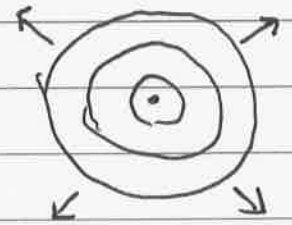
Lecture 13.2 | I. Doppler Effect
II Double Slit Interference
III. Multiple Slit Interference

I. Doppler Effect if source moves relative to medium, the wave pattern is modified

→ Stationary point source:
emits circular/spherical waves
centered on the source



→ If point source moves then the wave pattern is modified

2 types of phenomena, depending on relative velocity of source, and wave velocity

1) $V_{wave} > V_{source}$
   - → wave fronts do not cross
   - → no interference
   - → wave fronts bunched along velocity vector, spread out behind it

2) $V_{wave} < V_{source}$
   - → wave fronts do cross
   - → significant interference
   - → constructive interference of multiple wave fronts = Shock wave phenomenon

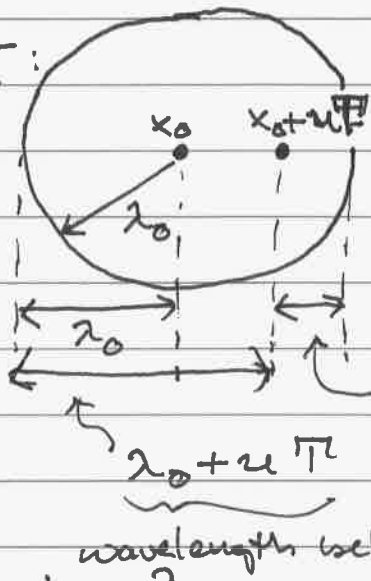
Source speed: u

wave speed: v

If a wave front is initiated at $t=0$, after time t, radius of front is vt; source has moved ut

→ take time $t = T$, periodicity of source, and wavelength of stationary source to be λ_0

$u < v$:



new wavefront about to be created

now $T = \frac{1}{\nu} = \frac{\lambda_0}{v}$

$$\lambda_{min} = \lambda_0 - uT = \lambda_0 - u\left(\frac{\lambda_0}{v}\right) = \lambda_0\left(1 - \frac{u}{v}\right)$$

$$\lambda_{max} = \lambda_0 + uT = \lambda_0\left(1 + \frac{u}{v}\right)$$

→ Perform demonstration again

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*Cosmology and the doppler effect for light

Quantum mechanics: electron orbits in atoms determined by solution to a wave equation

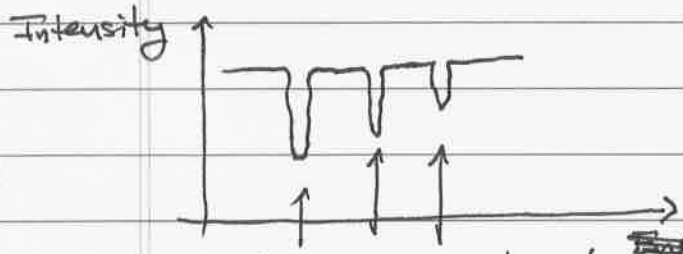
→ Electrons sit in normal modes, each with particular frequency / energy

→ Photons carry energy $E = hf = \frac{hc}{\lambda}$ (Planck Constant)

More up in energy by absorbing photon (light), but only with ~~frequency~~ energy equal to spacing in energy between normal modes

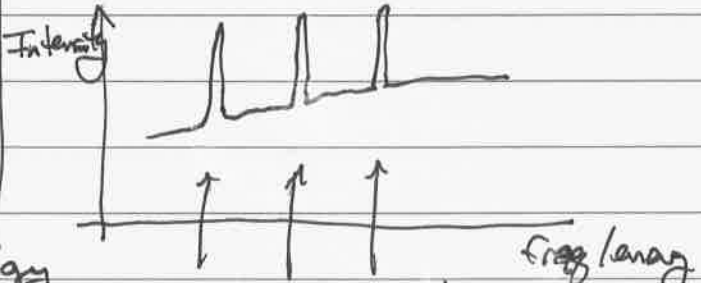
More down in energy by emitting photon with energy equal to spacing between modes

Light shining through gas:



holes in spectrum! at very specific ~~energies~~ energies

Hot gas:

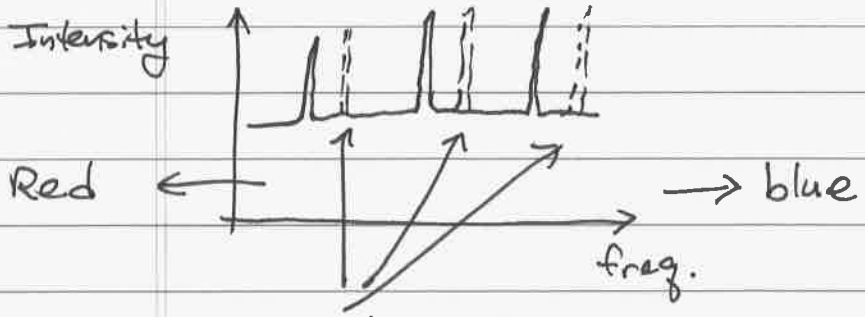


peaks in spectrum

* locations of dips / peaks universal

same for all hydrogen ~~atoms~~, etc

When we look at distant galaxies:



location of peaks of hot gas at rest

→ Peaks are red-shifted f is smaller ⇒ λ is longer

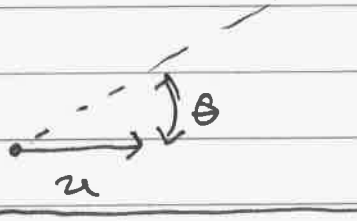
⇒ galaxies are receding!

* Speed of galaxies, thus inferred, is proportional to distance

UNIVERSE IS EXPANDING

General doppler formula:

$$\lambda(\theta) = \lambda_0 \left(1 - \frac{u\cos\theta}{v}\right) \quad \left(\text{or } f(\theta) = \frac{f_0}{1 - \frac{u\cos\theta}{v}}\right)$$



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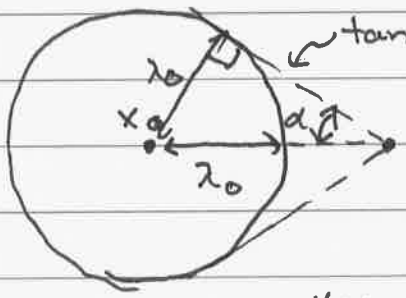
* Now take $u > v$ (source faster than wave)

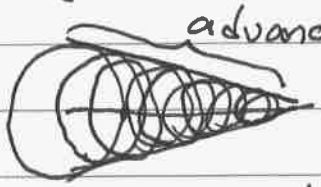


$$\sin\alpha = \frac{\lambda_0}{uT} = \frac{\lambda_0}{u\left(\frac{\lambda_0}{v}\right)} = \frac{v}{u}$$

"Mach Number": $\frac{u}{v} > 1$ for supersonic speeds

α is the "Mach Angle"

* Along these lines, wave fronts pile up:



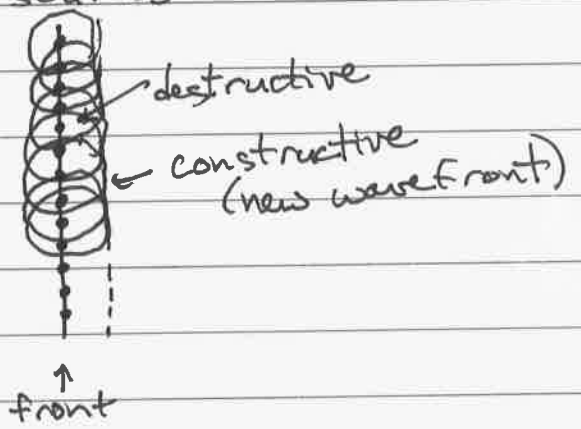
* Show Chelyabinsk Meteor Video, Images of trans-sonic vapor cones

Double Slit interference

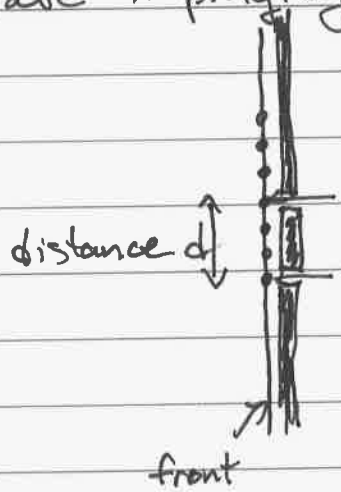
→ what happens when a wave is obstructed by barriers?

Huygen's principle → each point on a wavefront acts like point source ...
evolution of wave is superposition of all those point sources

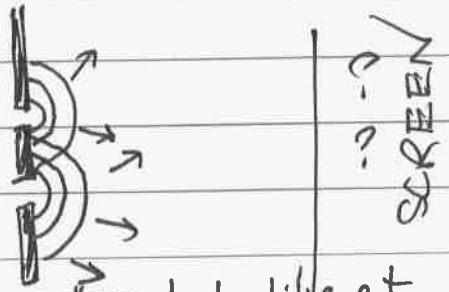
Plane wave:



→ Plane wave impinging on boundary with 2 holes:

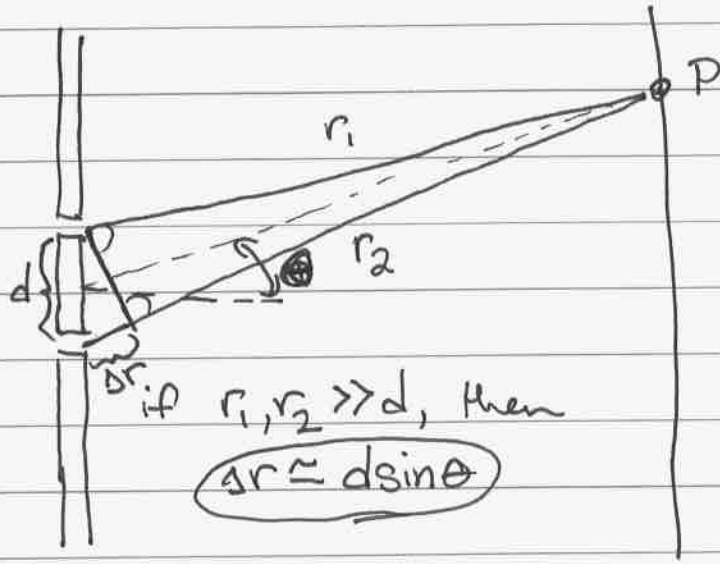


Resulting wave:



what does pattern look like at screen?

(6)



Pattern at P is superposition of 2 traveling waves

$$y_p(t) = A_1 \cos\omega\left(t - \frac{r_1}{v}\right) + A_2 \cos\omega\left(t - \frac{r_2}{v}\right)$$

(assume phase at each slit is the same)
→ is the case for <u>plane wave</u> hitting barrier

taking $A_1 = A_2 = A_0$:

Beat formula! $y_p(t) = 2A_0 \cos\omega\left(t - \frac{\bar{r}}{v}\right)\cos\left(\frac{\omega}{2v}(r_2 - r_1)\right)$

$$\Rightarrow \quad y_p(t) \simeq 2A_0 \cos\omega\left(t - \frac{\bar{r}}{v}\right)\cos\left[\frac{\pi}{\lambda}(r_2 - r_1)\right]$$

$r_2 - r_1 \simeq d\sin\theta$

$$\Rightarrow \quad y_p(t) = 2A_0 \cos\omega\left(t - \frac{\bar{r}}{v}\right)\cos\left[\frac{\pi d\sin\theta}{\lambda}\right]$$

Amplitude of interference pattern as function of λ:

$$A(\theta) = 2A_0 \cos\left(\frac{\pi d\sin\theta}{\lambda}\right)$$

Quantum Mechanics Pattern ⇔ probability of particle hitting there!

Wave / Particle Duality !!