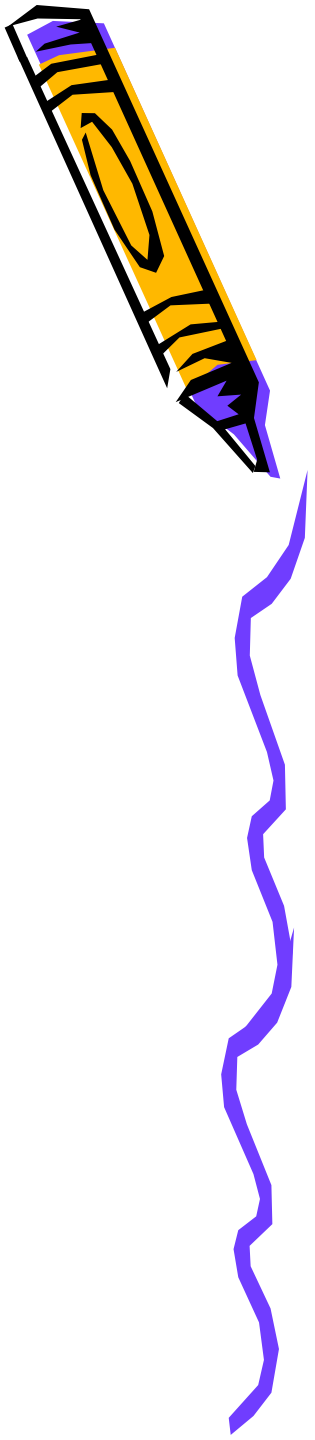
PHYSICS 102N
Spring 2022

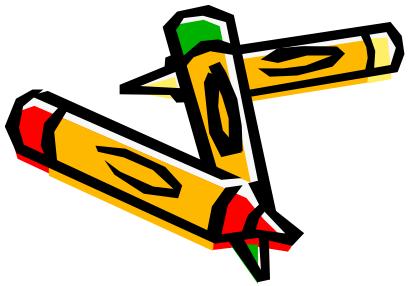
Week 10

Interference and Diffraction

Recap:
The strange life of waves

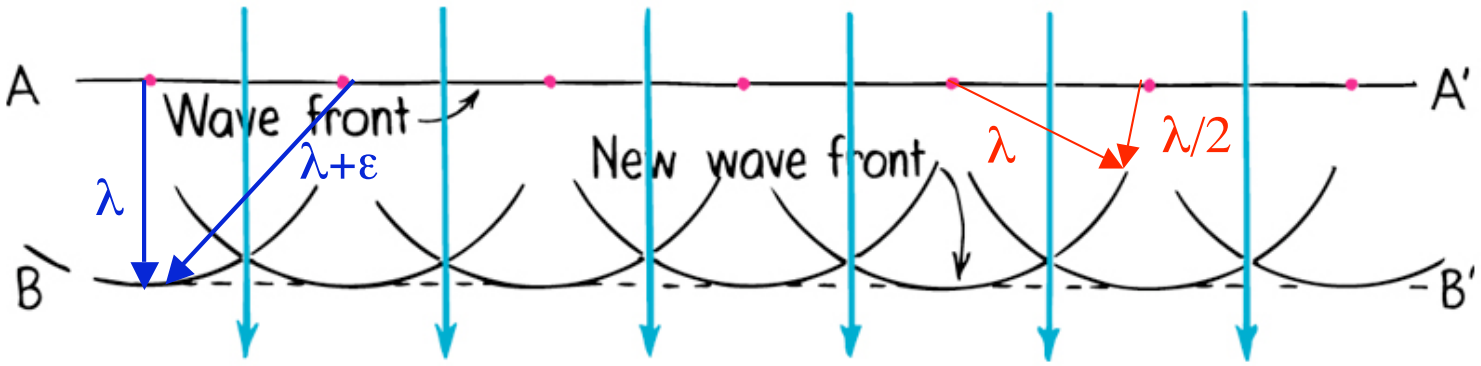


- Huygen's and Fermat's Principle
- Reflection and Refraction
- Interference
- Standing Waves
- Diffraction
- Polarization
- Doppler Effect

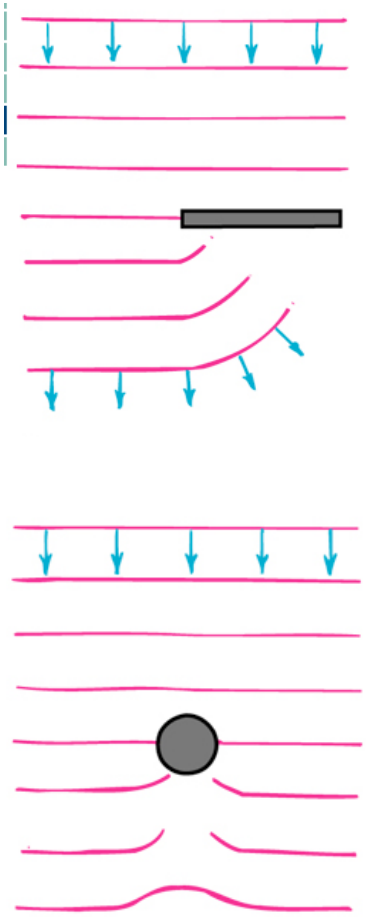


Huygen's Principle

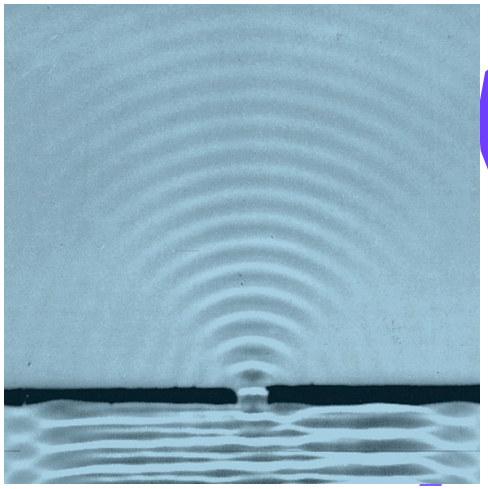
- Each point reached by a wave oscillates with the frequency of the wave and becomes the origin of a new, spherical wave
- All those spherical "wavelets" emitted by every point along the wave combine to build up the complete wave
- Both constructive and destructive interference play a crucial role

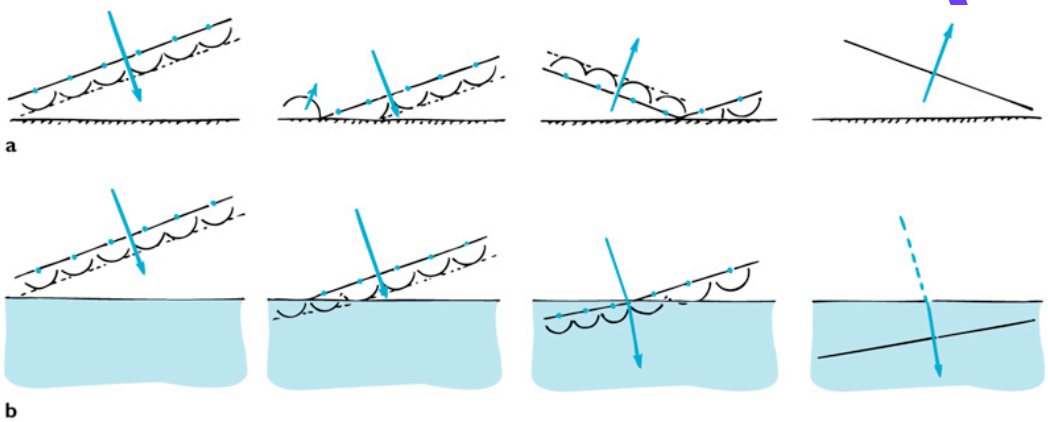


Huygen's Principle - Consequences



- A light "beam" can never have totally sharp edges - instead, it will "go around corners"
- After going through a narrow opening, light will "fan out" (diffraction)
- Lower limit on resolving power (microscope, telescope)
- Can explain both refraction and reflection



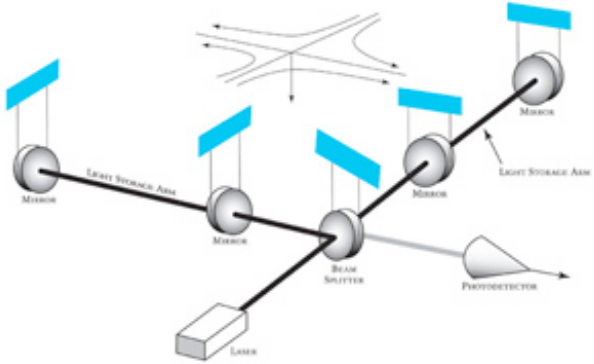


Interference - Thin Films

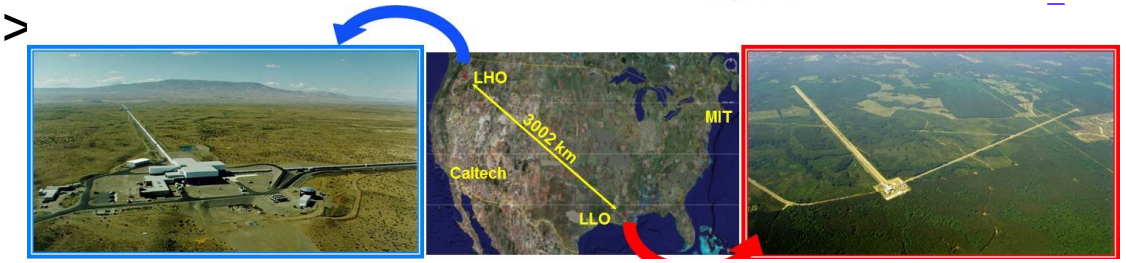
- Analog to short string or air column: Reflected waves interfere
  - two surfaces => two reflected waves => extinction or enhancement
    - air-medium-air: first interface => phase flip, 2nd interface => no phase flip =>
      - ultrathin film: destructive interference (no reflected light)
      - $\lambda/4$ film: constructive interference (color-dependent!)
    - medium-air-medium: Similar
      - Newton rings, foil on foil interference pattern
    - air-medium1-medium2:
      - Same if medium1 is “slower” (Oil film on Water: n=1,1.47,1.33)
      - constructive/destructive reversed if $n_2 > n_1$ (e.g. water film on glass)
    - Example: Coating on Lenses to increase transmission

Interference - Standing Waves

- Similar to waves on string: Have “fixed point” on both ends of finite length (mirrors)
  => Interferometers (e.g. Fabry-Perot)
- Harder to realize because wave lengths are so much smaller than usual physical dimensions
- Incredibly “sharp” resonance: 1 mm = 2000 x 500 nm wave lengths (constructive resonance) or $2000\,^1/_4$ x 499.94 nm λ’s (destructive)
- Essential part of each laser -> gives extremely “monochromatic” light



Example: Michelson Interferometer - can detect tiny changes in “optical length” of arms -> gravity wave detector (LIGO)

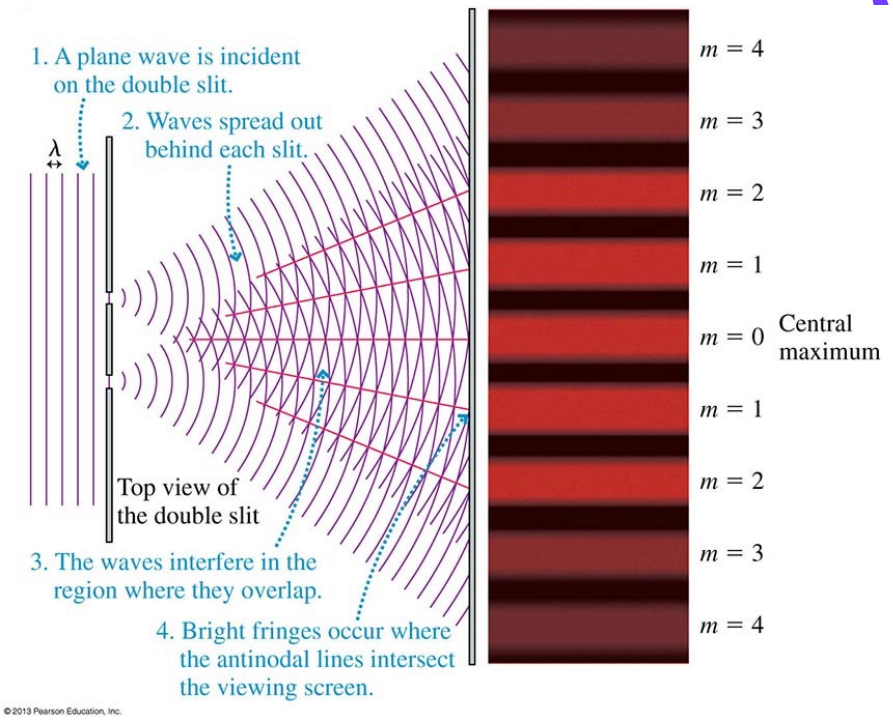


Interference - Double Slit

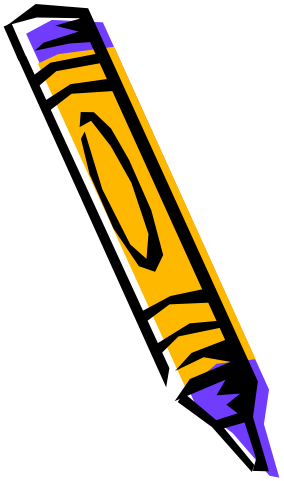
- Direct “plane” wave front to double slit
- Huygen’s principle: Each slit acts as an independent source for wave of same frequency (in sync - “coherent”) spreading out in all directions
- At some distance, “catch” waves with screen - the two waves interfere -> pattern of constructive and destructive interference (bright and dark stripes)
- Separation *s* between (and width of) interference stripes on screen is proportional to

$$s \propto (\lambda/d) \times D$$

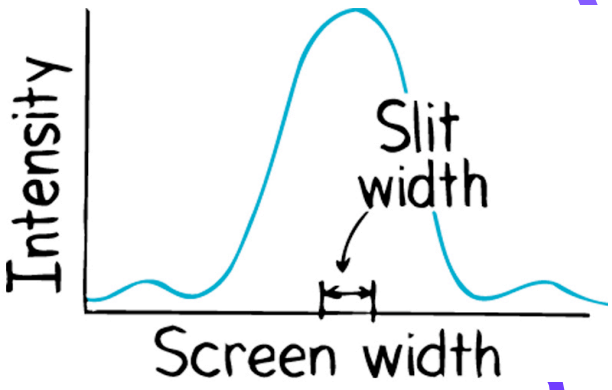
(*d* = distance between slits, *D* = distance to screen)



Interference + Diffraction - Single Slit



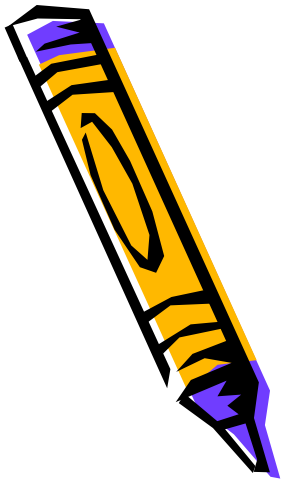
- Can get interference pattern even with a single slit: different parts of the slit can interfere with each other
- Think of 2 slits moved so close together that there is no separation between them
- Pattern yields bright maximum with dimmer “fringes
- Limits resolution of telescopes, microscopes etc.



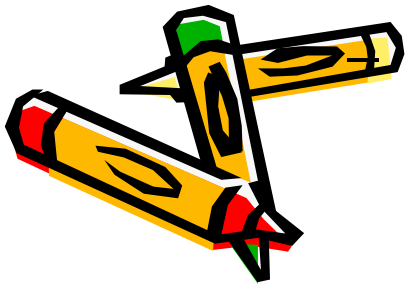
Diffraction Gratings and Holography

- 1000s of slits in regular pattern: Diffraction grating
  - Very sharp maxima separated by wide “dark bands”
    - Think of 2 slits, moving them apart by factors 2,4,8…
    - Excellent spectrometers - can measure wave length of light (“funny glasses”, element composition of substances and even stars)
- Holography: Complex 2-D patterns to generate complex images
  - reflection or transmission
    - Examples: credit cards, 3-D images, materials probing

Polarization



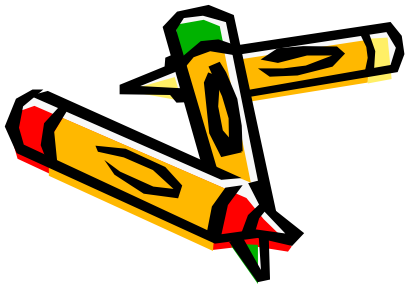
- Electric field always perpendicular to wave propagation
- Can be “vertical”, “horizontal” or any combination
  - (vector addition: “horizontal” + “vertical” = “diagonal”)
- Polarizers: Let only one direction pass
  - Example: reflection off glass, water, …
  - Polaroid filters: Stripy polymers
- Analyzers: Same as Polarizers - won’t let anything pass if light is polarized perpendicular to preferred axis.



Polaroid sun glasses: reduce glare (reflection from surfaces, scattered light from atmosphere

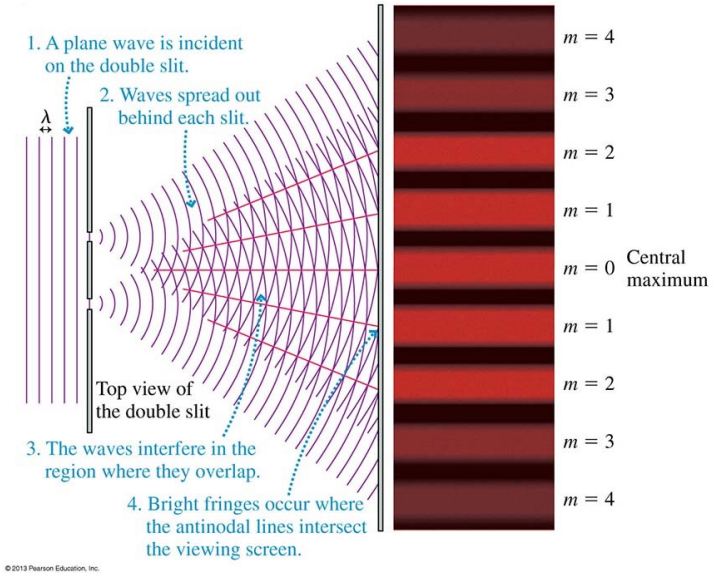
Doppler Effect

- Just like sound: Objects moving away from us appear to emit at lower frequency ("red shift"), objects moving towards us at higher frequency ("blue shift").
- Einstein: "It doesn't matter whether emitter or observer moves - only relative motion counts
- Proportional to v/c
- First proof of "big bang" cosmology:



All far-away galaxies appear red-shifted (shift and thus v proportional to distance)

What happens to the interference pattern from light impinging on a double slit when the distance between the 2 slits is increased?



A. The bright stripes move closer together

B. The bright stripes move further apart

C. Nothing changes

D. It depends on the wavelength of the light

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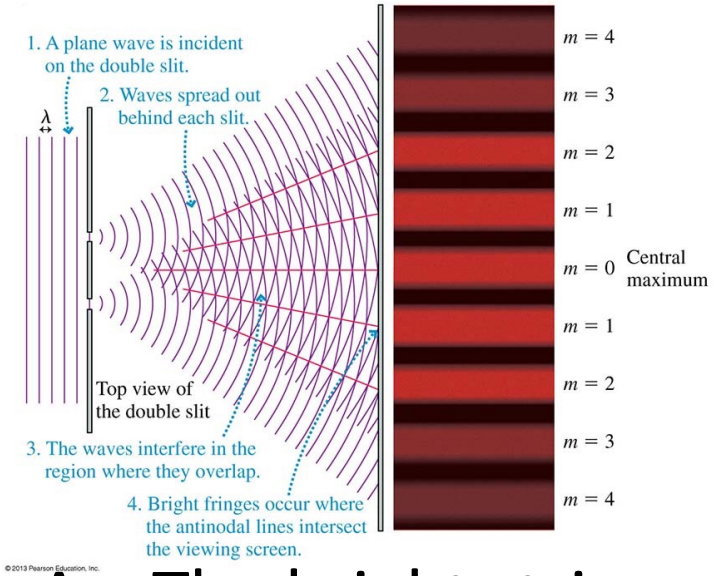

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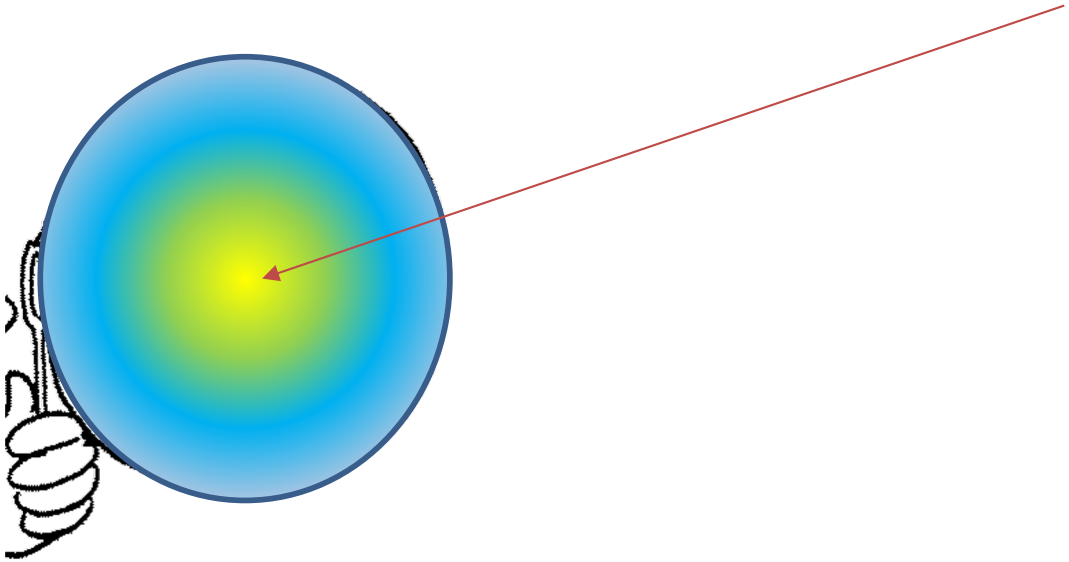
Some part of the soap bubble looks yellow in sunlight. What color is being cancelled by wave interference at that spot?



A. Red
B. Green
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D. All colors

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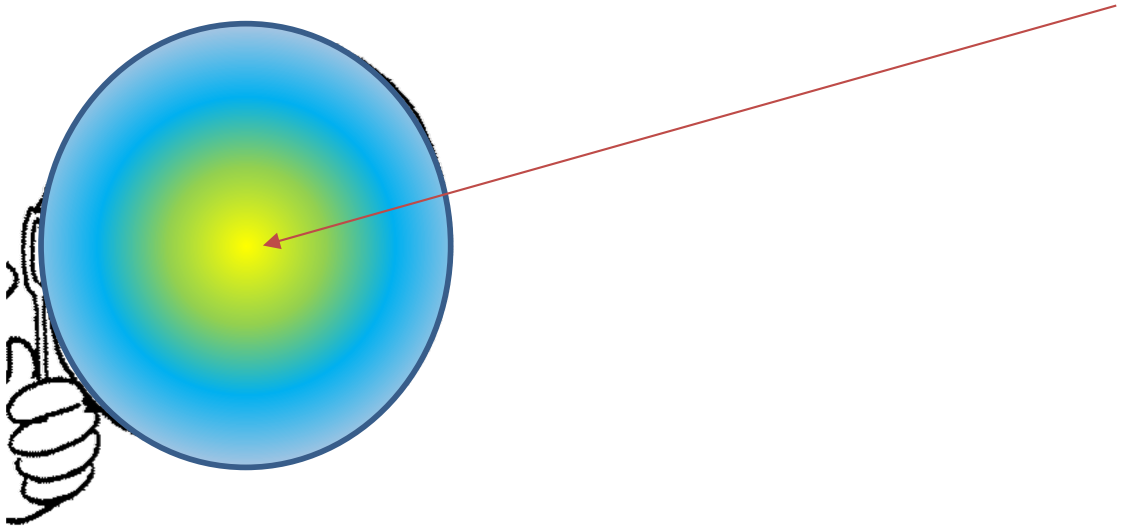

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