Lecture 18
(Huygens's Principle and Wave Fronts)

Physics 262-01 Spring 2019

Douglas Fields

Reading Quiz

Huygen’s Principle can be used to:

A) Derive the law of reflection.
B) Derive the law of refraction.
C) Understand how a mirage works.
D) All of the above.

But, WHY?

- We’ve stated a lot of facts, without giving a good foundation for why they happen – I don’t like that.
- Let’s take one lecture to try to understand EM wave (really, all wave) propagation.
- We are going to talk about a way to visualize wave propagation that is controversial in its exact physical interpretation.
- It has been discussed and debated by the likes of Albert Einstein, and Richard Feynman…
- For us, however, we will take it as just a nice principle, and use it to better our understanding.

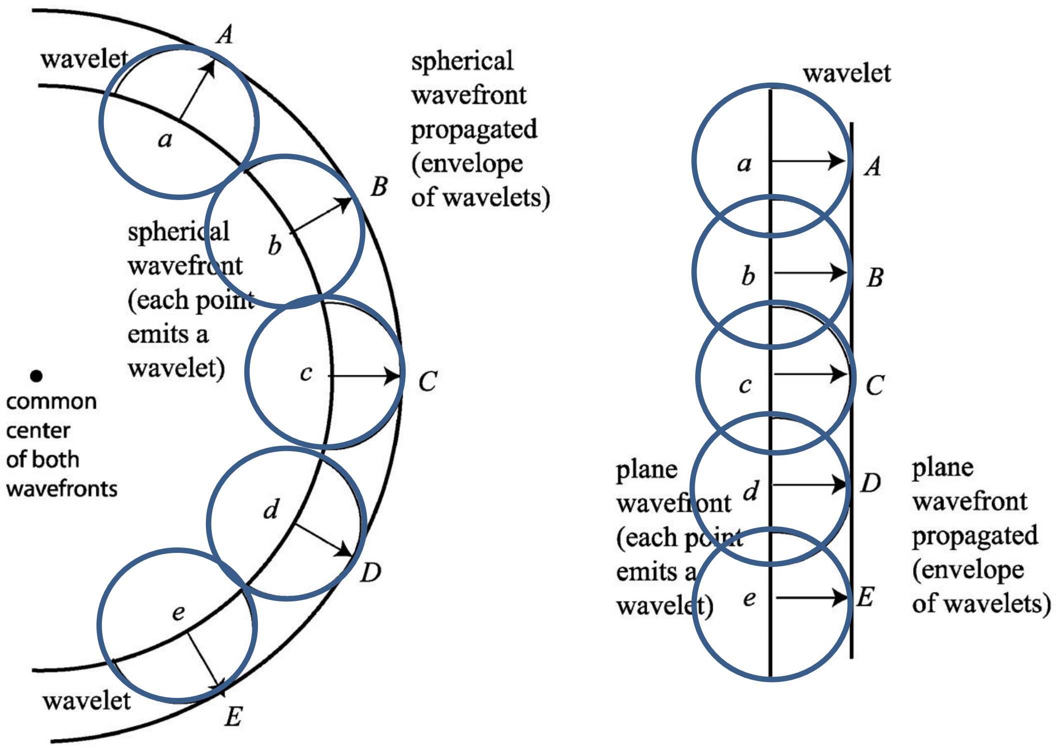
Huygens's Principle

In 1678 the great Dutch physicist Christian Huygens (1629-1695) wrote a treatise called *Traite de la Lumiere* on the wave theory of light, and in this work he stated that the wave front of a propagating wave of light at any instant conforms to the envelope of spherical wavelets emanating from every point on the wave front at the prior instant (with the understanding that the wavelets have the same speed as the overall wave). - http://www.mathpages.com/home/kmath242/kmath242.htm

- Basically, each point on a wave front can be thought of as a new source of wavelets, and the development of the new wave front at a later time is determined by the propagation of these wavelets.

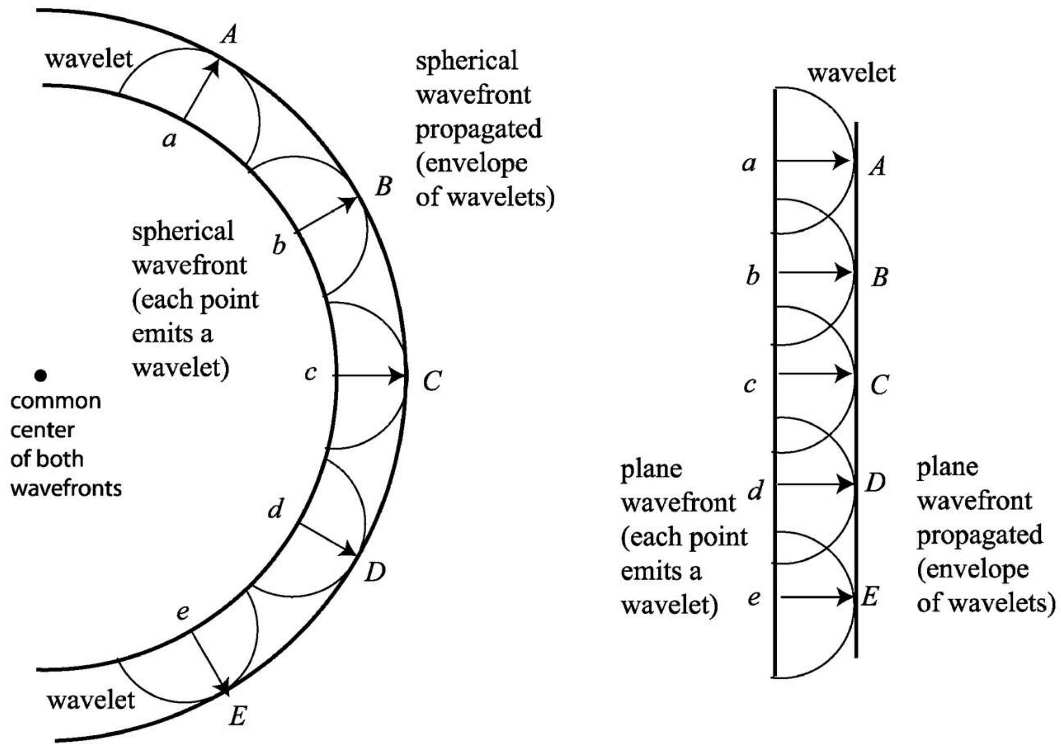
Wave Propagation

- Each point (on a wave front) acts as a new source of (spherically, in 3D) propagating wavelets:



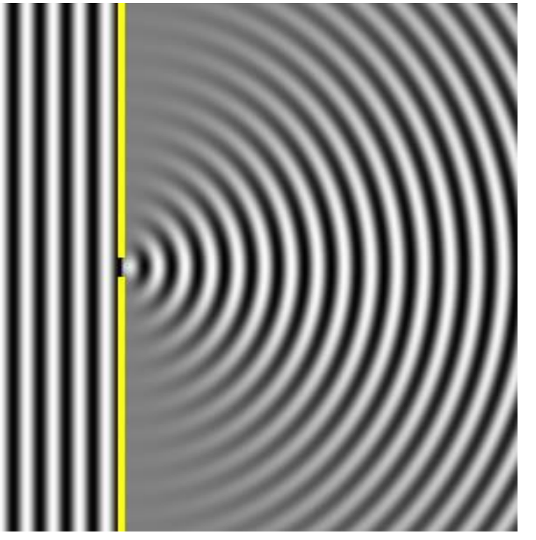
Wave Propagation

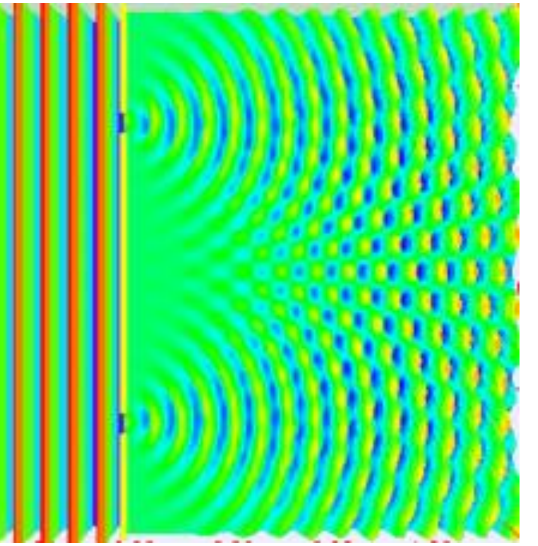
- But, we will ignore the backward propagating parts of the wavelets (the reasons are very complicated), and only consider the forward-going (with respect to the previous wave front motion) part of the wave.



Example

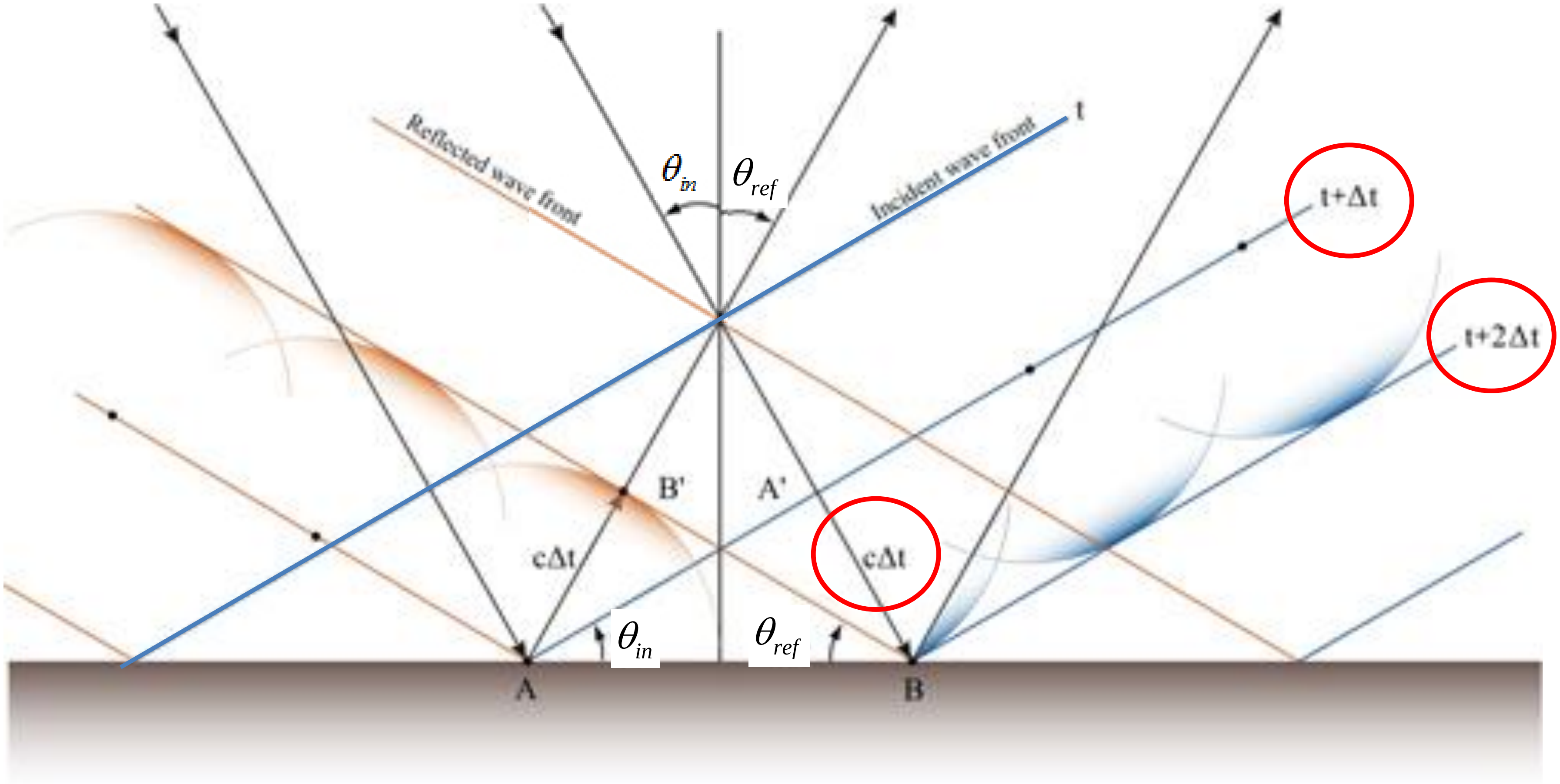
- But is this just BS?
- A plane wave hitting a "point" hole in a blocking plate creates a point source like propagating wave.
- For two holes, you get two point sources.
- What would you get if you kept increasing the number of holes to eventually remove the barrier?



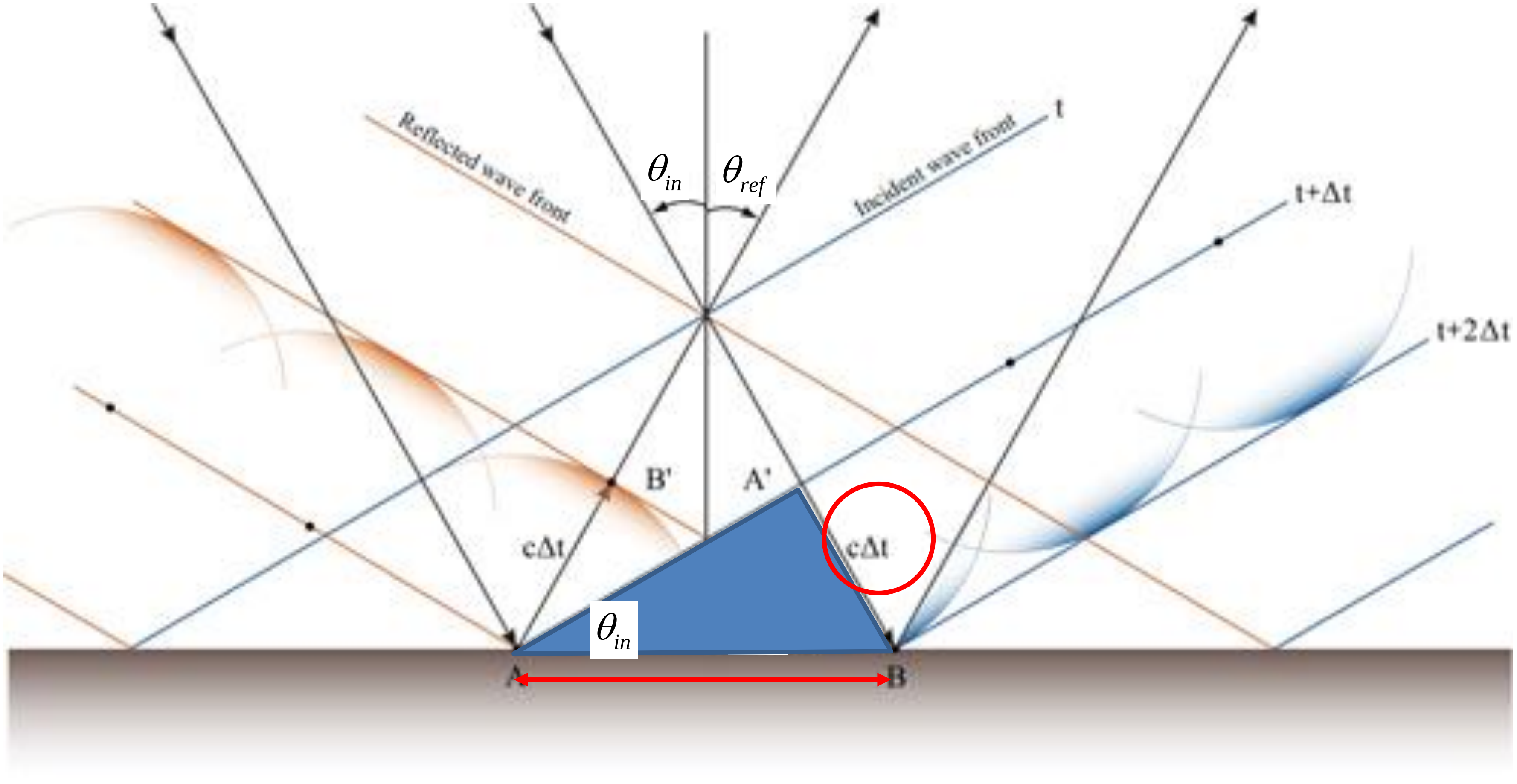


Reflection

- Consider a plane wave striking a reflecting surface…



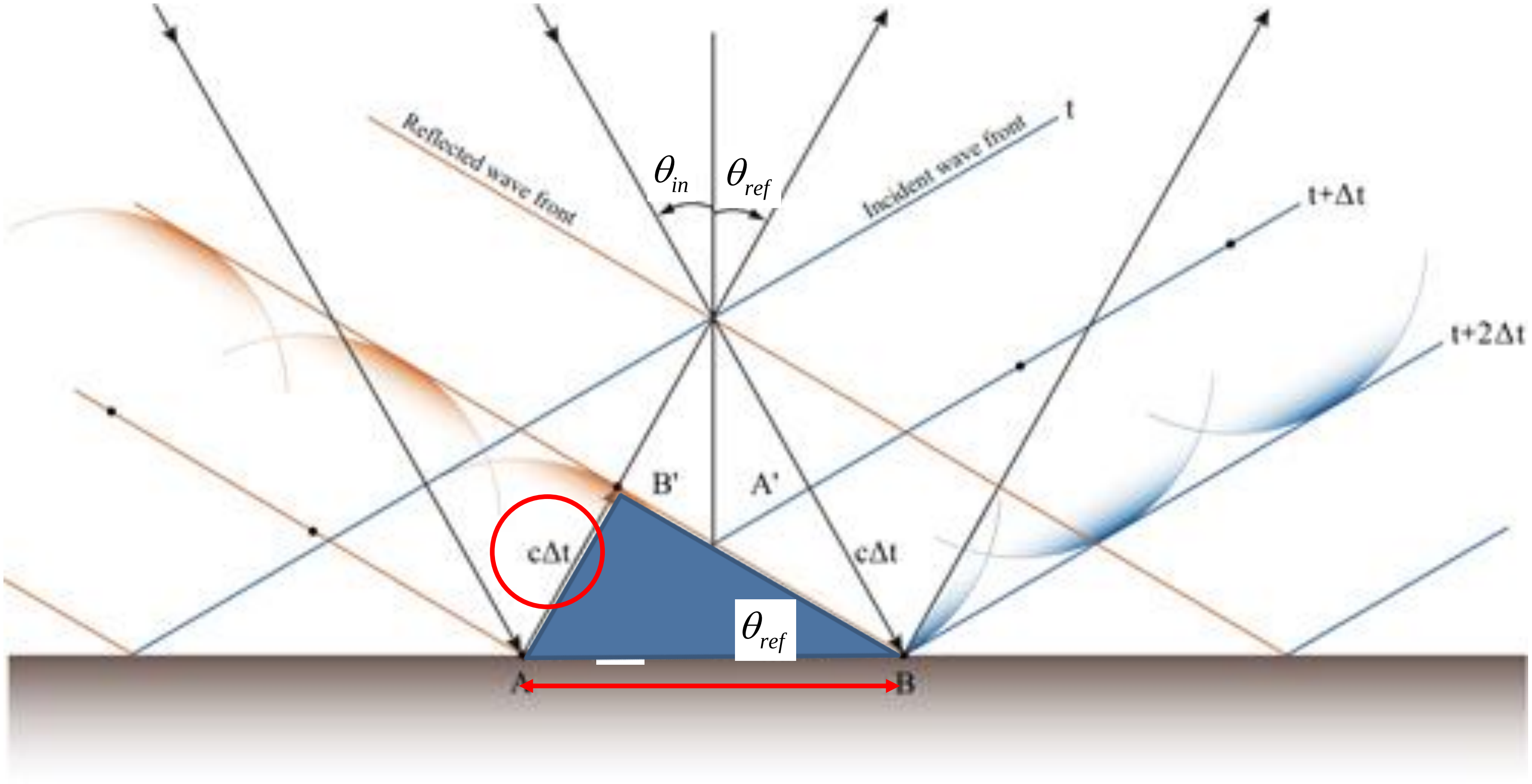
Reflection



Reflected wave front
Incident wave front
t
t+Δt
t+2Δt
θ_{in}
θ_{ref}
B'
A'
cΔt
cΔt
θ_{in}
A
B

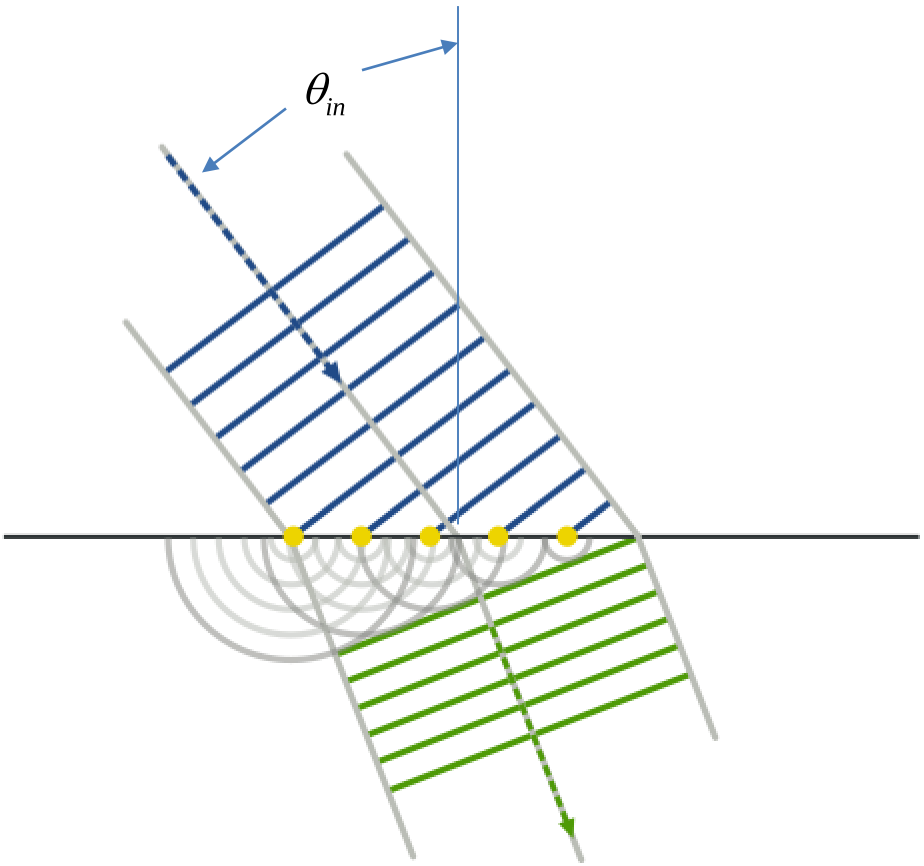
Reflection

- So, $\theta_{in} = \theta_{ref}$

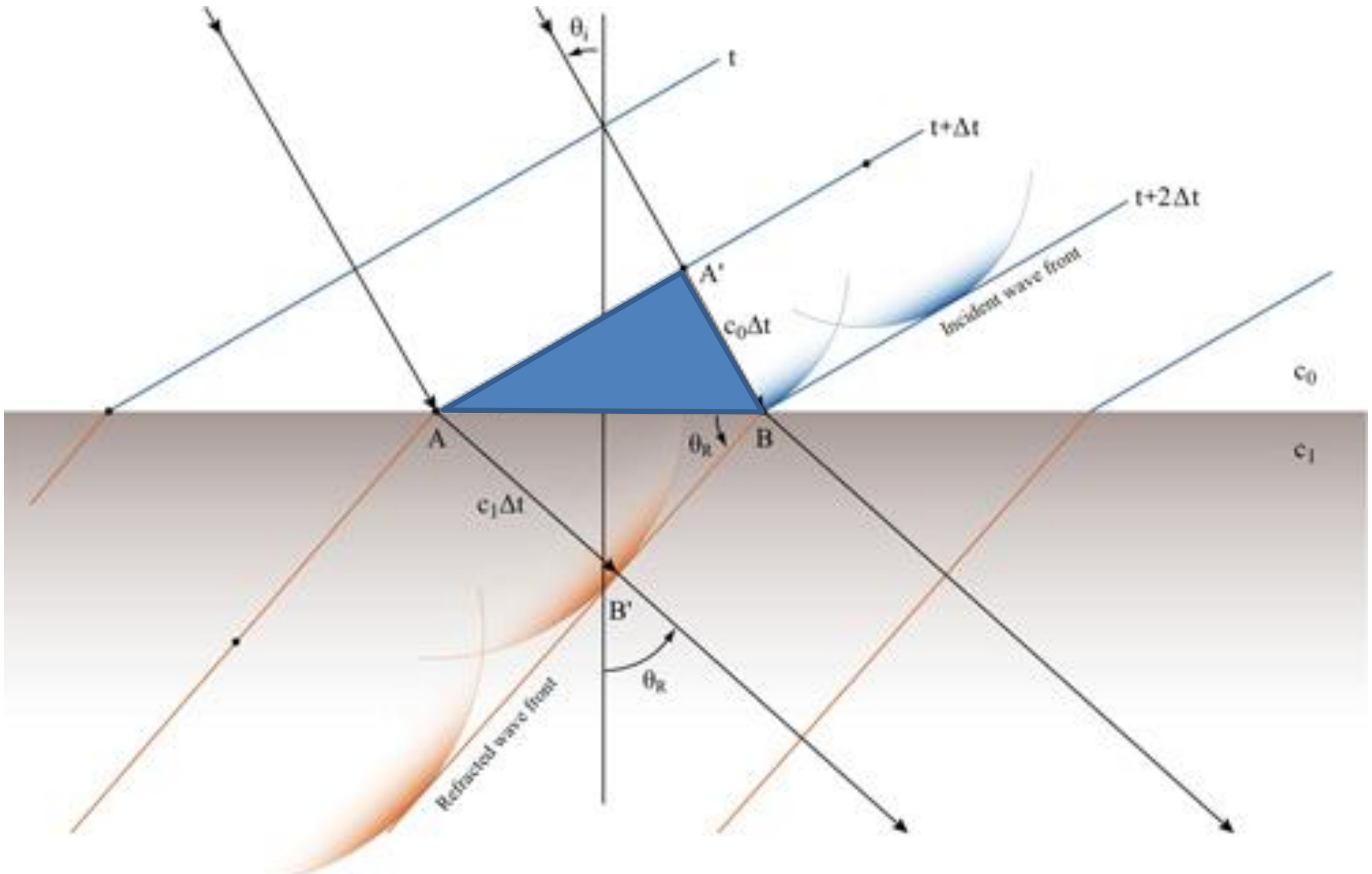


Refraction

- We can do a similar exercise for refraction.
- Again, we have incoming plane wave fronts coming in at an incident angle.
- Since each point on the wave front is a new source of waves…



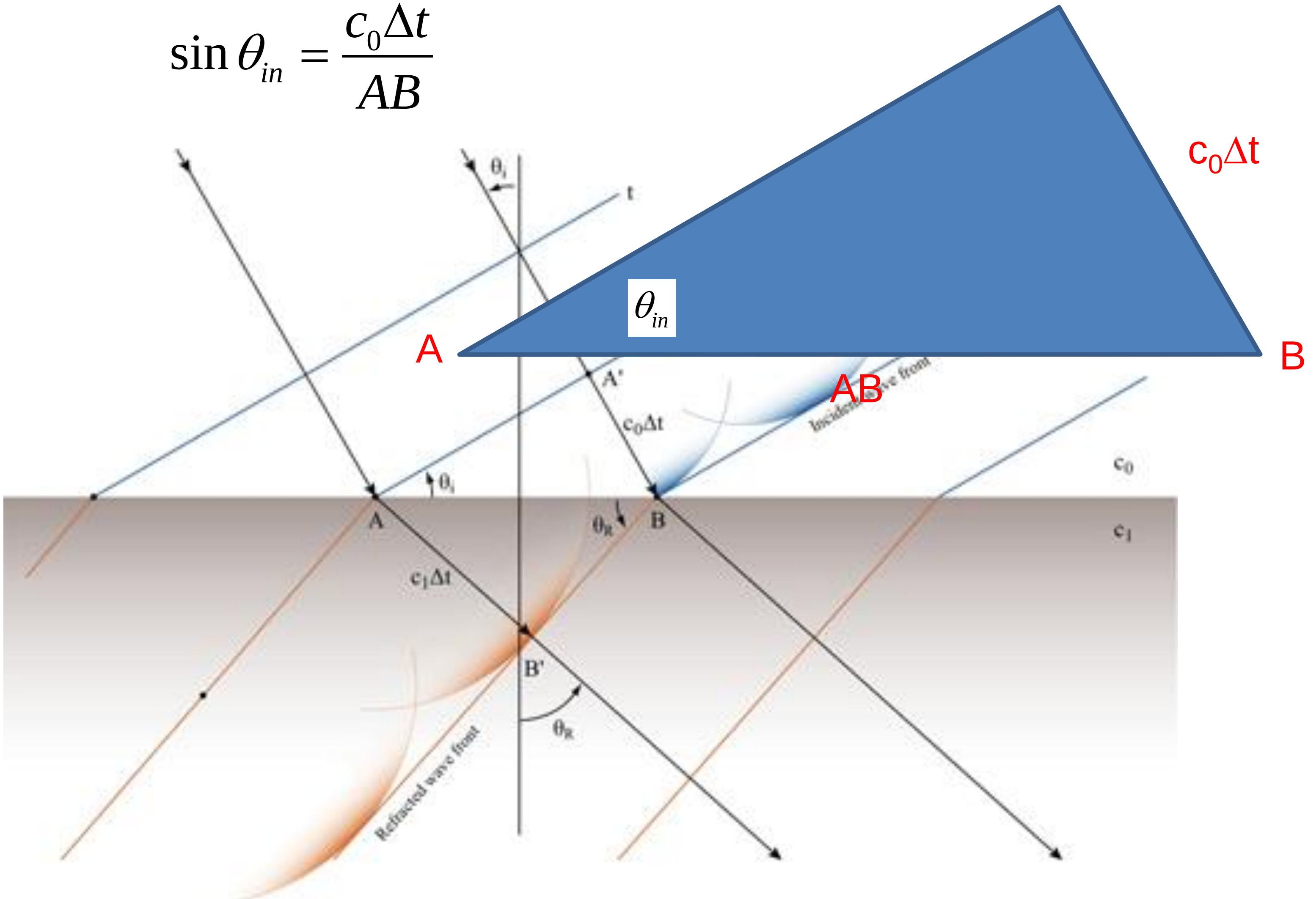
Refraction



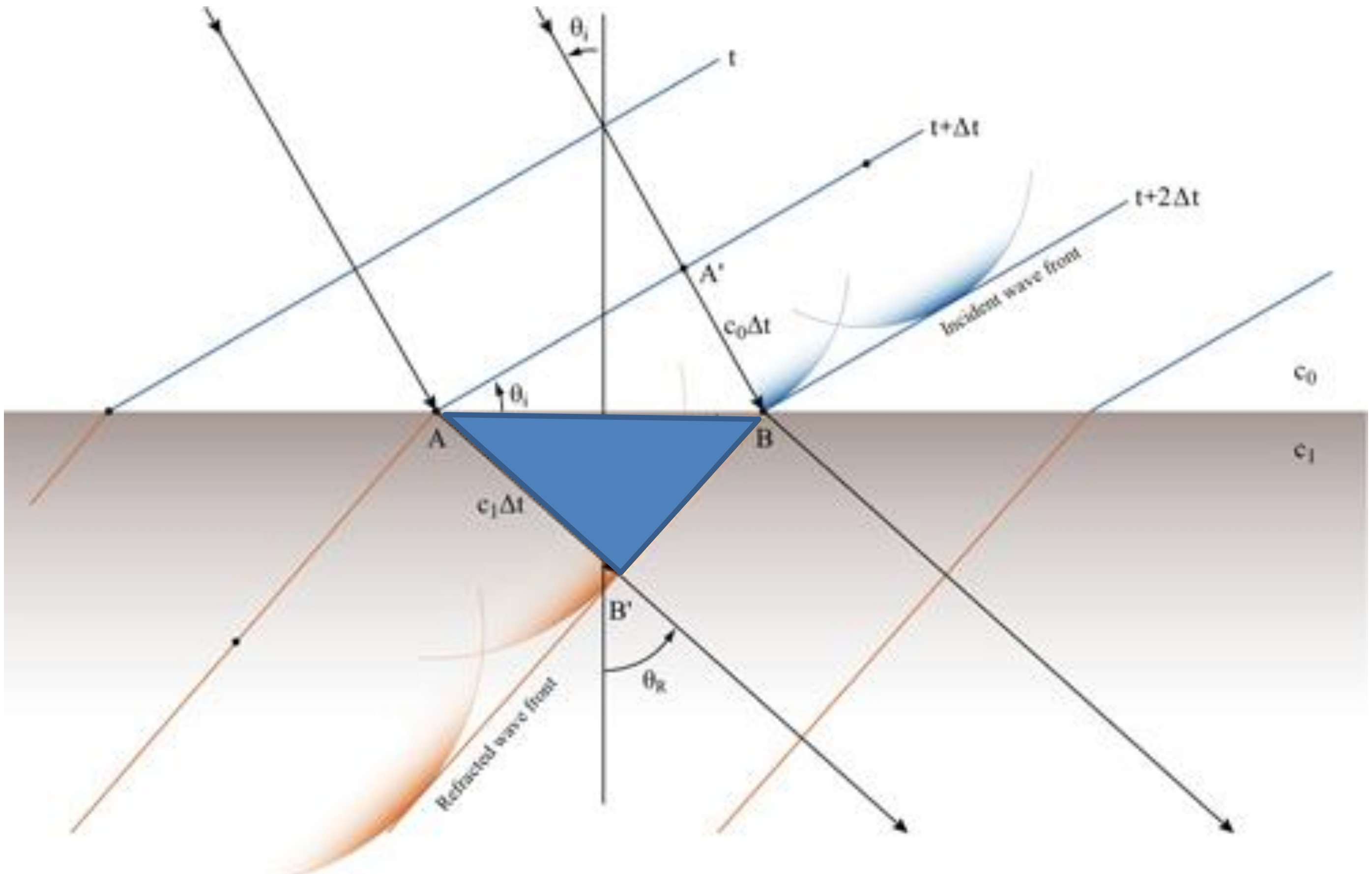
θi
t
t+Δt
t+2Δt
A'
c0Δt
Incident wave front
c0
c1
A
B
θR
c1Δt
B'
θR
Refracted wave front

Refraction

$$\sin\theta_{in} = \frac{c_0 \Delta t}{AB}$$



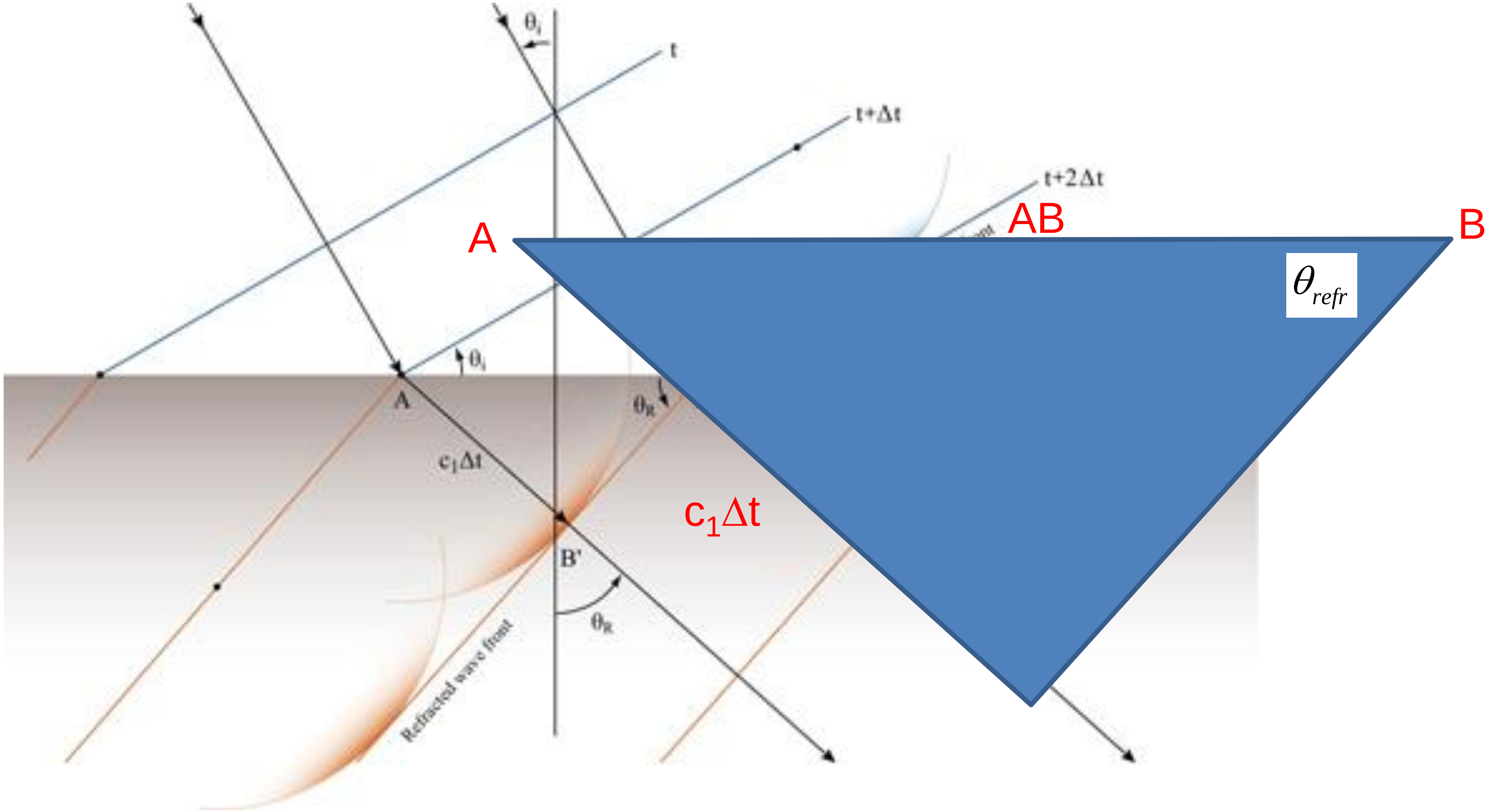
Refraction



θi
t
t+Δt
t+2Δt
A'
c0Δt
Incident wave front
c0
θi
A
B
c1
c1Δt
B'
θR
Refracted wave front

Refraction

$$\sin\theta_{in} = \frac{c_0 \Delta t}{AB} \qquad \sin\theta_{refr} = \frac{c_1 \Delta t}{AB}$$



Refraction

$$\sin\theta_{in} = \frac{c_0 \Delta t}{AB} \qquad \sin\theta_{refr} = \frac{c_1 \Delta t}{AB}$$

$$AB = \boxed{\frac{c_1 \Delta t}{\sin\theta_{refr}} = \frac{c_0 \Delta t}{\sin\theta_{in}}} \Rightarrow$$

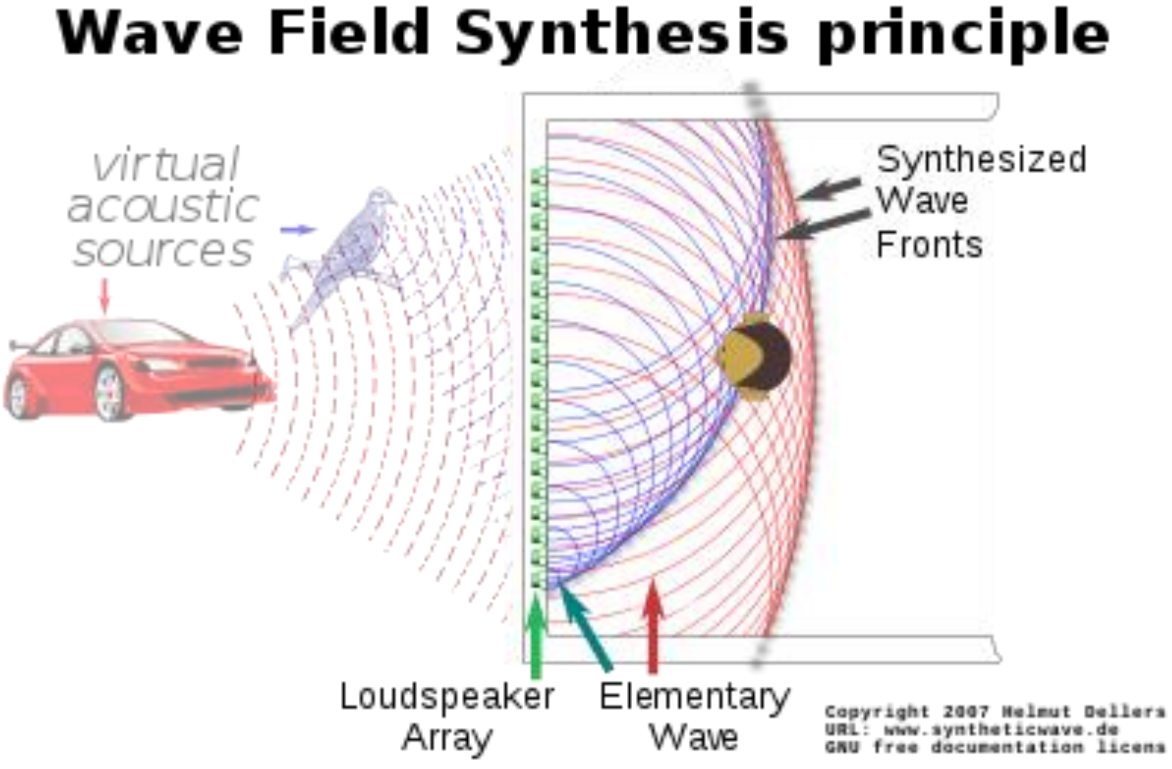
$$c_0 = \frac{c}{n_0}, \quad c_1 = \frac{c}{n_1}$$

$$\therefore \boxed{\frac{c \Delta t}{n_1 \sin\theta_{refr}} = \frac{c \Delta t}{n_0 \sin\theta_{in}}} \Rightarrow$$

$$n_0 \sin\theta_{in} = n_1 \sin\theta_{refr}$$

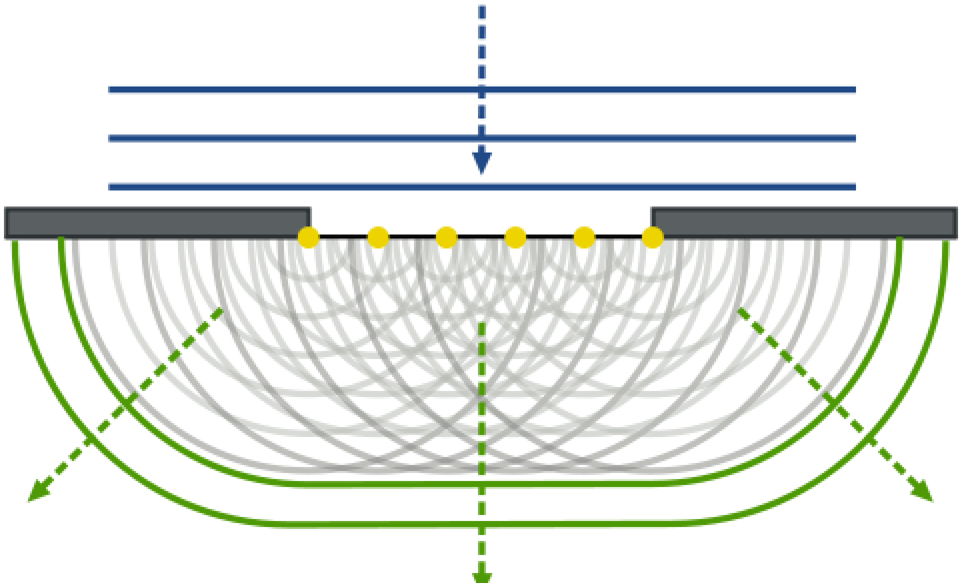
Cool Applications

- Wave Field synthesis by speaker arrays…



Diffraction

- Next week we will study the phenomena known as diffraction.
- It will be useful to keep in mind Huygens' Principle, as it will make some of the strange things we see a little less strange.



Examples