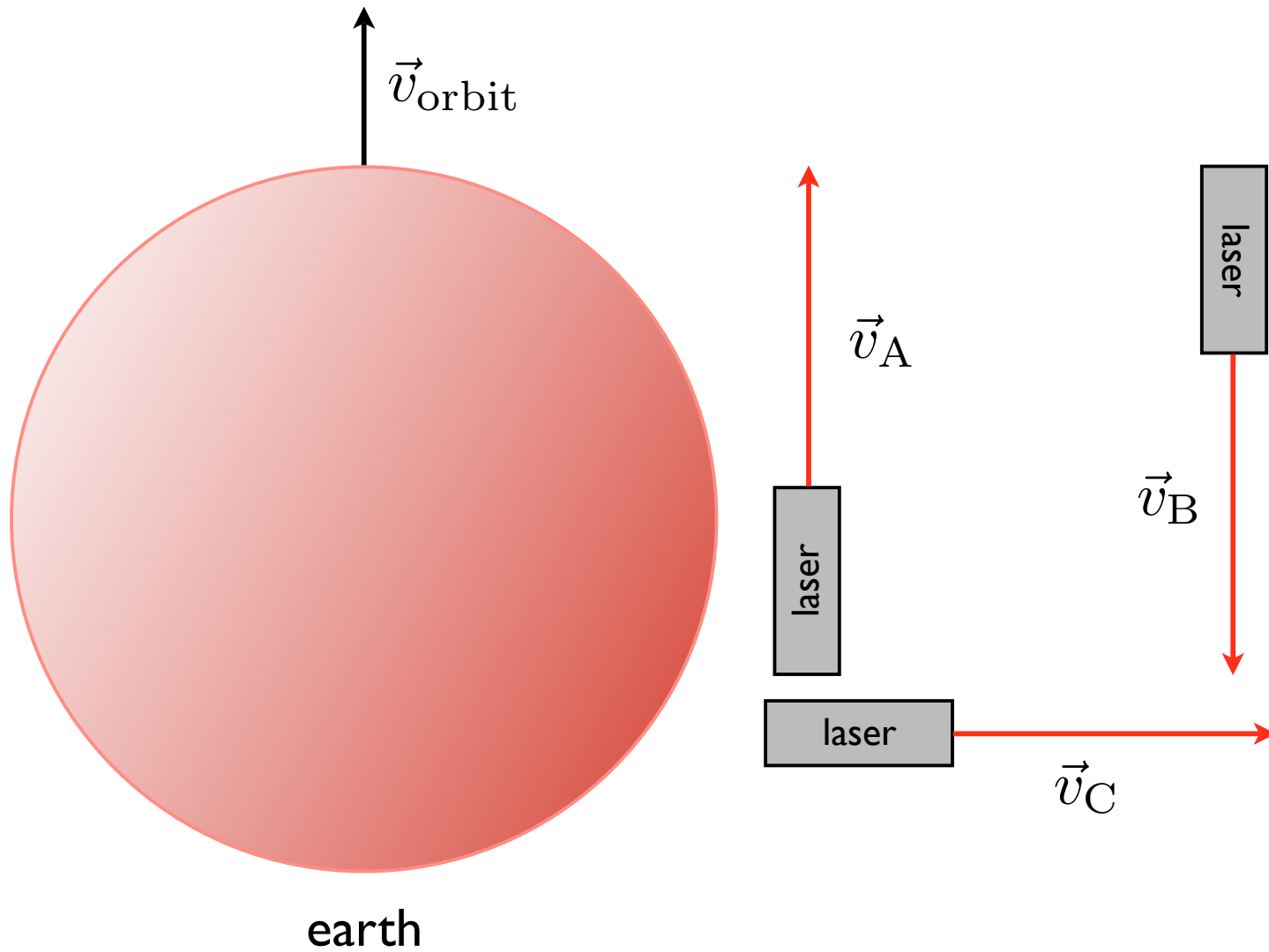




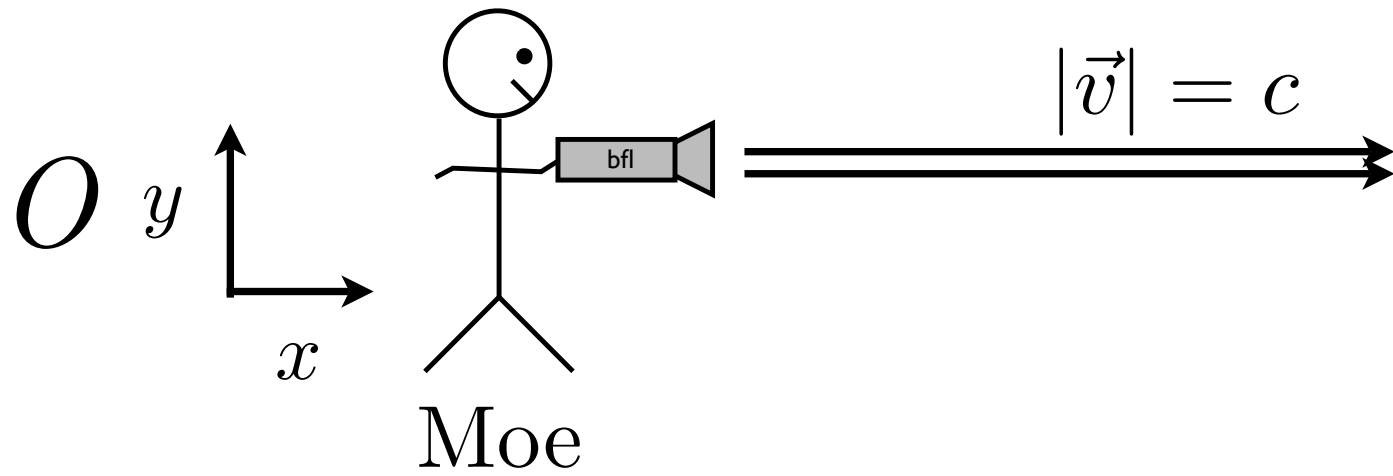
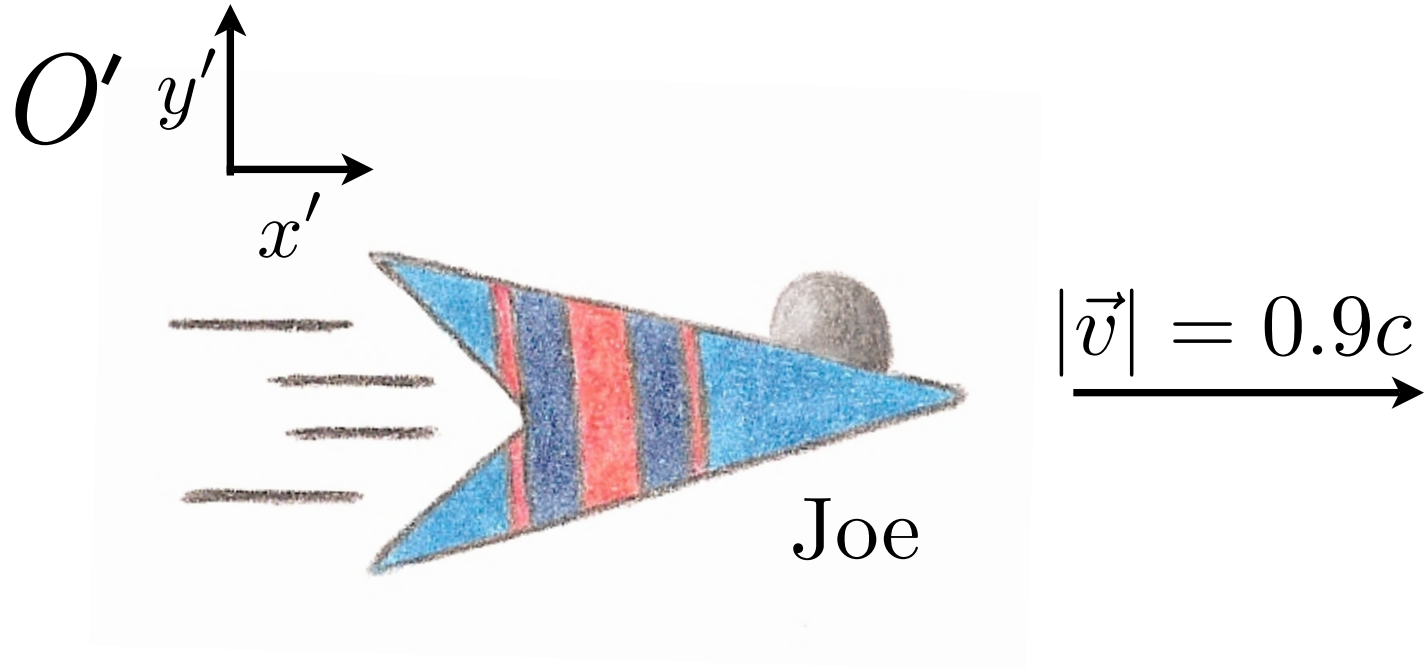


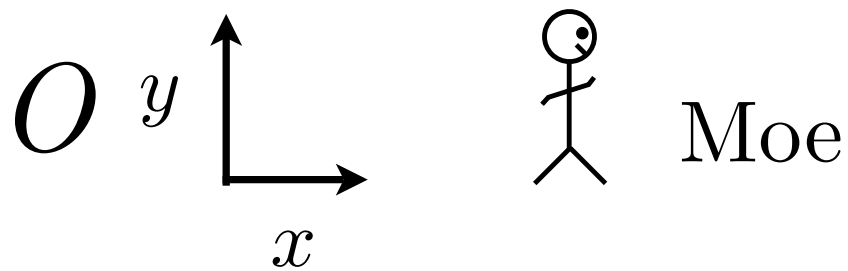
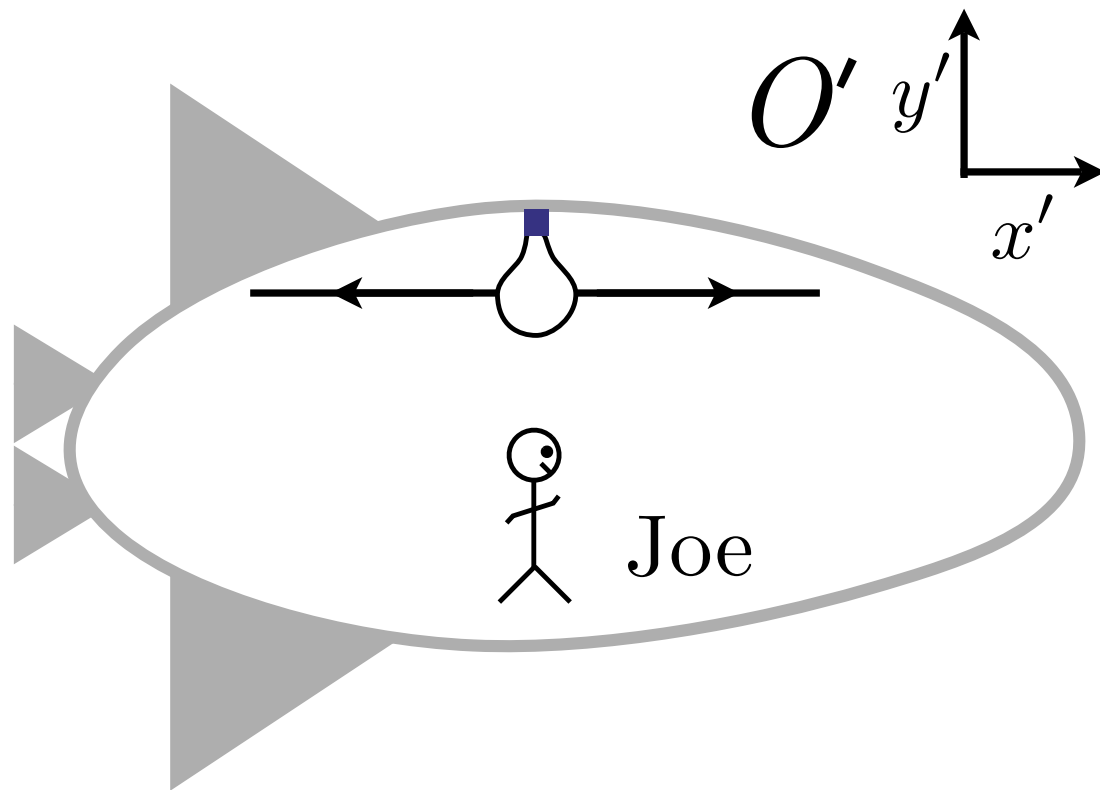
Choosing a coordinate system:

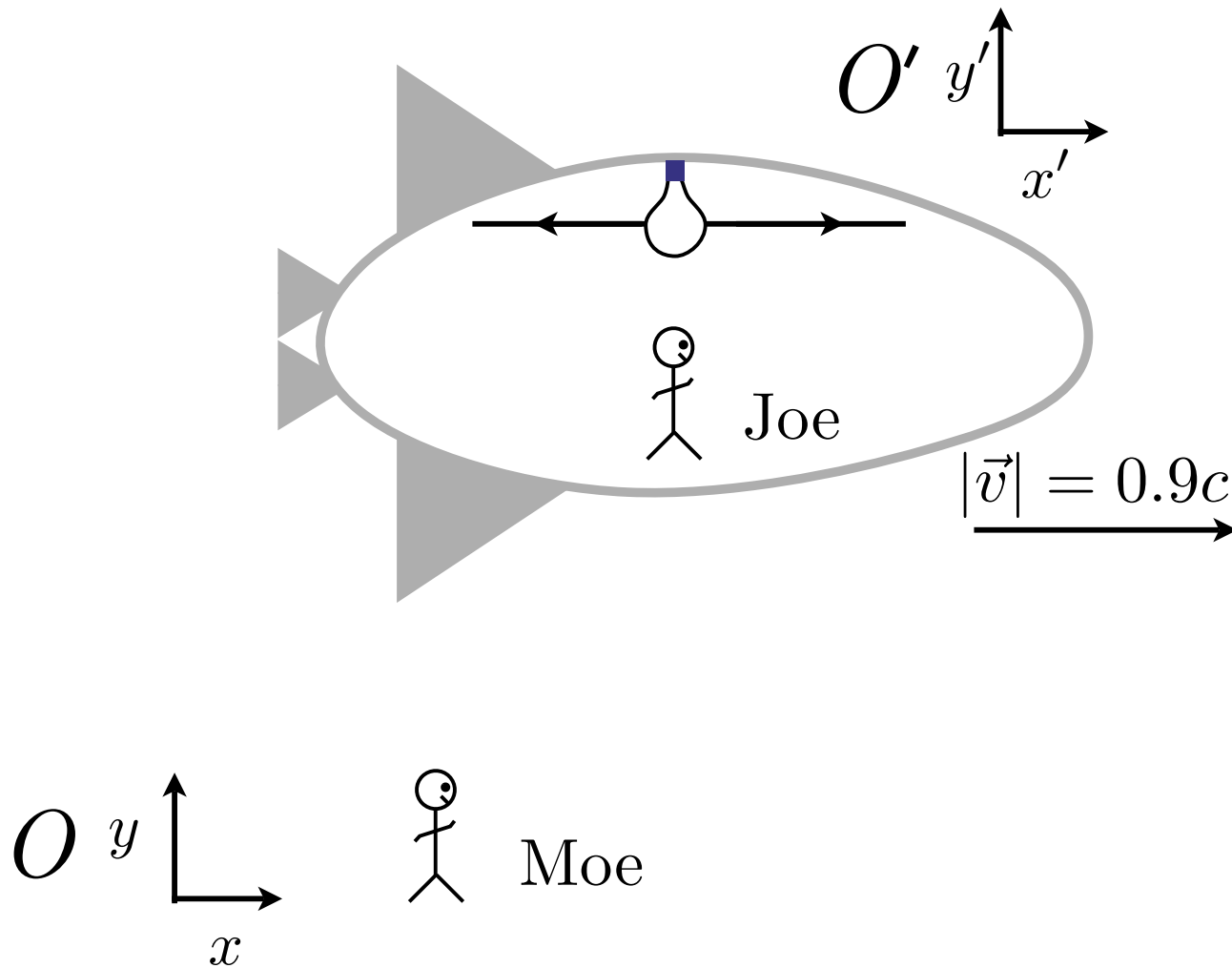
1. Choose an origin. This may coincide with a special point or object given in the problem - for instance, right at an observer's position, or halfway between two observers. Make it convenient!
2. Choose a set of axes, such as rectangular or polar. The simplest are usually rectangular or *Cartesian* x - y - z , though your choice should fit the symmetry of the problem given - if your problem has circular symmetry, rectangular coordinates may make life difficult.
3. Align the axes. Again, make it convenient - for instance, align your x axis along a line connecting two special points in the problem. Sometimes a thoughtful but less obvious choice may save you a lot of math!
4. Choose which directions are positive and negative. This choice is arbitrary, in the end, so choose the least confusing convention.



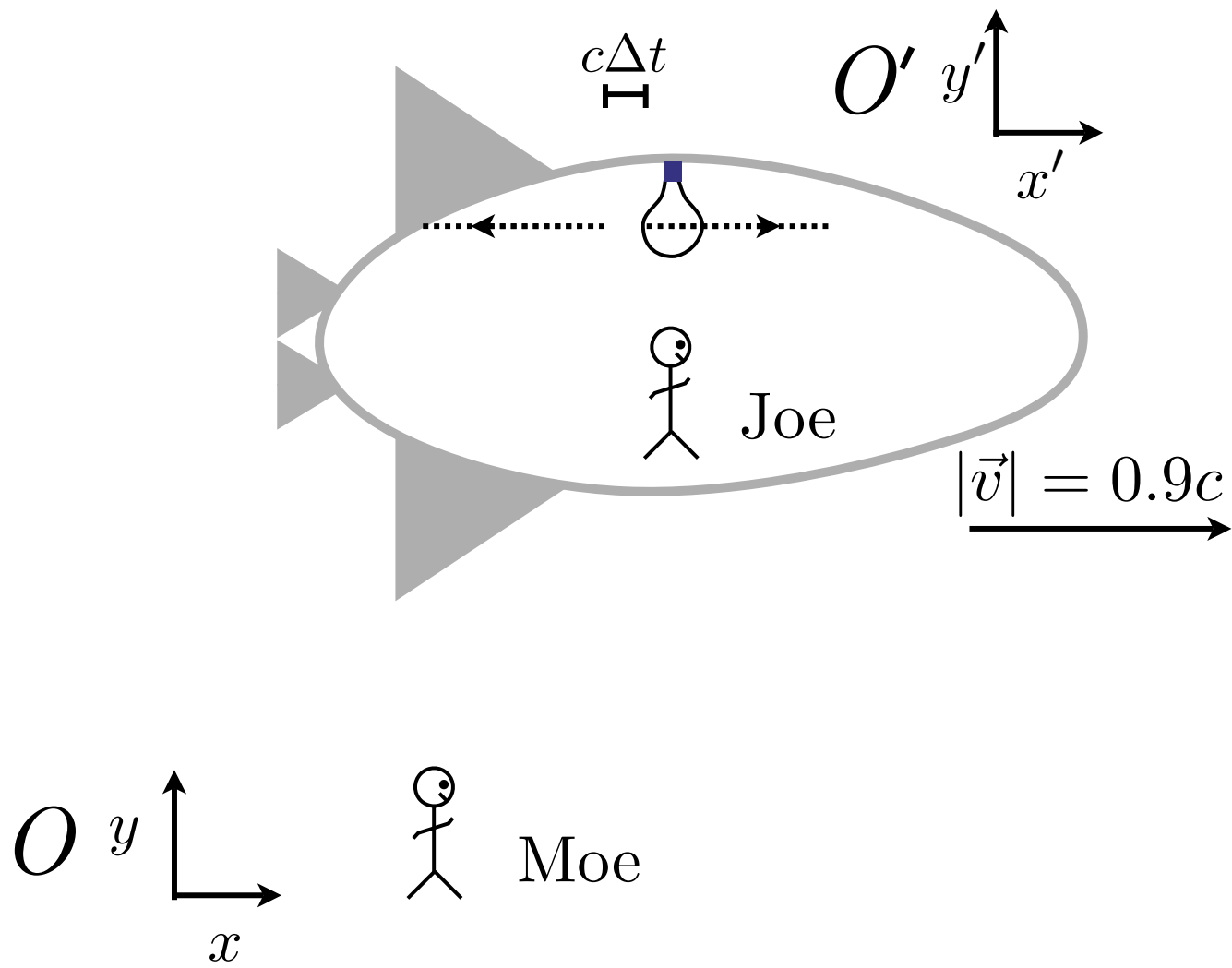
no difference
can't measure earth's velocity
relative to empty space



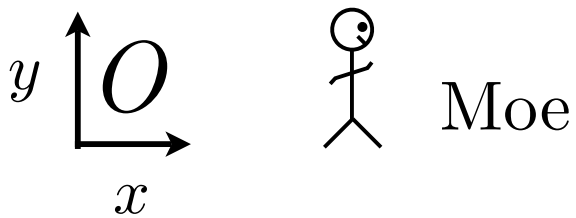
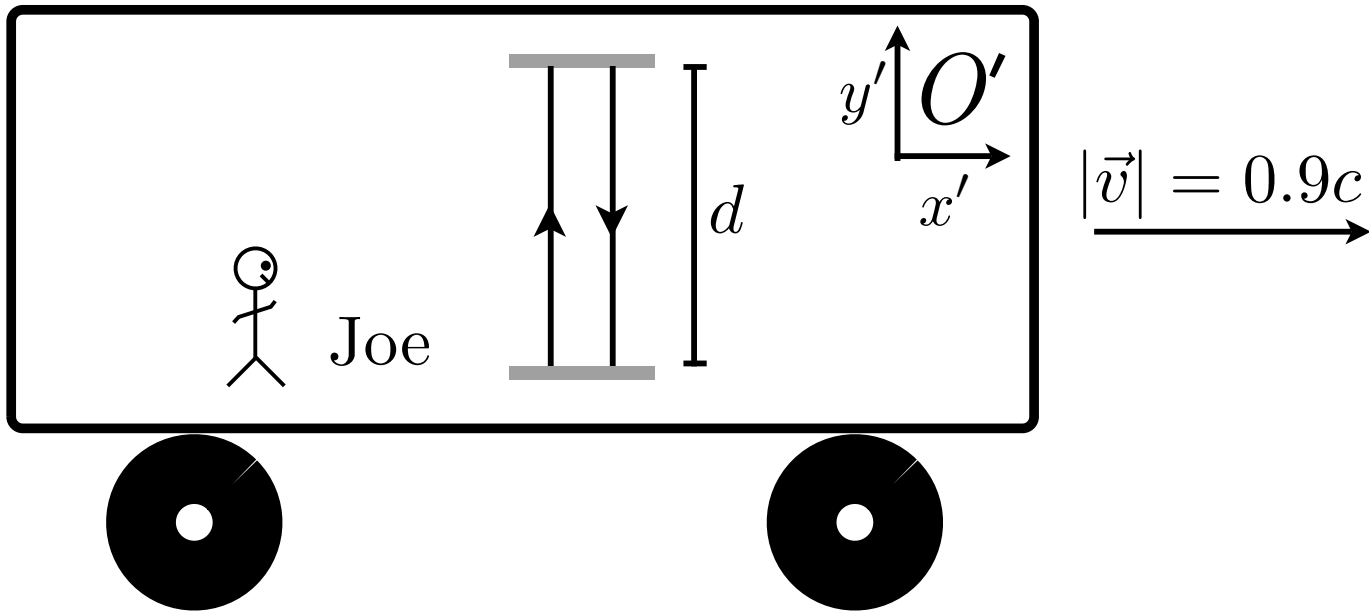




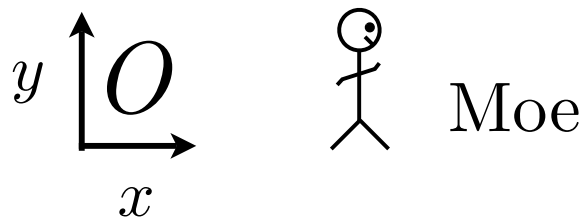
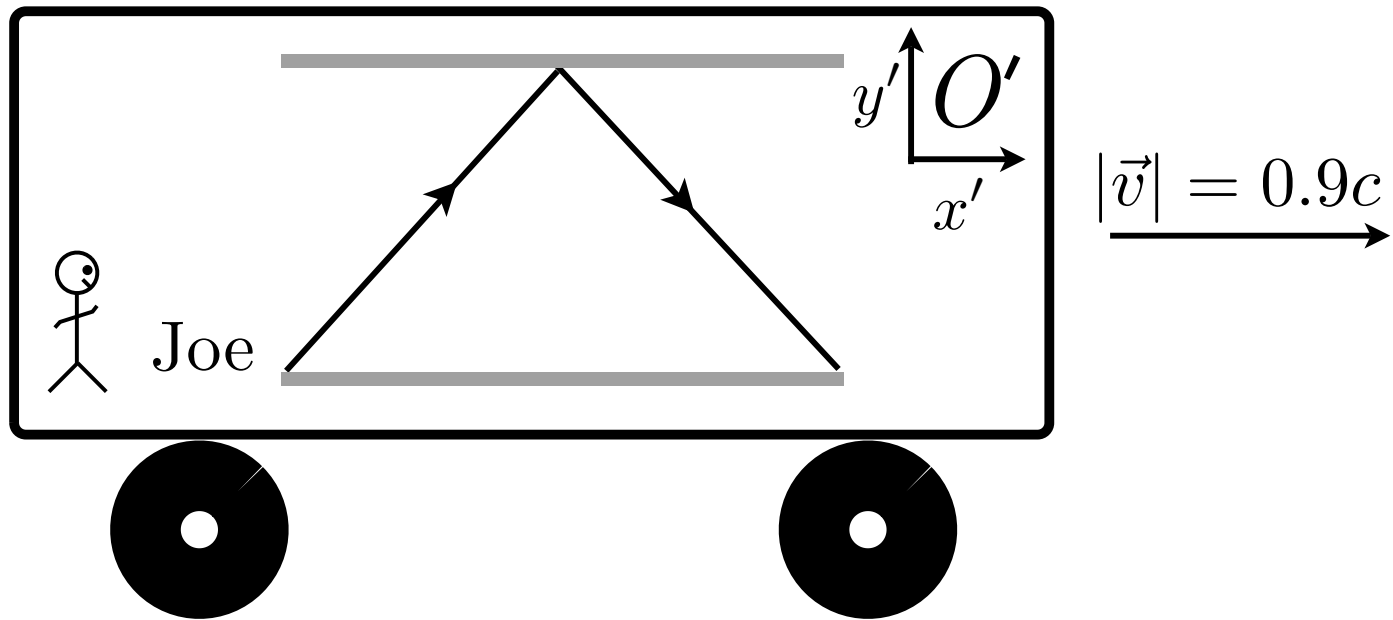
Joe flips on the light
he sees the light hit
the walls at the same time



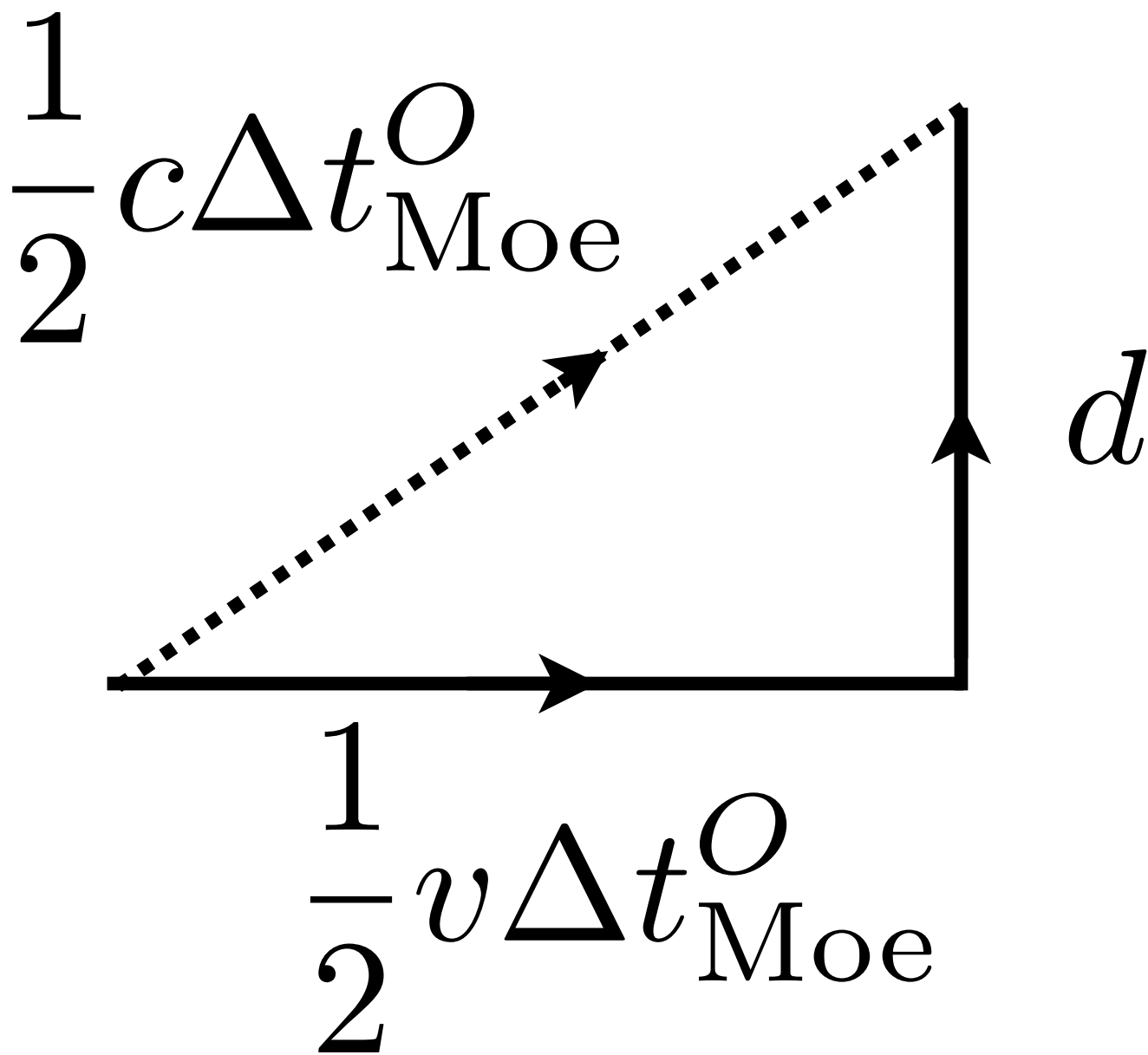
What does Moe see?
 the ship moved;
 the origin of the light did not



Joe bounces a laser off of some mirrors
he counts the round trips
this measures distance

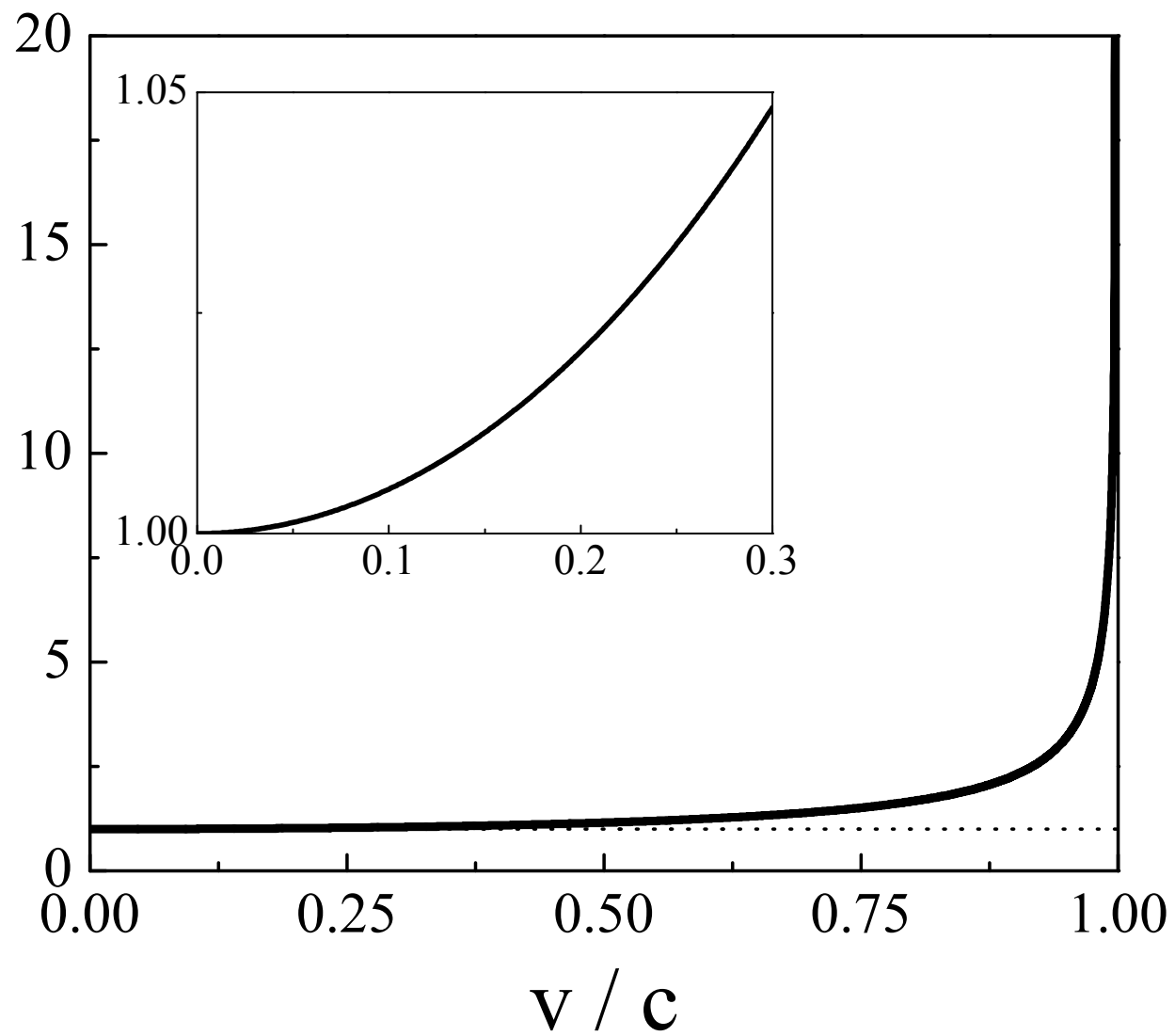


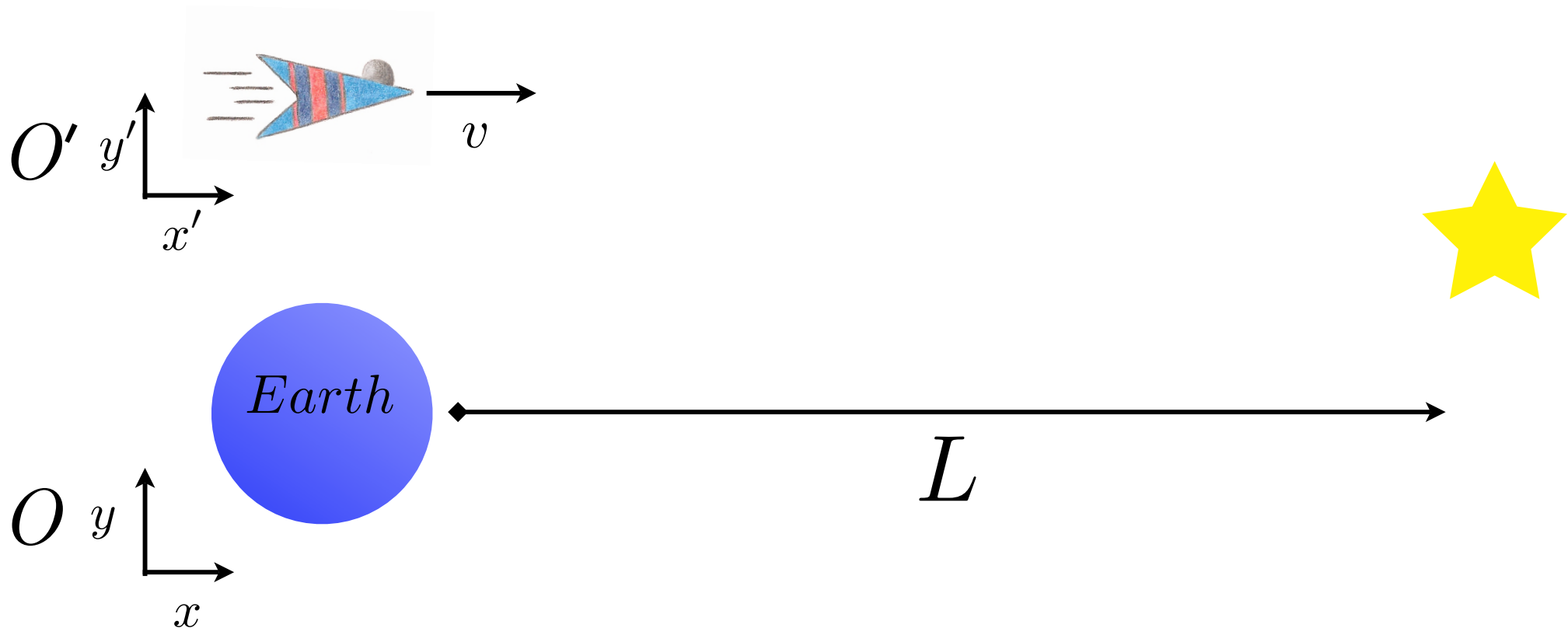
Moe sees the boxcar move;
 once the light is created, it does not.
 Moe sees a triangle wave

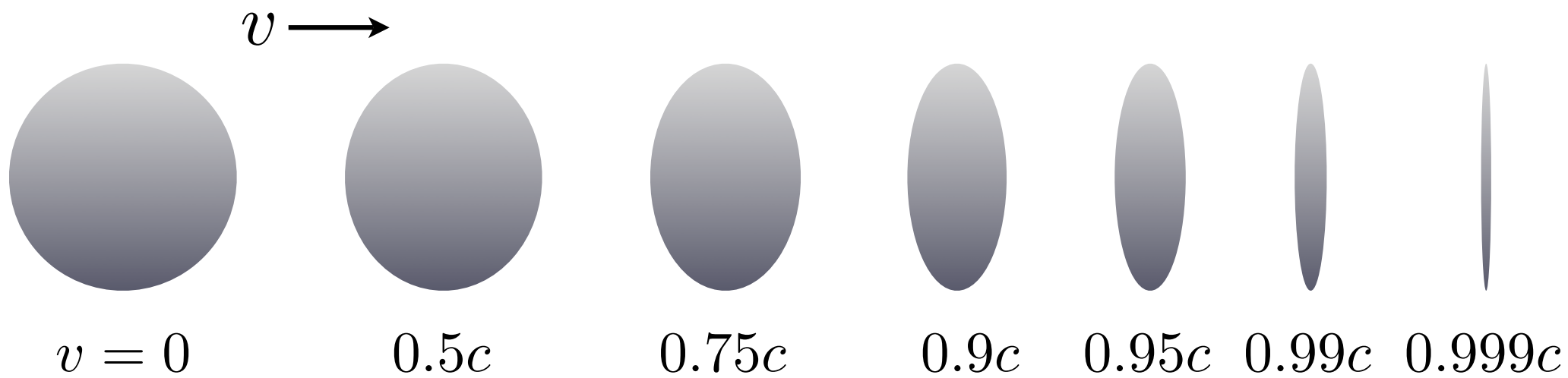


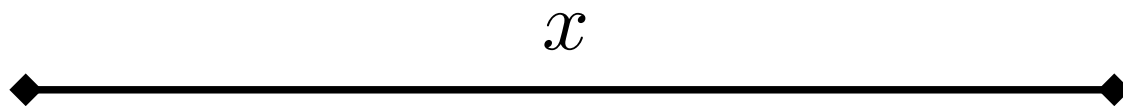
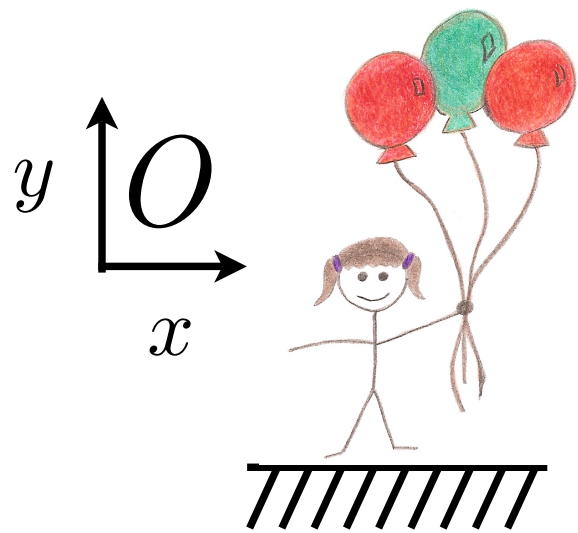
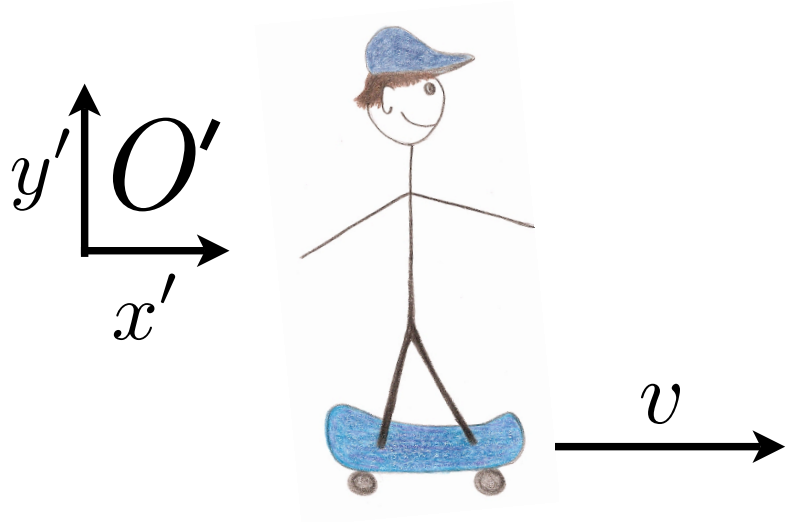
v [m/s]	$\frac{v}{c}$	γ	$1/\gamma$
0	0	0	∞
3×10^6	0.01	1.00005	0.99995
3×10^7	0.1	1.005	0.995
6×10^7	0.2	1.02	0.980
1.5×10^8	0.5	1.16	0.866
2.25×10^8	0.75	1.51	0.661
2.7×10^8	0.9	2.29	0.436
2.85×10^8	0.95	3.20	0.312
2.97×10^8	0.99	7.09	0.141
2.983×10^8	0.995	10.0	0.0999
2.995×10^8	0.999	22.4	0.0447
2.996×10^8	0.9995	31.6	0.0316
2.998×10^8	0.9999	70.7	0.0141
c	1	∞	0

γ









Transformation of distance between reference frames:

$$x' = \gamma(x - vt) \quad (1.3)$$

$$x = \gamma(x' + vt') \quad (1.3)$$

Here (x, t) is the position and time of an event as measured by an observer in O stationary to it. A second observer in O' , moving at velocity v , measures the same event to be at position x' and time (x', t') .

Time measurements in different non-accelerating reference frames:

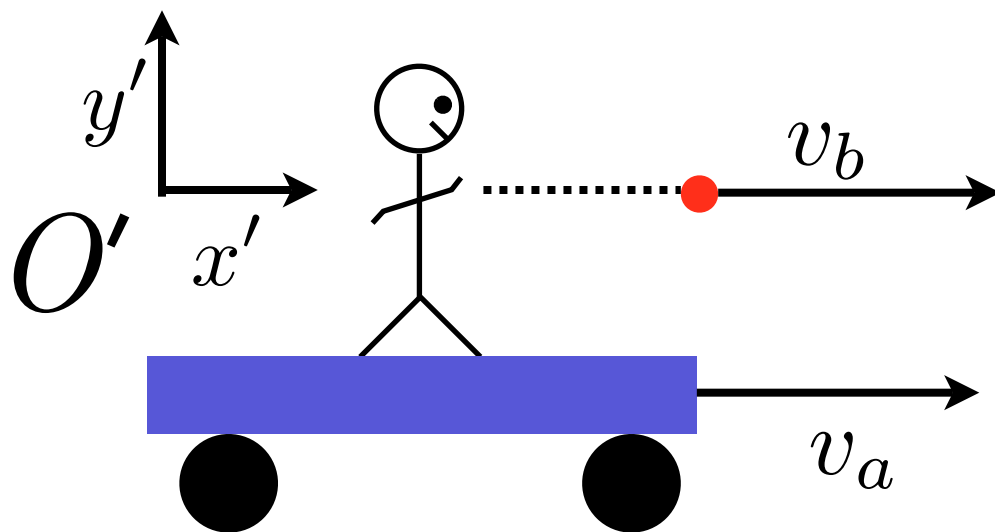
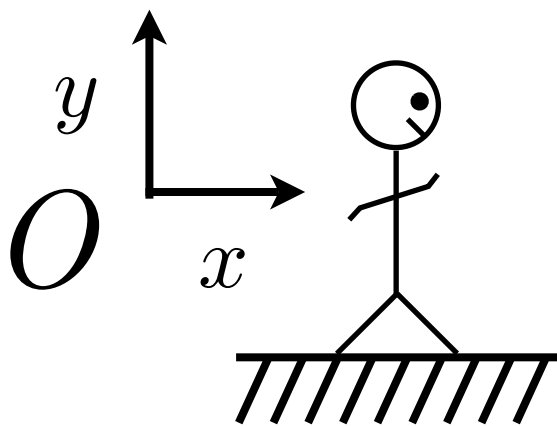
$$t' = \gamma\left(t - \frac{vx}{c^2}\right) \quad (1.46)$$

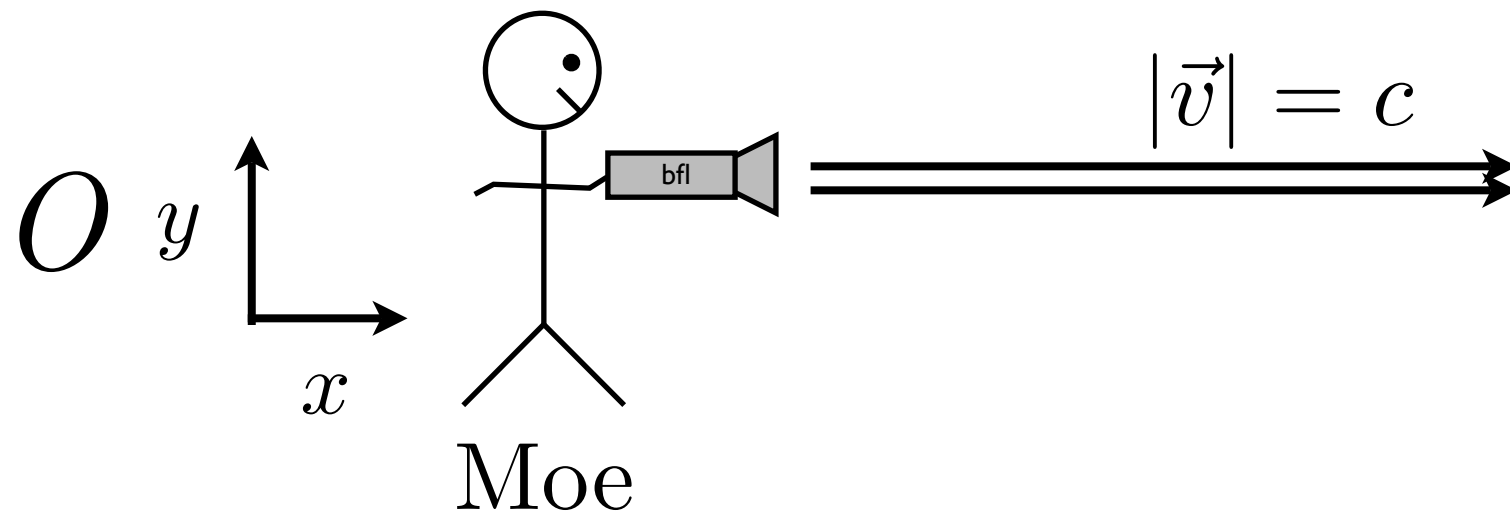
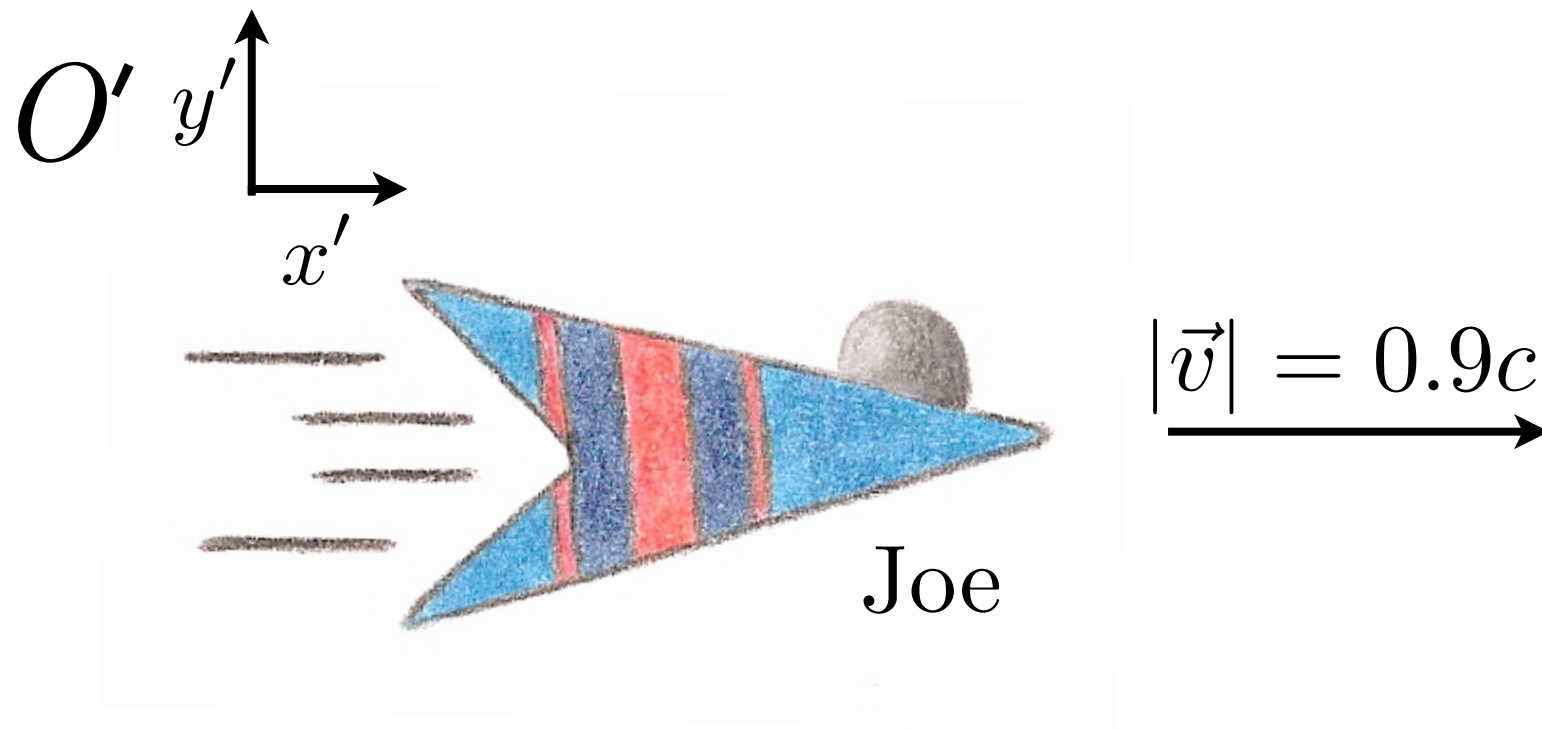
$$t = \gamma\left(t' + \frac{vx'}{c^2}\right) \quad (1.47)$$

Here (x, t) is the position and time of an event as measured by an observer in O stationary to it. A second observer in O' , moving at velocity v , measures the same event to be at position x' and time (x', t') .

Elapsed times between events in non-accelerating reference frames:

$$\Delta t' = t'_1 - t'_2 = \gamma\left(\Delta t - \frac{v\Delta x}{c^2}\right) \quad (1.4)$$





let's work out some problems

1. An astronaut traveling at $v=0.80c$ taps her foot 3.0 times per second. What is the frequency of taps determined by an observer on earth? (*Hint: be careful about the difference between time and frequency!*)

- 5.0 taps/sec
- 6.7 taps/sec
- 1.8 taps/sec
- 3.0 taps/sec

2. A spaceship moves away from earth at high speed. How do experimenters on earth measure a clock in the spaceship to be running? How do those in the spaceship measure a clock on earth to be running?

- slow; fast
- slow; slow
- fast; slow
- fast; fast

3. If you are moving in a spaceship at high speed relative to the earth, would you notice a difference in your pulse rate? In the pulse rate of the people back on earth?

- no; yes
- no; no
- yes; no
- yes; yes

4. The period of a pendulum is measured to be 3.00 in its own reference frame. What is the period as measured by an observer moving at a speed of $0.950c$ with respect to the pendulum?

- 6.00 sec
- 13.4 sec
- 0.938 sec
- 9.61 sec

1. **1.8 taps/sec.** The 'proper time' Δt_p is that measured by the astronaut herself, which is 1/3 of a second between taps (so that there are 3 taps per second). The time interval *between taps* measured on earth is dilated (longer), so there are *less* taps per second. For the astronaut:

$$\Delta t_p = \frac{1 \text{ s}}{3 \text{ taps}}$$

On earth, we measure the dilated time:

$$\Delta t' = \gamma \Delta t_p = \frac{1}{\sqrt{1 - \frac{0.8^2 c^2}{c^2}}} \cdot \left(\frac{1 \text{ s}}{3 \text{ taps}} \right) = \frac{1}{\sqrt{1 - 0.8^2}} \cdot \left(\frac{1 \text{ s}}{3 \text{ taps}} \right) \approx \frac{0.56 \text{ s}}{\text{tap}} = \frac{1 \text{ s}}{1.8 \text{ taps}}$$

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2. slow; slow. The time-dilation effect is symmetric, so observers in each frame measure a clock in the other to be running slow. Put another way, the *relative* velocity of the earth and the ship is the same no matter who you ask – each says the other is moving with some speed v , and they are sitting still. Therefore, the dilation effect is the same in both cases.

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3. no; yes. There is no relative speed between you and your own pulse, since you are in the same reference frame, so there is no difference in your pulse rate (possible space-travel-related anxieties aside). There is a relative velocity between you and the people back on earth, however, so you would find their pulse rate *slower* than normal. Similarly, they would find *your* pulse rate slower than normal, since you are moving relative to them. Relativistic effects are always attributed to the other party – you are always at rest in your own reference frame.

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- no; no
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- 0.938 sec
- 9.61 sec

4. **9.61 sec.** The proper time is that measured by in the reference frame of the pendulum itself, $\Delta t_p = 3.00$ sec. The moving observer has to observe a *longer* period for the pendulum, since from the observer's point of view, the pendulum is moving relative to it. Observers always perceive clocks moving relative to them as running slow. The factor between the two times is just γ :

$$\Delta t' = \gamma \Delta t_p = \frac{3.0 \text{ sec}}{\sqrt{1 - \frac{0.95^2 c^2}{c^2}}} = \frac{3.0 \text{ sec}}{\sqrt{1 - 0.95^2}} \approx 9.61 \text{ sec}$$

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6. You are packing for a trip to another star, and on your journey you will travel at $0.99c$. Can you sleep in a smaller cabin than usual, because you will be shorter when you lie down? Explain your answer.

7. A deep-space probe moves away from Earth with a speed of $0.88c$. An antenna on the probe requires 4.0 s , in probe time, to rotate through 1.0 rev . How much time is required for 1.0 rev according to an observer on Earth?

8. A friend in a spaceship travels past you at a high speed. He tells you that his ship is 24 m long and that the identical ship you are sitting in is 18 m long.

(a) According to your observations, how long is your ship?

(b) According to your observations, how long is his ship?

(c) According to your observations, what is the speed of your friend's ship?

6. No. There is no relative speed between you and your cabin, since you are in the same reference frame. You and your bed will remain at the same lengths relative to each other.

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(c) According to your observations, what is the speed of your friend's ship?

7. 8.42 s. The time interval in the probe's reference frame is the proper one Δt_p ... which makes sense, since the antenna is part of the probe itself! The probe and antenna are moving relative to the earth, and therefore the earthbound observer measures a longer, dilated time interval $\Delta t'$:

$$\begin{aligned}\text{probe} &= \Delta t_p \\ \text{earth} &= \Delta t' \\ \Delta t' &= \gamma \Delta t_p\end{aligned}$$

As usual, we first need to calculate γ . No problem, given the probe's velocity of $0.88c$ relative to earth:

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{1}{\sqrt{1 - \frac{(0.88c)^2}{c^2}}} = \frac{1}{\sqrt{1 - 0.88^2}} = 2.11$$

The proper time interval for one revolution Δt_p in the probe's reference frame is 4.0 s, so we can readily calculate the time interval observed by the earthbound observer:

$$\Delta t' = \gamma \Delta t_p = 2.11 \cdot (4.0 \text{ s}) = 8.42 \text{ s}$$

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8. A friend in a spaceship travels past you at a high speed. He tells you that his ship is 24 m long and that the identical ship you are sitting in is 18 m long.

(a) According to your observations, how long is your ship?

(b) According to your observations, how long is his ship?

(c) According to your observations, what is the speed of your friend's ship?

8. **24 m; 18 m; 0.661c.** Once again: if you are observing something in your own reference frame, there is no length contraction or time dilation. You always observe your own ship to be the same length. If your friend's ship is 24 m long, and yours is identical, you will measure it to be 24 m.

On the other hand, you are moving relative to his ship, so you would observe his ship to be length contracted, and measure a shorter length. Your friend, on the other hand, will observe *exactly the same thing* - he will see *your* ship contracted, by precisely the same amount. Your observation of his ship has to be the same as his observation of his ship - since you are only the two observers, and you both have the same *relative* velocity, you must observe the same length contraction. If he sees your ship as 18 m long, then you would also see his (identical) ship as 18 m long.

Given the relationship between the contracted and proper length, we can find the relative velocity easily. Your measurement of your own ship is the proper length L_p , while your measurement of your friend's ship is the contracted length L' :

$$\begin{aligned}L_p &= \gamma L' \\ \Rightarrow \gamma &= \frac{L_p}{L'} = \frac{24}{18} = \frac{4}{3} \\ \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} &= \frac{4}{3} \\ 1 - \frac{v^2}{c^2} &= \frac{3^2}{4^2} = \frac{9}{16} \\ \frac{v^2}{c^2} &= 1 - \frac{9}{16} = \frac{7}{16} \\ v &= \sqrt{\frac{7}{16}}c = \frac{\sqrt{7}}{4}c \approx 0.661c\end{aligned}$$