Waves/Interference/Diffraction refresher

• Brian Wecht’s streaming video and lecture notes available
  – http://tijuana.ucsd.edu/sharma/review

• Your will need Quicktime 6 player (MPEG 4) to view it
  – Should just work at UCSD computers (CLICS/GIESEL etc)
  – For Cable Modem/DSL Users => Sitting behind a firewall?
    • Need to get in DMZ zone to prevent UDP port blocking

• Email problems / feedback to 2dvideo@physics.ucsd.edu
Lecture 1: Relativity

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

• Newtonian Relativity and Inertial Frames
  – Laws of Physics and Frame 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
The Universe as a Clockwork of Reference Frames

In relativity we use a reference frame consisting of a coordinated grid and a set of synchronized clocks.
“Imagining” Ref Frames And Observers
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
⇒ Newton’s laws are valid in all Inertial frames of references
⇒ No Experiment involving laws of mechanics can differentiate between any two inertial frames of reference
⇒ Only the relative motion of one frame of ref. w.r.t other can be detected
⇒ Notion of ABSOLUTE motion thru scape is meaningless
⇒ There is no such thing as a preferred frame of reference

*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.
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 \(\leq\) 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 \(S\).
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 $S$.

**Rules of Transformation**

$$x' = x - vt$$

$$y' = y$$

$$z' = z$$

$$t' = t$$
Galilean Addition Law For Velocities

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

\[
dx' = dx - v \, dt \\
dt = dt' \\
\frac{dx'}{dt'} = \frac{dx}{dt} - v \\
u'_x = u_x - v
\]

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

How fast: \( v = ? \)

- As Fast as light can travel in a medium
But Newton’s Laws Remain Same!

\[
\frac{d^2 x'}{dt^2} = \frac{d^2 x'}{dt^2} - \frac{dv}{dt}
\]

\[\Rightarrow\]

\[a' = a\]

Description of Force does not change from one inertial frame of reference to another.
Light Is An Electromagnetic Wave

• Maxwell’s Equations:

\[
\begin{align*}
\oint_S \mathbf{E} \cdot d\mathbf{A} &= \frac{Q}{\varepsilon_0} \\
\oint_S \mathbf{B} \cdot d\mathbf{A} &= 0 \\
\oint_{\partial S} \mathbf{E} \cdot ds &= -\frac{d\Phi_B}{dt} \\
\oint_{\partial S} \mathbf{B} \cdot ds &= \mu_0 I + \mu_0 \varepsilon_0 \frac{d\Phi_E}{dt}
\end{align*}
\]

\[
\frac{\partial^2 E}{\partial x^2} = \mu_0 \varepsilon_0 \frac{\partial^2 E}{\partial t^2}
\]

\[
\frac{\partial^2 B}{\partial x^2} = \mu_0 \varepsilon_0 \frac{\partial^2 B}{\partial t^2}
\]

\[
E = E_{\text{max}} \cos( kx - \omega t) \\
B = B_{\text{max}} \cos( kx - \omega t)
\]

\[
c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}
\]

permeability  permittivity
Measuring The Speed Of Light

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

1. Shoot pulses of light to mirror
2. Light should take $t = \frac{2L}{c}$ 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)
It would appear to Observer O in S frame that velocity of light
\[ V_S = c + v \]

This contradicts Maxwell’s theory of Light!

Are Newton’s Laws and Maxwell’s laws inconsistent??!!
Einstein’s Theory of Relativity

• **Einstein’s Postulates of SR**
  – The laws of physics must be the same in all inertial reference frames.
  – The speed of light in vacuum has the same value, in all inertial frames, regardless of the velocity of the observer or the velocity of the source emitting the light.

\[ c = 3.0 \times 10^8 \text{ m/s} \]
Simultaneity: When two events occur at same time, held absolute for Classical Phys

Events that are simultaneous for one Observer are not simultaneous for another Observer in relative motion

Simultaneity is not absolute !!

Time interval depends on the Reference frame it is measured in
Time Dilation and Proper Time

Watching a time interval with a simple clock

Observer O': \( \Delta t' = \frac{2d}{c} \)

Observer O: Apply Pythagoras Theorem

\[
\left( \frac{c\Delta t}{2} \right)^2 = (d)^2 + \left( \frac{v\Delta t}{2} \right)^2 , \text{ but } d = \left( \frac{c\Delta t'}{2} \right)
\]

\[
\therefore c^2 (\Delta t)^2 = c^2 (\Delta t')^2 + v^2 (\Delta t)^2
\]

\[
\therefore \Delta t = \frac{\Delta t'}{\sqrt{1 - \left( \frac{v}{c} \right)^2}} = \gamma \Delta t' , \Delta t > \Delta t'
\]
The \( \gamma \) factor

\[
\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}
\]

as \( v \to 0, \gamma \to 1 \)

as \( v \to c, \gamma \to \infty \)