Physics 2D Lecture Slides
Lecture 1

Jan. 4, 2010

Modern Physics (PHYS 2D)

- Exploration of physical ideas and phenomena related to
  - High velocities and acceleration (Einstein's Theory of Relativity)
  - Sub Atomic structure and Dynamics (Quantum Physics)
  - The very small (quarks) and the Very large (cosmos)

- A glimpse of the cutting edge of thought in Physics and technology that it is generating
- A different kind of course :
  - Exciting (Gee Whiz stuff) BUT intense
  - About 40 Nobel Prize winning ideas/experiment in course (~4 / week!)
  - Non-intuitive (how do you figure how electrons act inside an atom)
    - Will require abstract thought
    - Fountainhead of Chemistry, Biology, Electronics, Computing
  - Foundation for tomorrow's technology, chemistry and medicine

Quizzes, Final and Grades

- Course score = 60% Quiz + 40% Final Exam
  - 9 quizzes (every Friday starting Jan. 8), best 7 scores count
    - Two problems in each quiz, 50 minutes to do it
      - One problem HW like, other more interesting
    - Closed book exam, some formulae will be provided
      - No "CHEAT SHEETS" please
    - Blue Book required, Code numbers will be given at the 1st quiz. Bring calculator, check battery !
    - No makeup quizzes / See handout for **Quiz regrade protocol**
- Final Exam : March 15th , 11:30am - 2.30 pm
  - Inform me of possible conflict within 2 weeks of course
  - Don't plan travel/vacation before finals schedule is confirmed !
    - No makeup finals for any reason

What to Expect / Not Expect on the Quiz / Final Handout

Some Useful Numbers, Equations and Identities

$$\textbf{Speed of Light, c} = \mathbf{3.0} \times \mathbf{10^8}\mathrm{m/s}$$

$$\gamma = \frac{1}{\sqrt{1 - v^2/c^2}}$$

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

$$t' = \gamma(t - \frac{xv}{c^2})$$

$$V'_x = \frac{V_x - v}{1 - \frac{V_x v}{c^2}}$$

$$p = \frac{mV_x}{\sqrt{1 - V_x^2/c^2}}$$

$$E = \frac{mc^2}{\sqrt{1 - V_x^2/c^2}} = K + mc^2$$

$$\nu_{obs} = \frac{\sqrt{1 + v/c}}{\sqrt{1 - v/c}}\,\nu_{source}$$

$$\vec{F} = m\vec{a}$$

$$a = \frac{d^2x}{dt^2}$$

$$\vec{F} = q(\vec{v} \times \vec{B})$$

$$Sin^2\theta + Cos^2\theta = 1$$

All constants will be provided
No need to memorize them

Course Grade

- Our wish is that every body gets an A ! So no curve
- Grading on an absolute scale. Roughly it looks like this :

Total Score	Grade
> 85	A+
> 70	A
> 50	B
> 35	C
< 25	F

- Hint : don't miss the early quizzes, they are easier

Expected Prior Knowledge: Brush up!

- Concepts learnt in Phys 2A, 2B and 2C will be used in 2D
- Familiarity with Vector Calculus & Differential Equations
- Knowledge of PHYSICS 2C material
  - Will need to know concepts in Waves : Interference & Diffraction
    - Hard to appreciate ideas in Modern Physics without them
  - Notes on 2C concepts needed will be posted on class web site
  - Consult TA or me if you need extra help
    - We can help you over weekends but pl. contact us early!!

How To Do Well In This Course

- Don’t rely on your intuition ! Always think thru the concept
- Read the assigned text BEFORE lecture to get a feel of the topic
- Attend lecture (ask questions during/before/after lecture) and discussion. Review lecture & discussion material using video-on-demand
- Attempt all homework problems yourself
  - Before looking at the problem solutions (available on web every Tuesday afternoon)
  - Before attending Problem Solving session
  - Work in sets of 2-3 to share ideas and problem solving approaches
- Do not try to memorize complicated formulae or Homework problems! Do not just accept a concept without understanding the logic
- Quarter goes fast, don’t leave every thing for the week before exam !!
- All-nighters don’t work in this course: Get decent sleep before Quiz or Finals
- Don’t hesitate to show up at Prof. or TA office hour (they don’t bite!)

Lecture 1: Relativity

- Describing a Physical Phenomenon
  - Event (s)
  - Observer (s)
  - Frame(s) of reference (the point of View !)
    - Inertial Frame of Reference
    - Accelerated Frame of Reference

Described on Black board

- Newtonian Relativity and Inertial Frames
  - Laws of Mechanics and Frames of Reference
  - Galilean Transformation of coordinates
    - Addition law for velocities
- Maxwell's Equations & Light
  - Light as Electromagnetic wave
  - Speed of Light is not infinite !
  - Light needs no medium to propagate

Event, Observer, Frame of Reference

- Event : Something happened => (x,y,z,t)
  - Same event can be described by different observers
- Observer(s) : Measures event with a meter stick & a clock
- Frame of Reference :observer is standing on it
  - Inertial Frame of reference 🡐 constant velocity, no force
- An event is not OWNED by an observer or frame of reference
- An event is something that happens, any observer in any reference frame can assign some (x,y,z,t) to it
- Different observers assign different space & time coordinates to same event
  - S describes it with : (x,y,z,t)
  - S' describes same thing with (x',y',x',t')

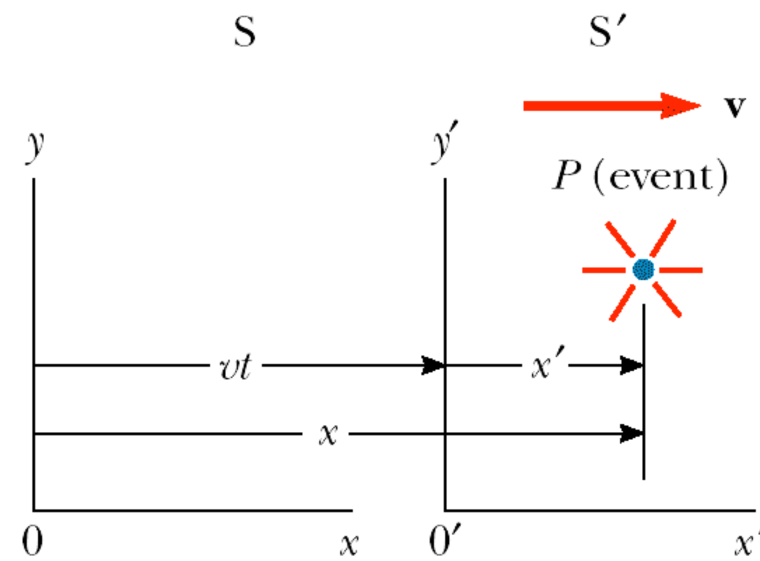
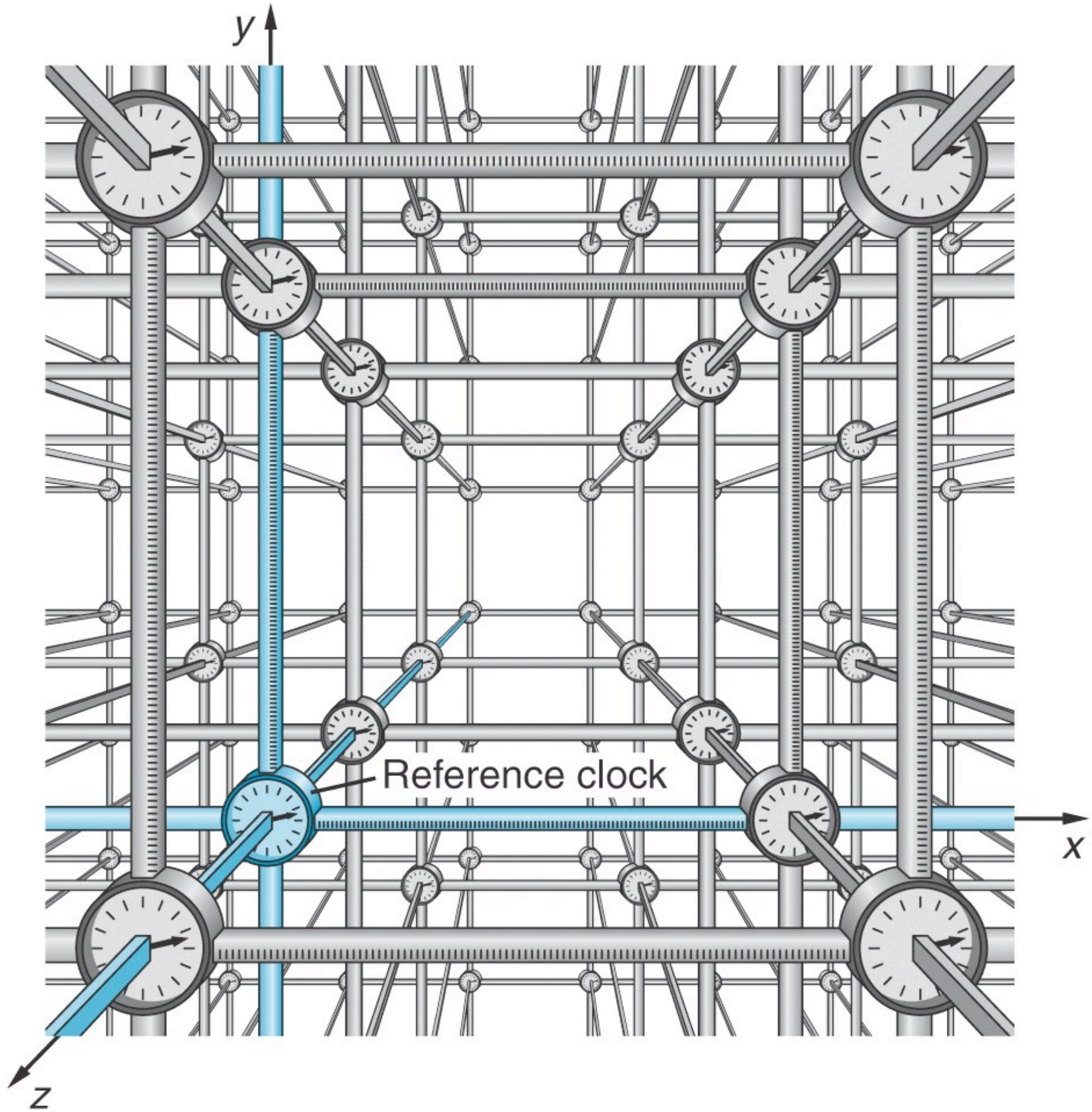
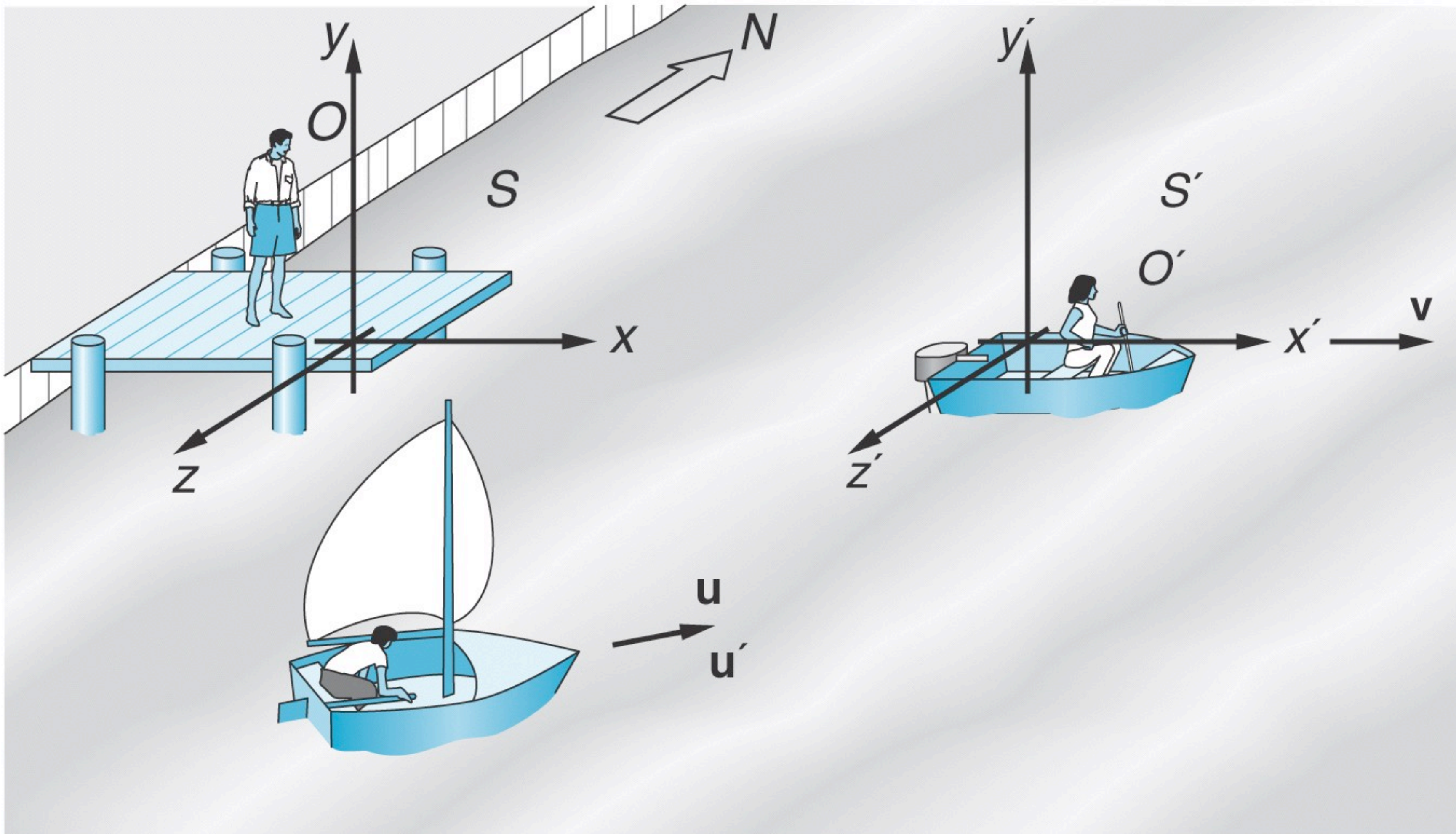


Figure 39.2 An event occurs at a point *P*. The event is seen by two observers in inertial frames S and S′, where S′ moves with a velocity **v** relative to S.

The Universe as a Clockwork of Reference Frames



“Imagining” Ref Frames And Observers



Newtonian/Galilean Relativity

Inertial Frame of Reference is a system in which a free body is not accelerating

Laws of Mechanics must be the same in all Inertial Frames of References

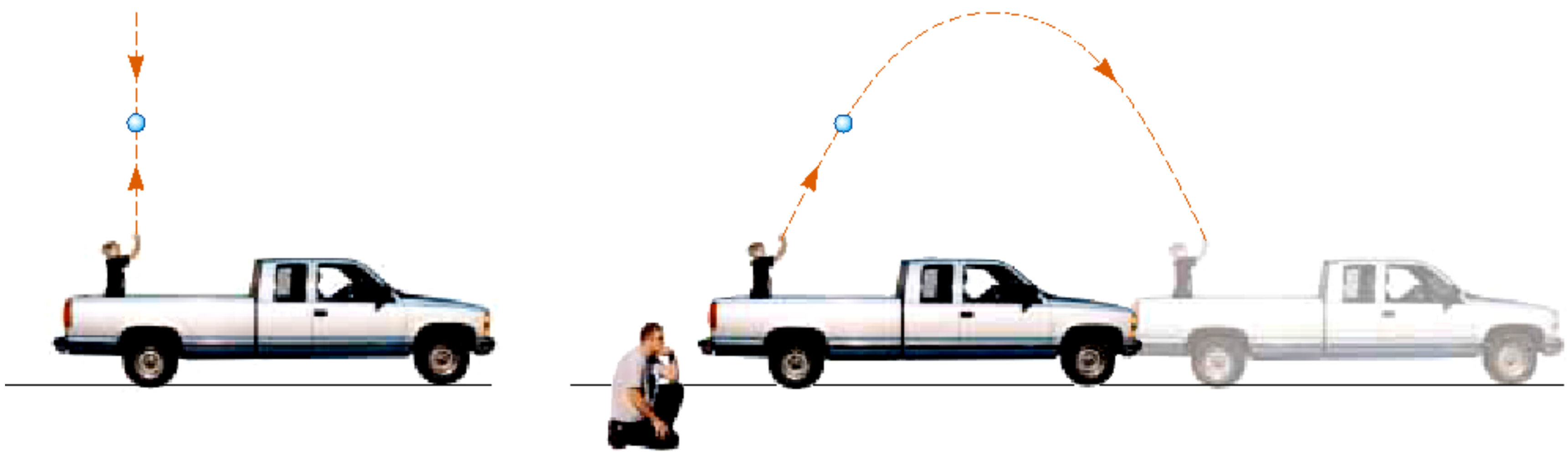
$\Rightarrow$Newton's laws are valid in all Inertial frames of references

$\Rightarrow$No Experiment involving laws of mechanics can differentiate between any two inertial frames of reference

$\Rightarrow$Only the relative motion of one frame of ref. w.r.t other can be detected

$\Rightarrow$ Notion of ABSOLUTE motion thru space is meaningless

$\Rightarrow$There is no such thing as a preferred frame of reference



(a) (b)

Figure 39.1 (a) The observer in the truck sees the ball move in a vertical path when thrown upward. (b) The Earth observer sees the path of the ball as a parabola.

Galilean Transformation of Coordinates

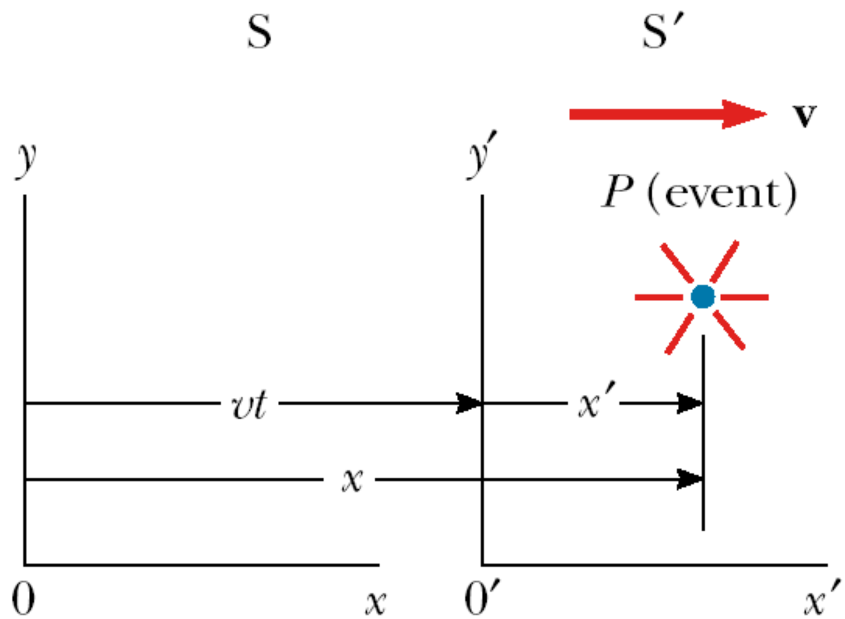


Figure 39.2 An event occurs at a point P. The event is seen by two observers in inertial frames S and S′, where S′ moves with a velocity $\mathbf{v}$ relative to S.

Galilean Rules of Transformation

$$x' = x - vt$$

$$y' = y$$

$$z' = z$$

$$t' = t$$

Quote from Issac Newton Regarding Time

Absolute, true and mathematical time, of itself, and from nature, flows equably without relation to anything external

$$t = t'$$

There is a universal clock

Or

All clocks are universal

Galilean Addition Law For Velocities

$$\boxed{dx' = dx - v\,dt}$$

$$\boxed{dt = dt'}$$

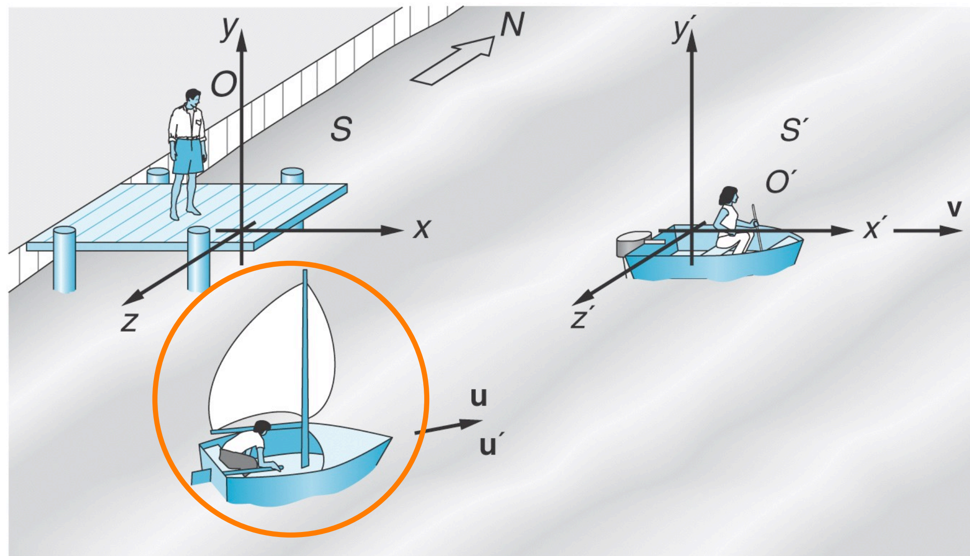
⇩

$$\frac{dx'}{dt'} = \frac{dx}{dt} - v$$

⇩

$$u'_x = u_x - v$$

This rule is used in our everyday observations (e.g. driving a car) and is consistent with our INTUITIVE notions of space and time



But what happens when I drive a car very fast !!

How fast: (v = ?)

- As fast as light can travel in a medium !!!

Light Is An Electromagnetic Wave (2C)

- Maxwell's Equations:

$$\oint_S \mathbf{E} \cdot d\mathbf{A} = \frac{Q}{\epsilon_0}$$

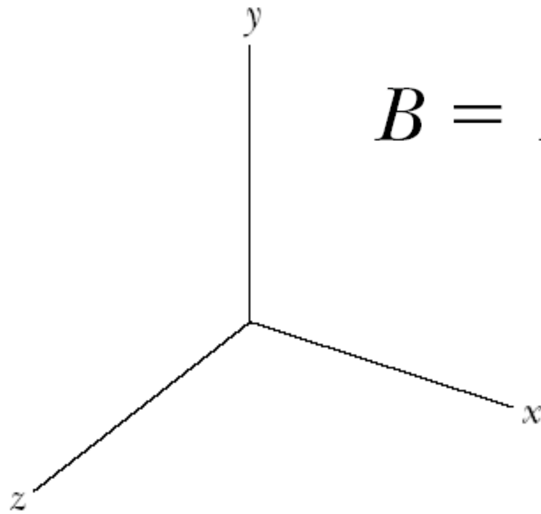
$$\oint_S \mathbf{B} \cdot d\mathbf{A} = 0$$

$$\oint \mathbf{E} \cdot d\mathbf{s} = -\frac{d\Phi_B}{dt}$$

$$\oint \mathbf{B} \cdot d\mathbf{s} = \mu_0 I + \mu_0 \epsilon_0 \frac{d\Phi_E}{dt}$$

$$\frac{\partial^2 E}{\partial x^2} = \mu_0 \epsilon_0 \frac{\partial^2 E}{\partial t^2}$$

$$\frac{\partial^2 B}{\partial x^2} = \mu_0 \epsilon_0 \frac{\partial^2 B}{\partial t^2}$$



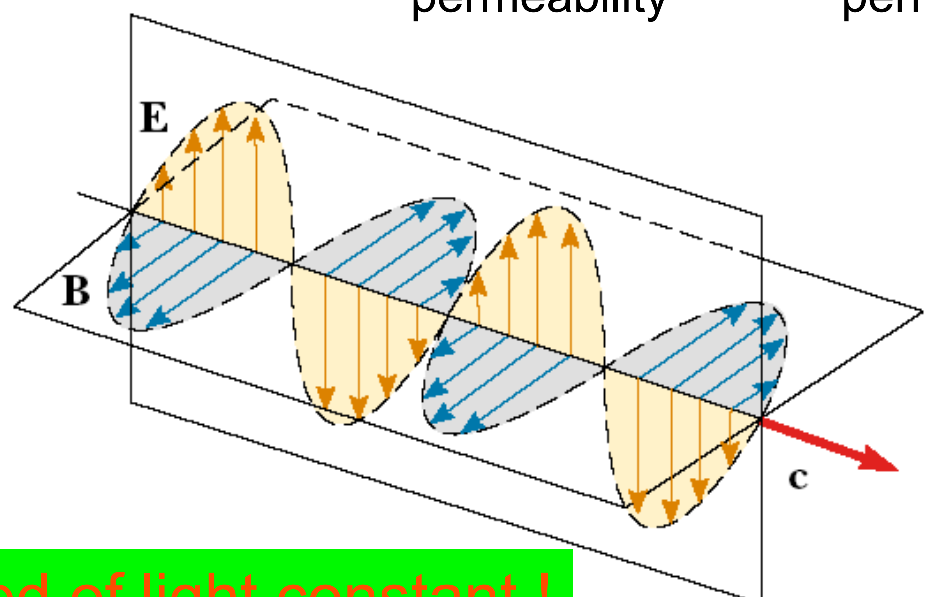
$$E = E_{\max} \cos(kx - \omega t)$$

$$B = B_{\max} \cos(kx - \omega t)$$

$$\boxed{c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}}$$

permeability

permittivity



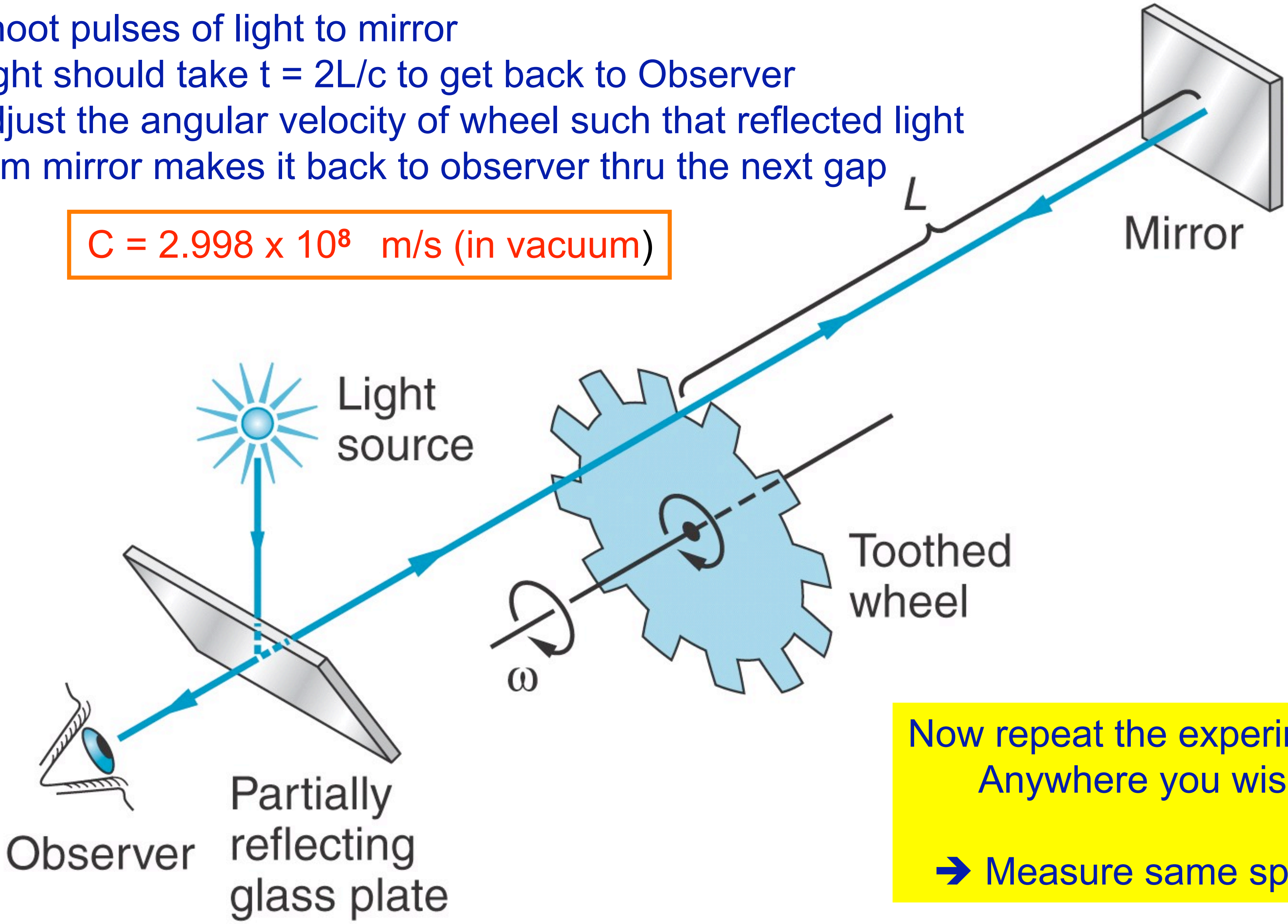
Speed of light constant !

Measuring The Speed Of Light

High Technology of 1880's: Fizeau's measurement of speed of light

1. Shoot pulses of light to mirror
2. Light should take t = 2L/c to get back to Observer
3. Adjust the angular velocity of wheel such that reflected light from mirror makes it back to observer thru the next gap

$C = 2.998 \times 10^8$ m/s (in vacuum)

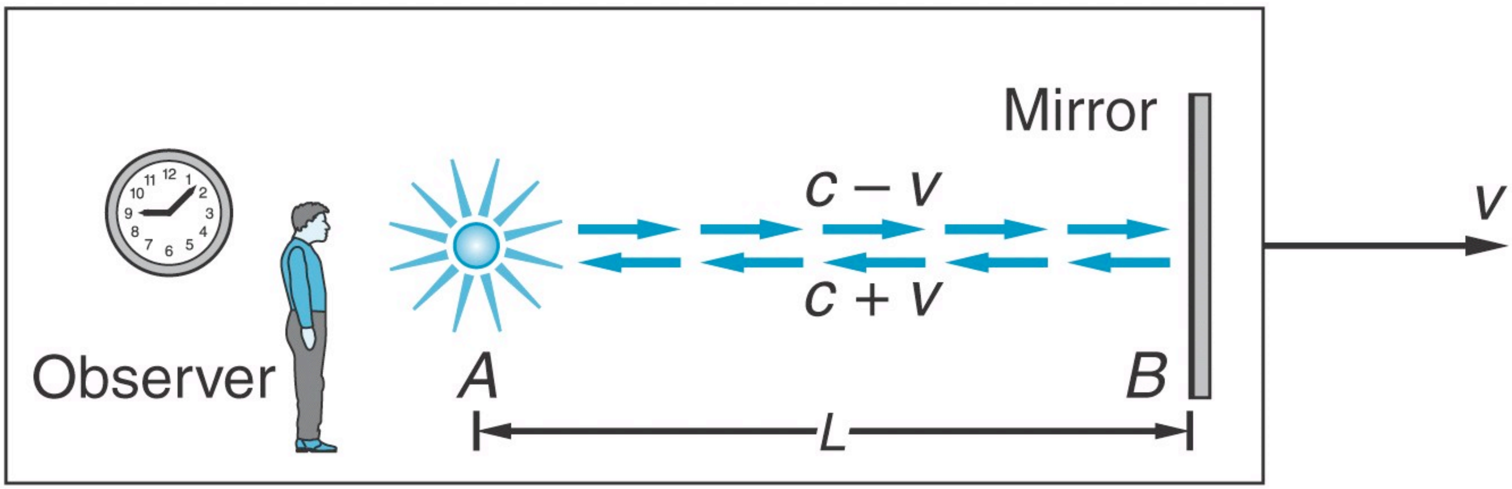


Now repeat the experiment Anywhere you wish

➔ Measure same speed

Newtonian Relativity & Light !

Light source, mirror & observer moving thru some medium with velocity V
Galilean Relativity ➔
• If the alien measures velocity of light = c
•Then observer must measure speed of light = c-v when it is leaving him
=c+v when it is reflected back



Alien dude

But Maxwell's Eq → speed of light is constant in a medium??

Must it be that laws of Mechanics behave differently from E&M in different inertial frames of references ? …if so how inelegant would nature be!