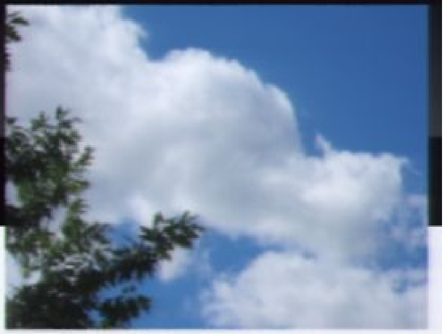
Title: Research Skills - Lecture 3C

Date: Aug 20, 2010 01:30 PM

URL: http://pirsa.org/10080031

Abstract:

Outline



- Why are clouds white?
- Mie theory:
  - Mie's Work
  - Mie's Approch

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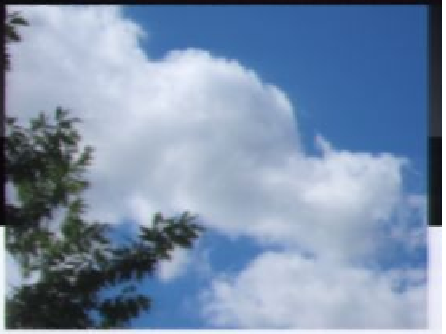

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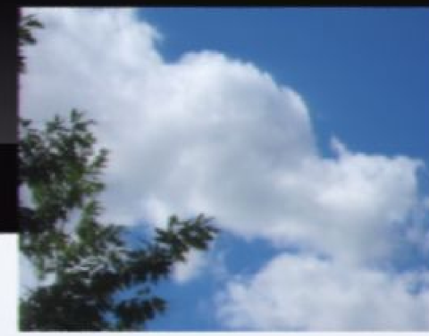

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- These scatter incident light
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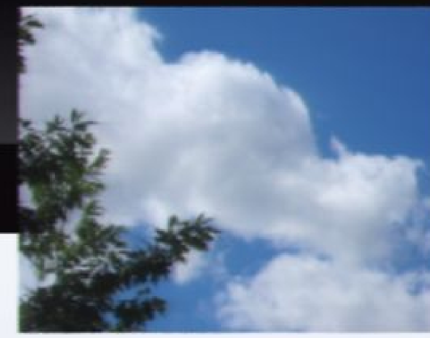

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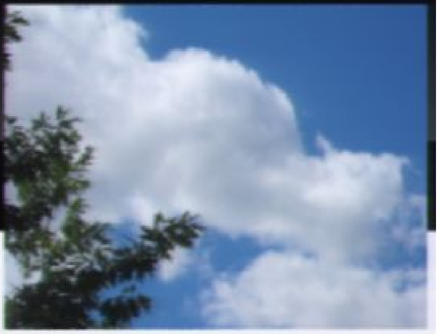

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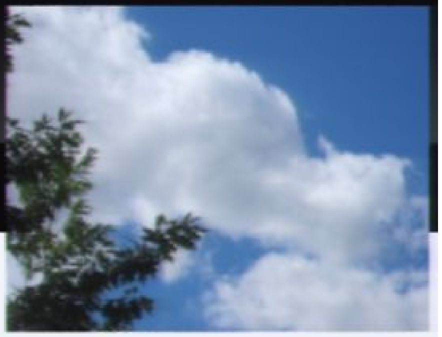

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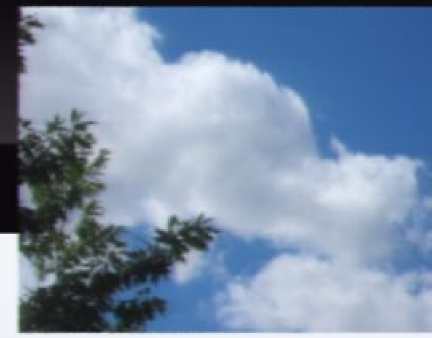

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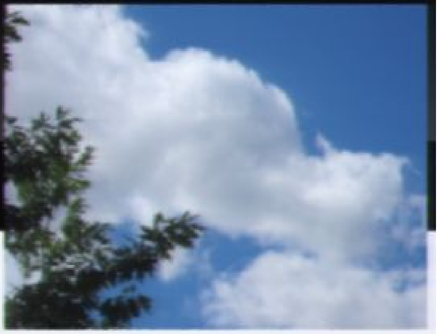

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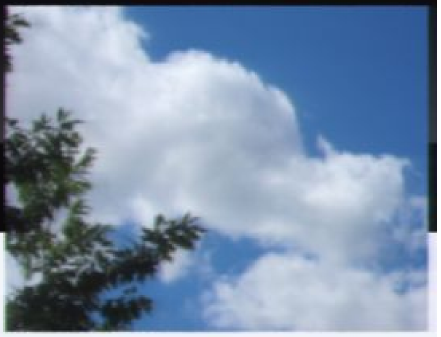

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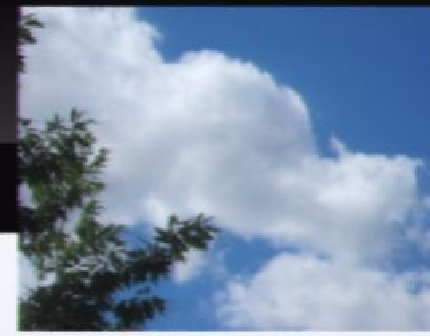

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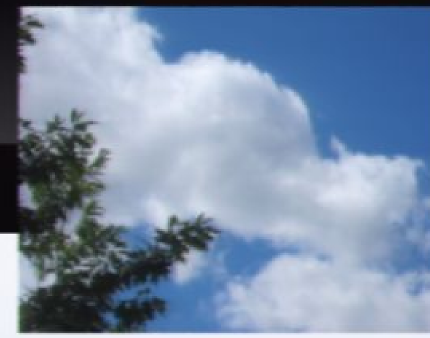

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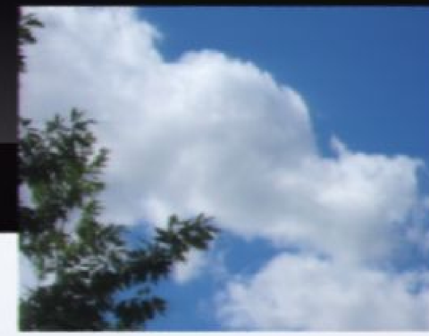

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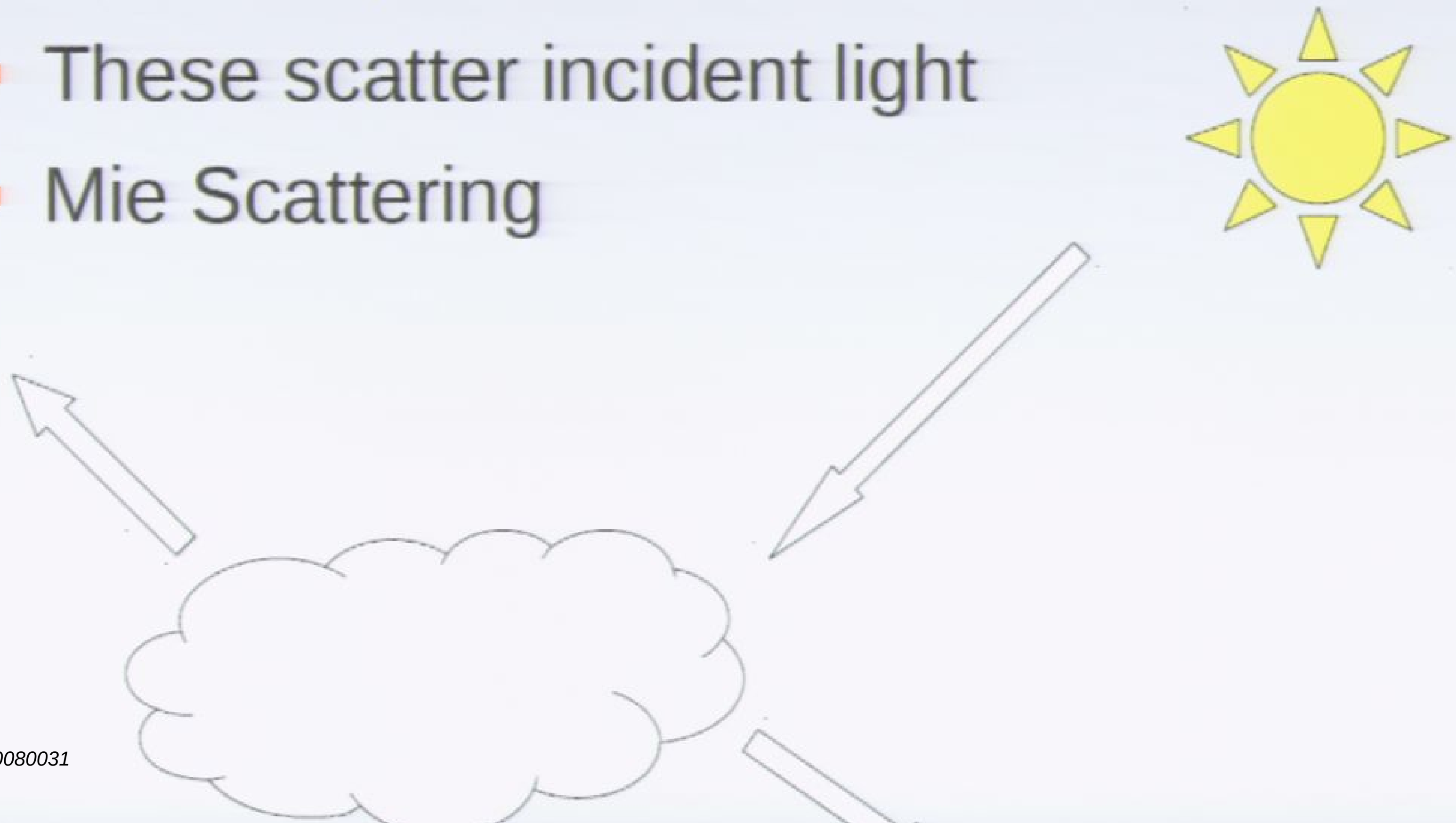

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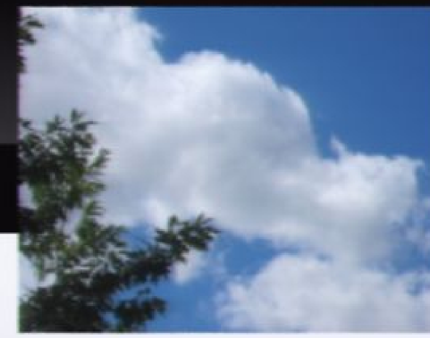

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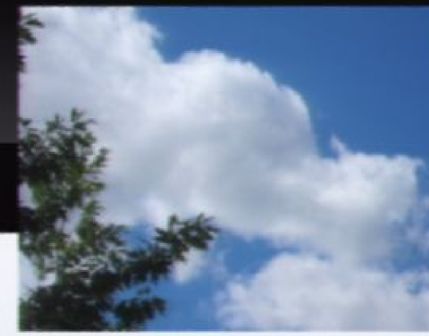

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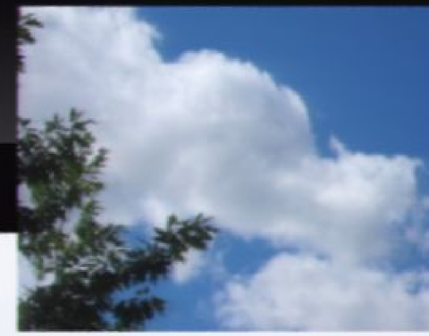

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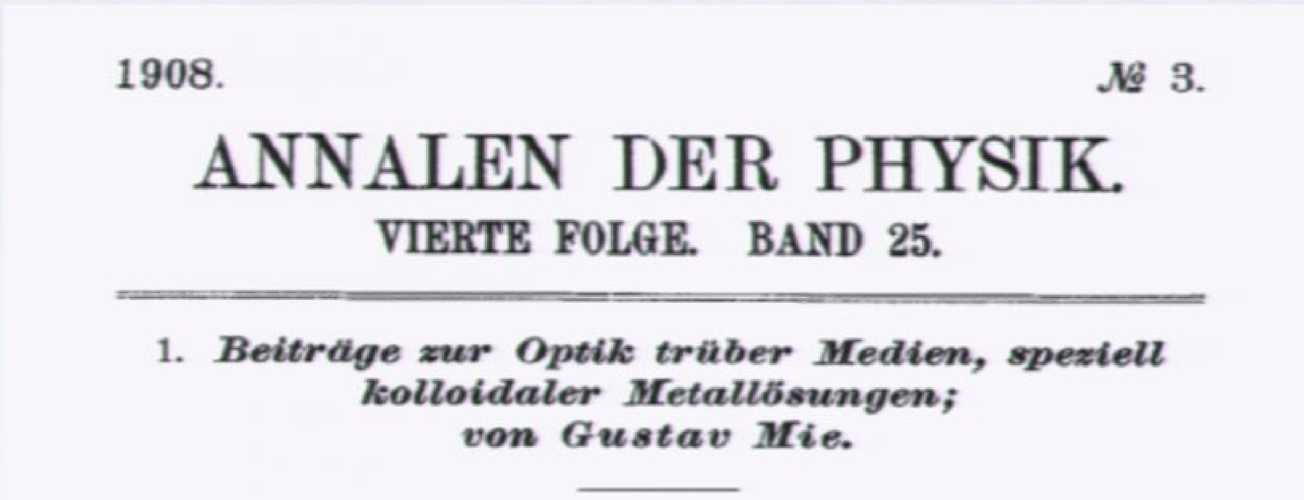

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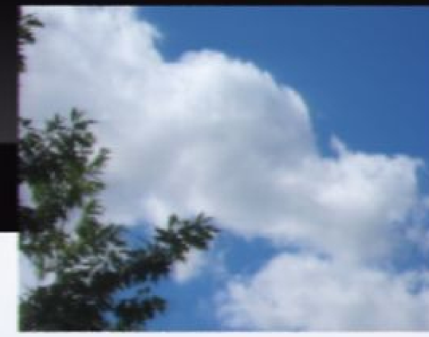

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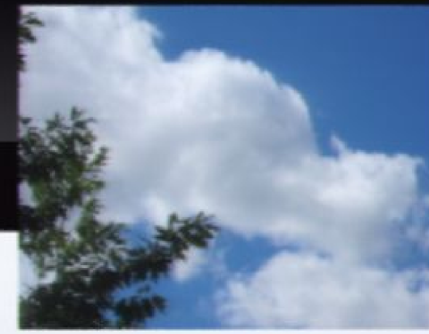

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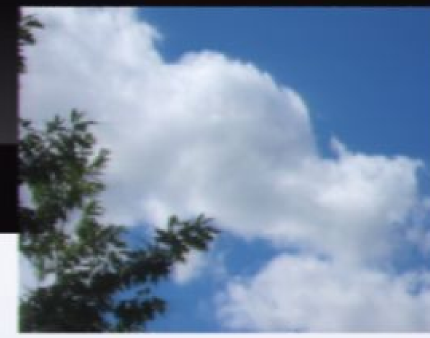

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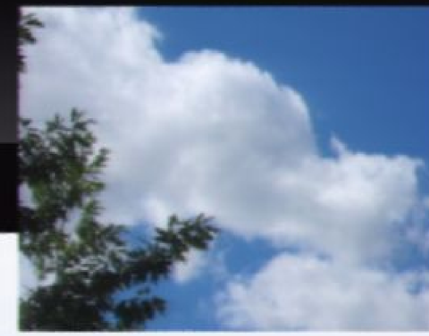

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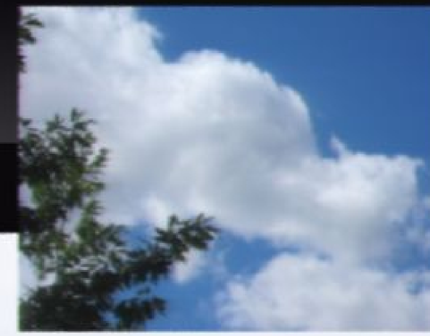

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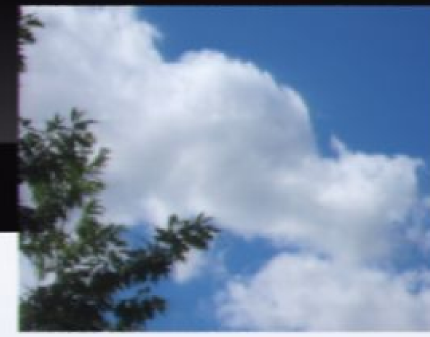

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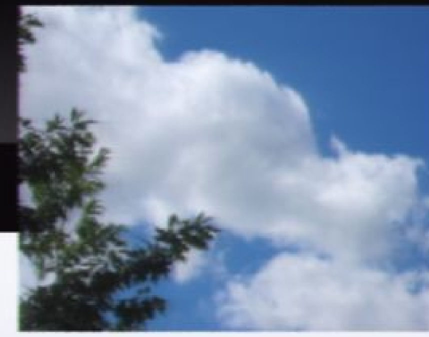

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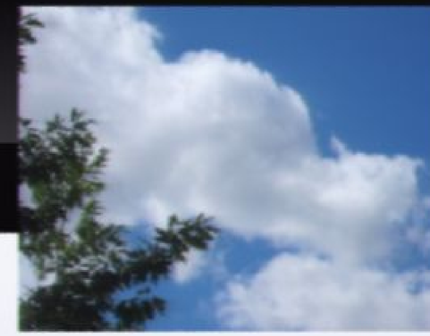

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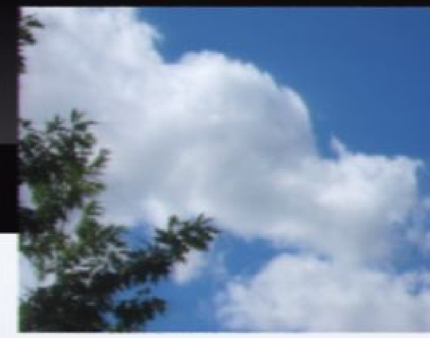

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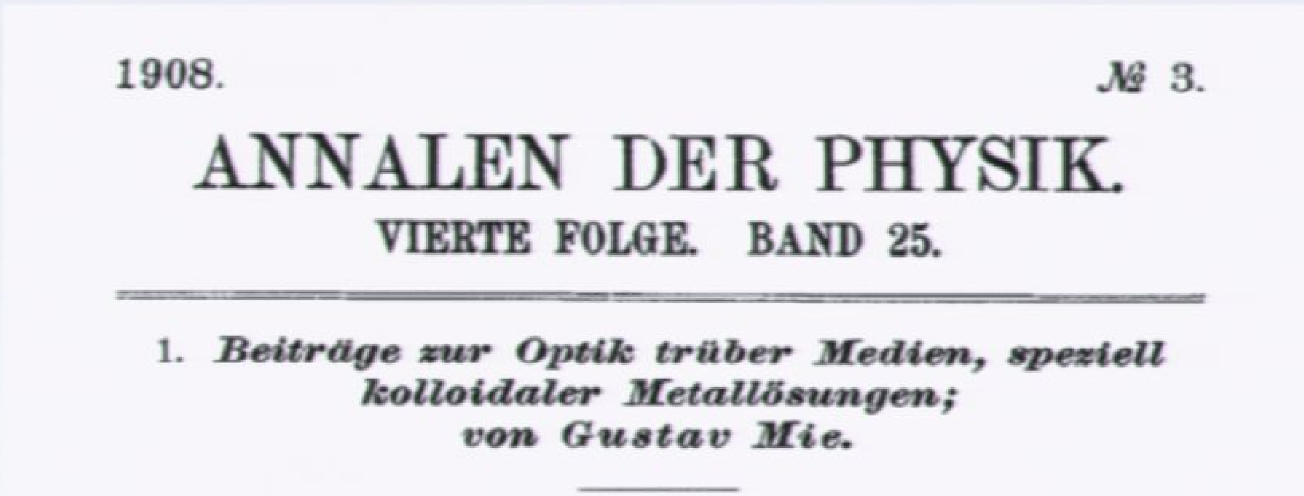

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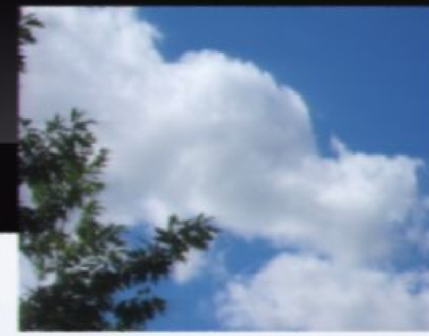

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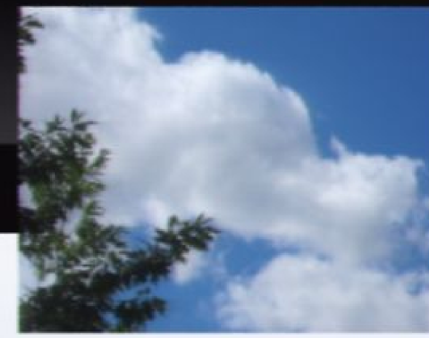

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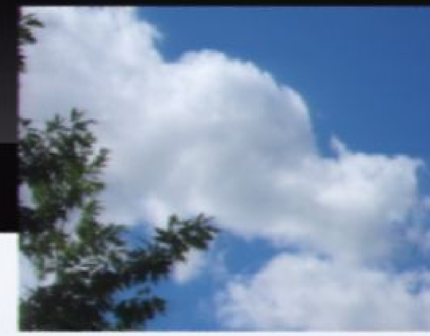

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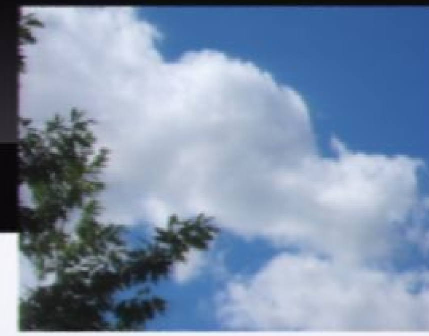

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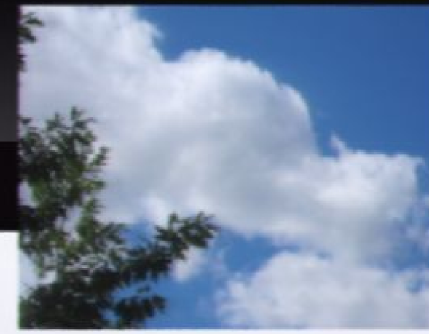

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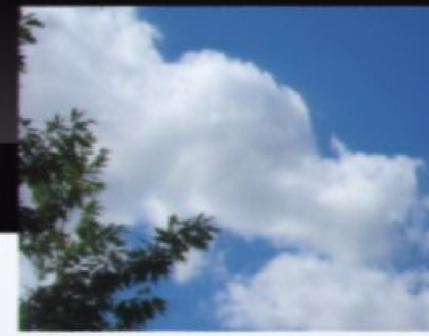

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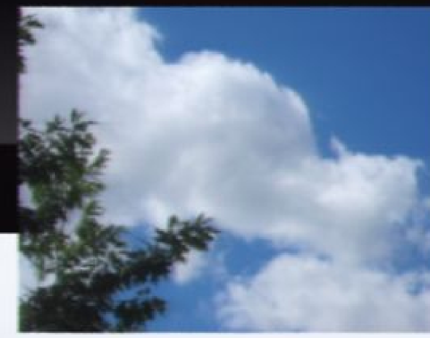

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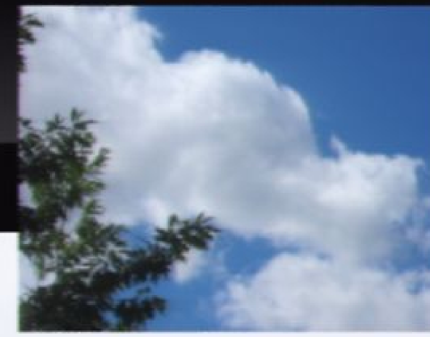

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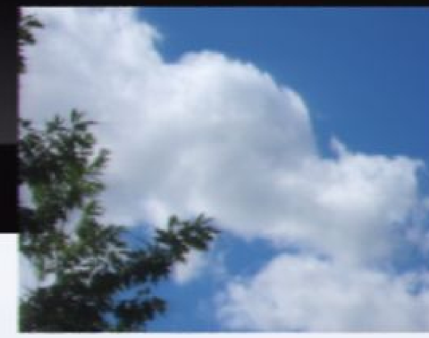

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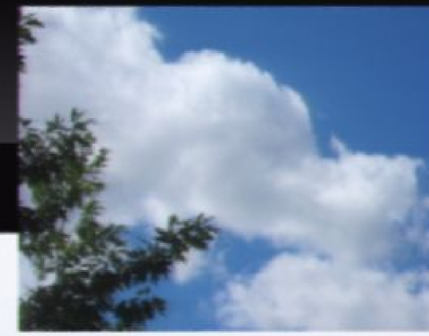

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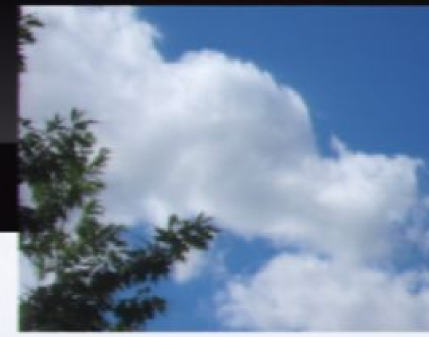

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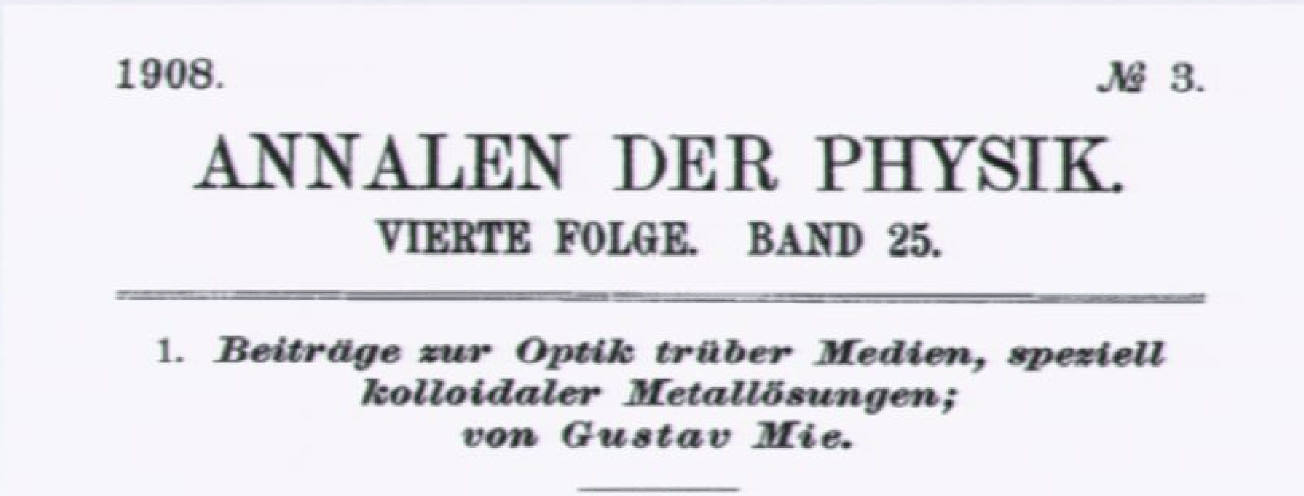

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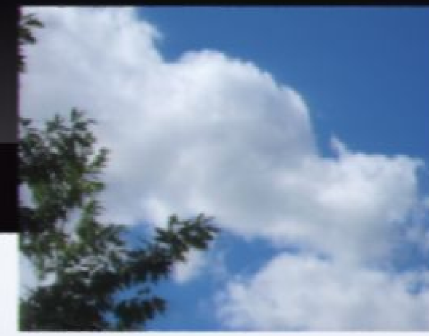

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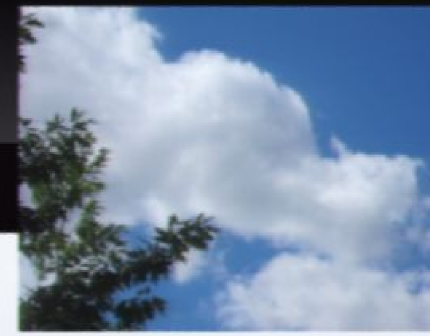

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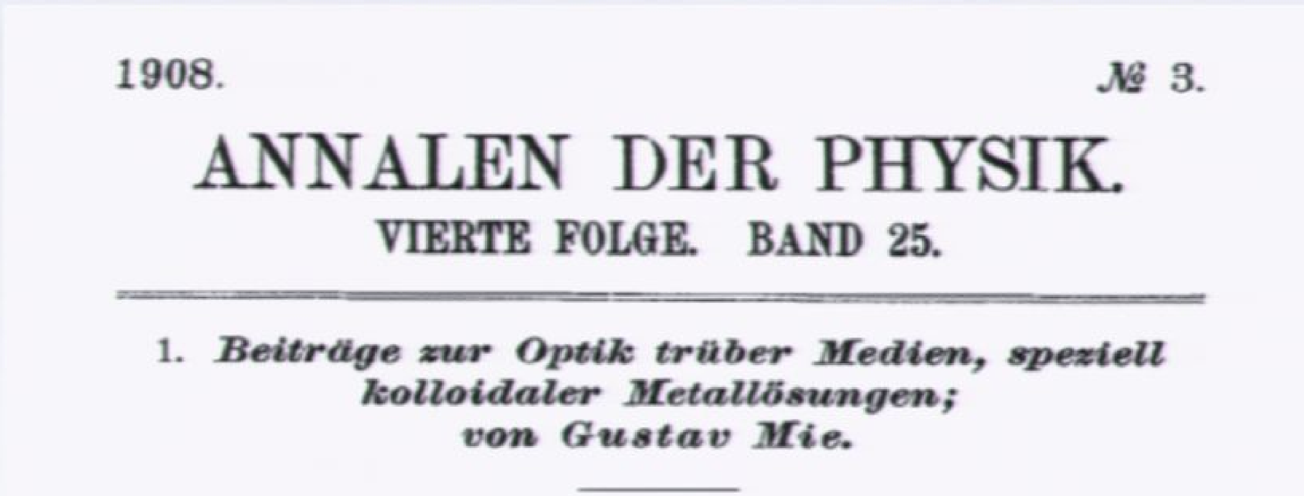

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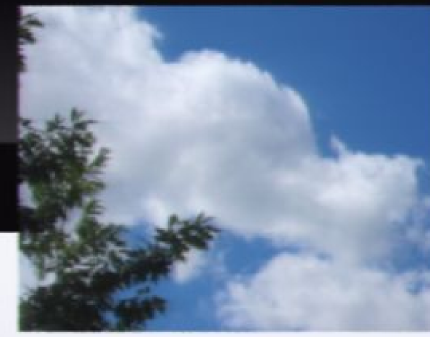

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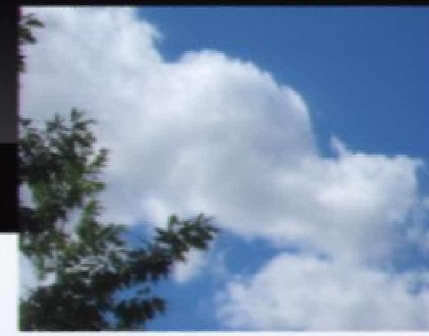

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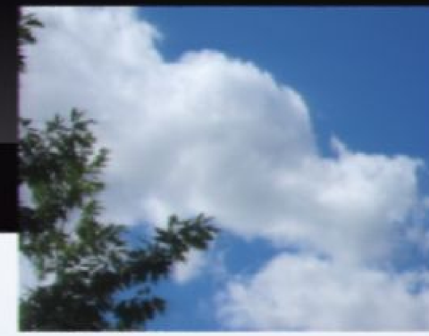

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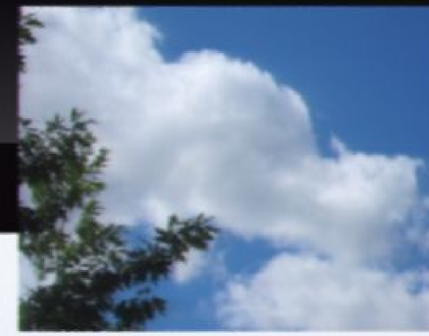

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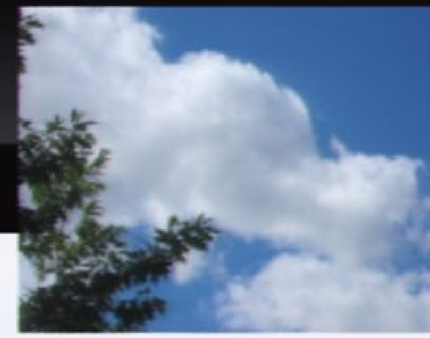

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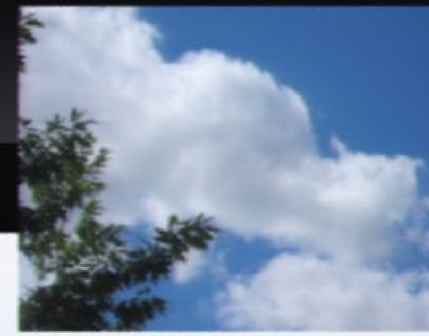

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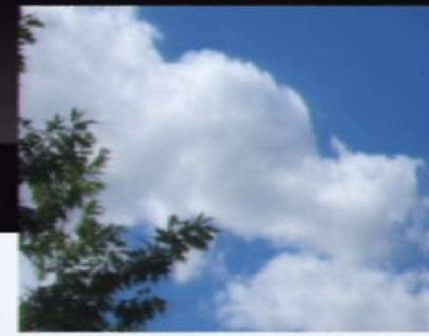

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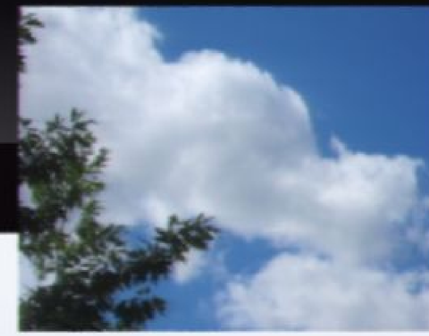

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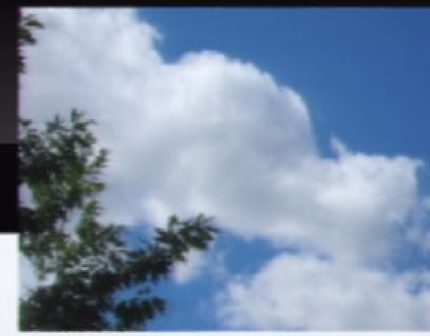

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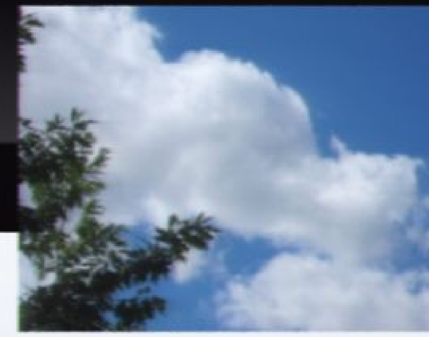

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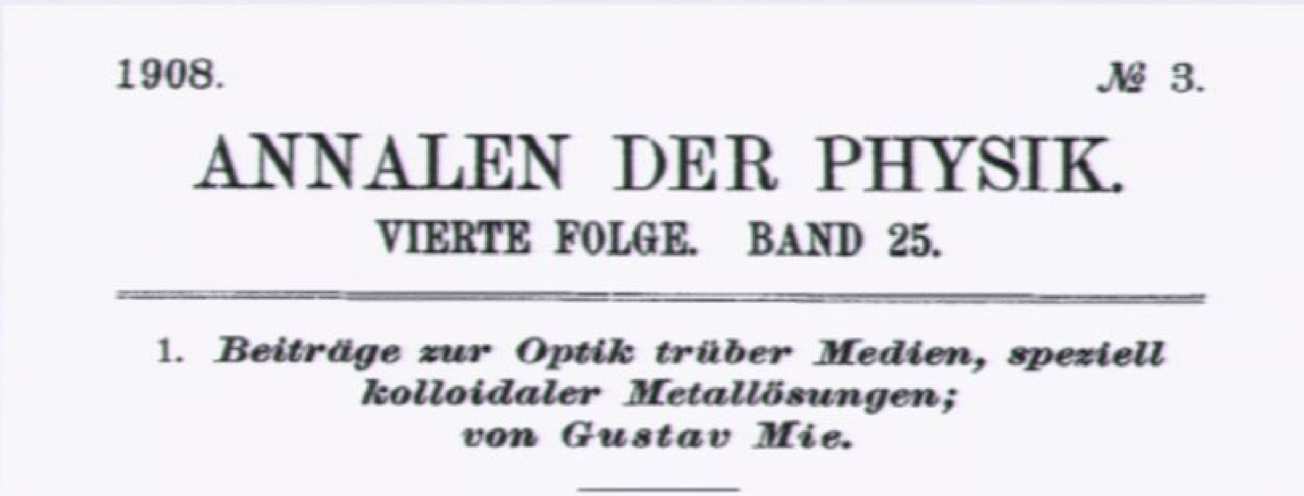

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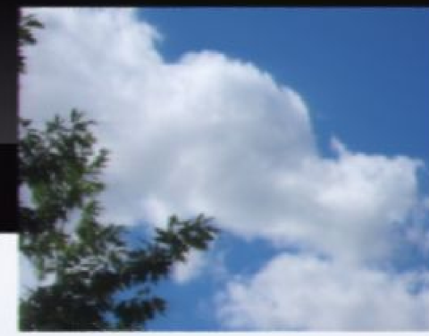

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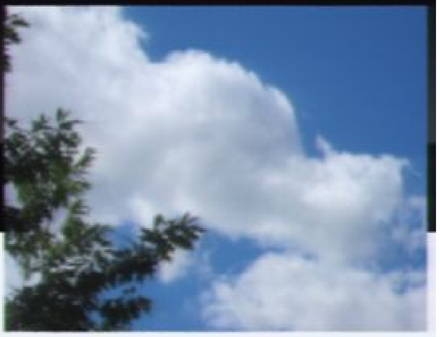

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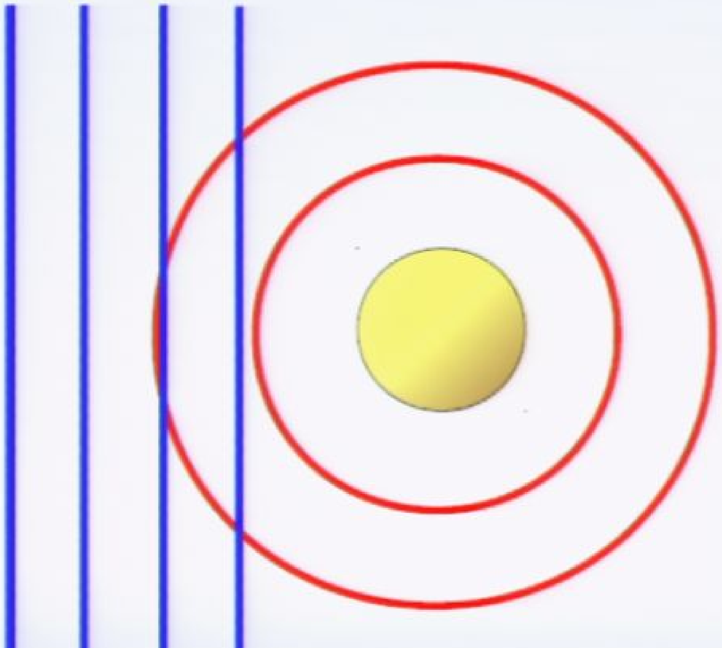

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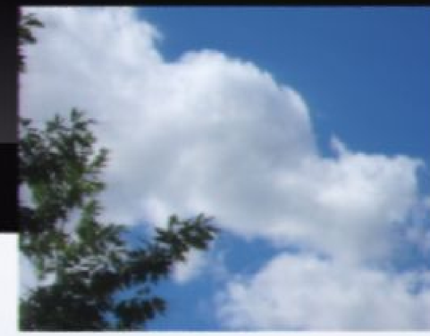

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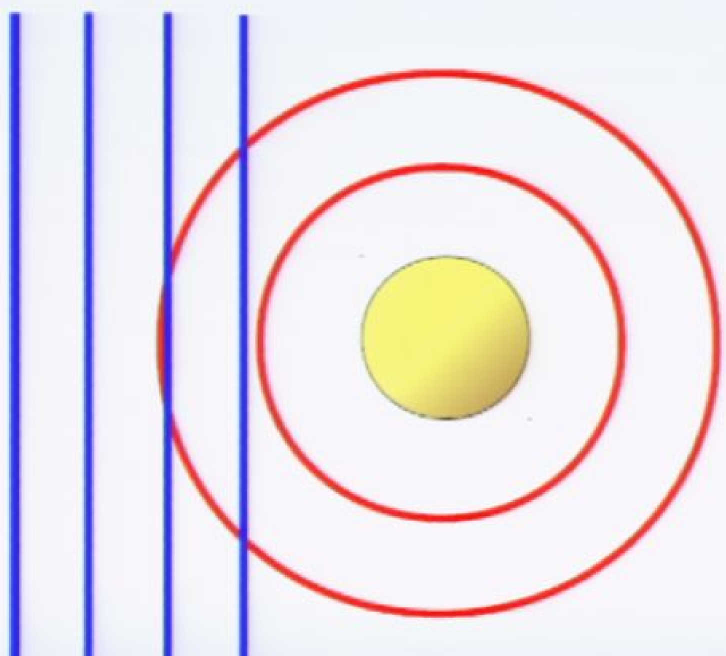

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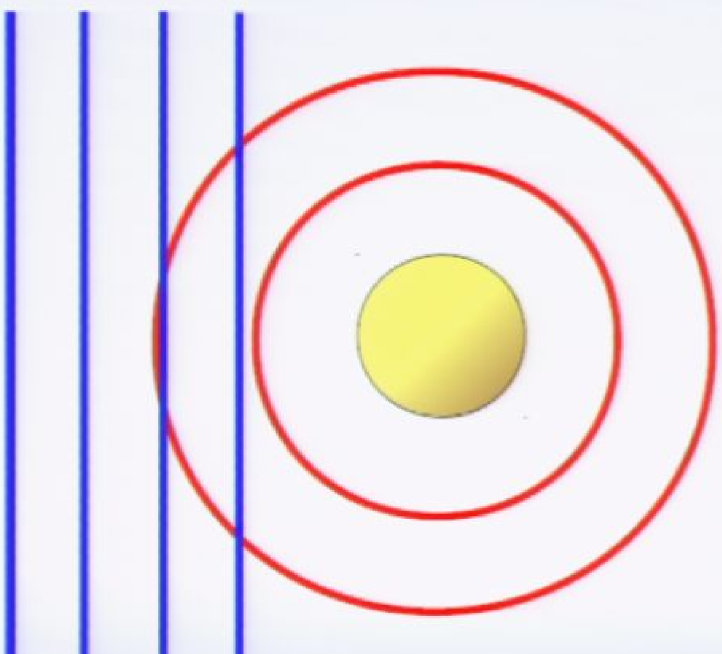

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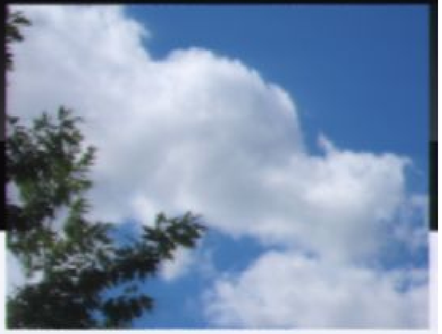

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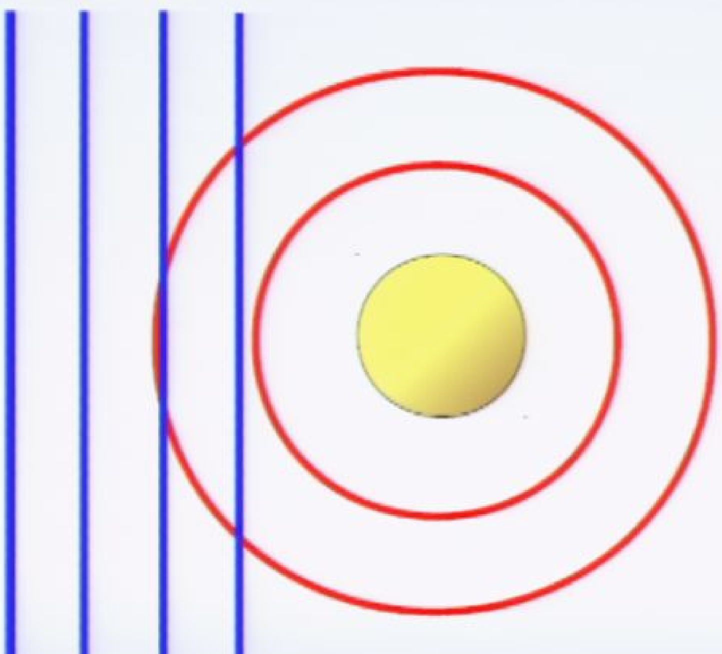

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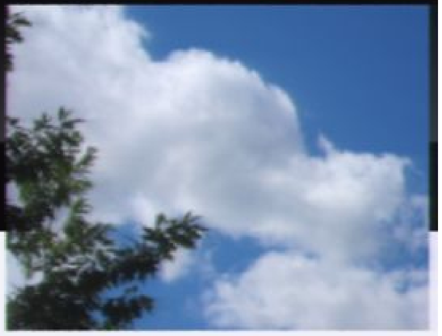

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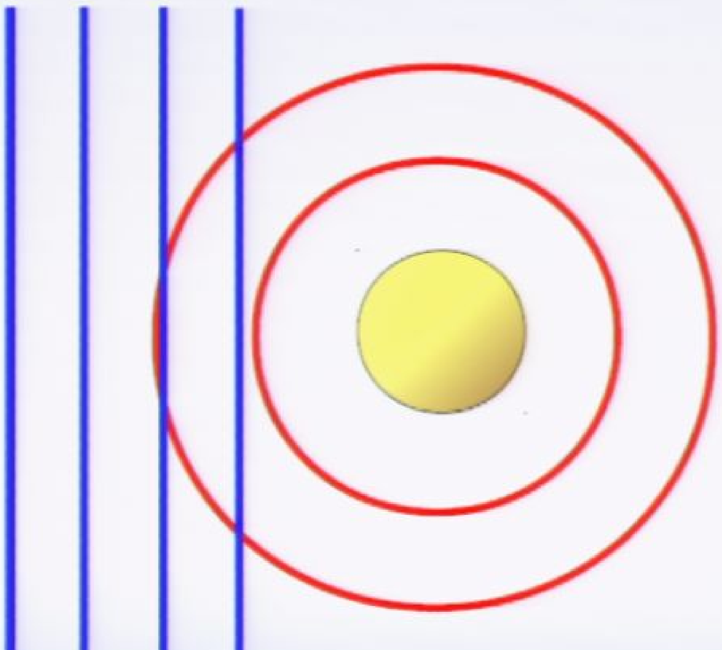

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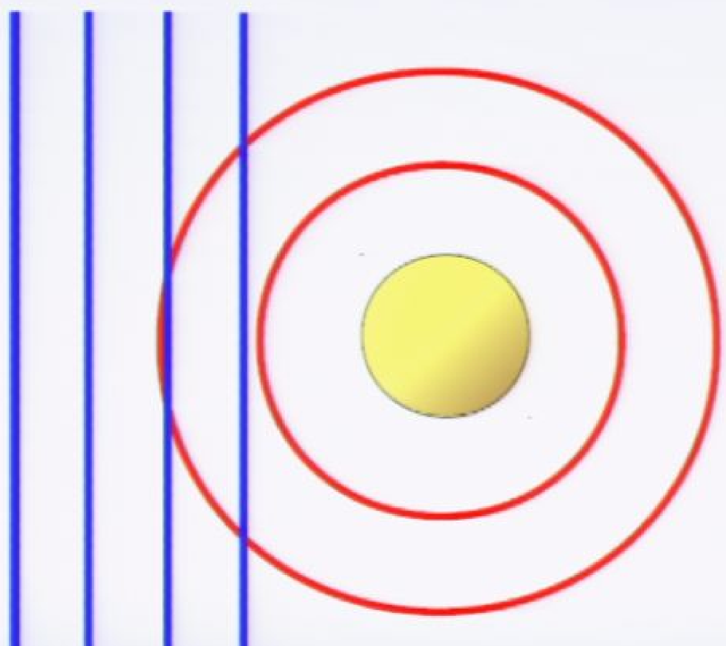

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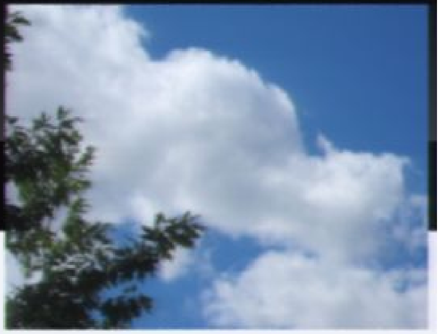

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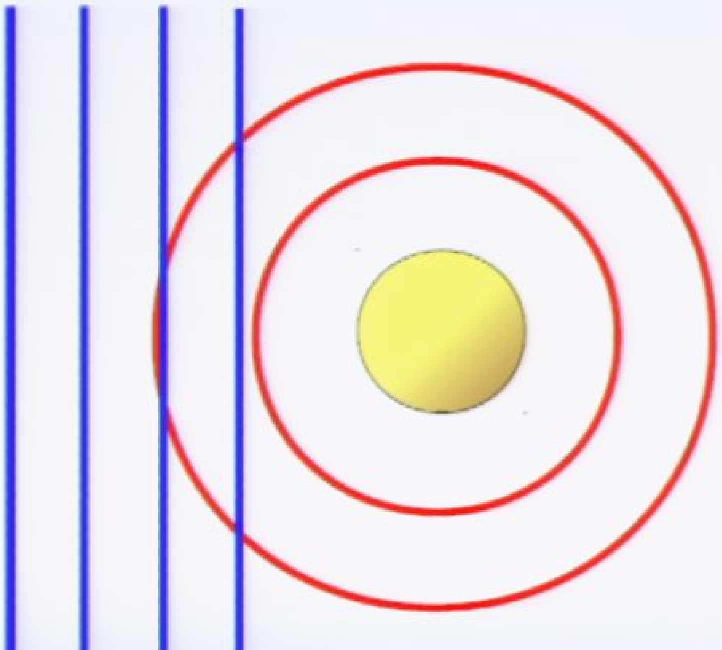

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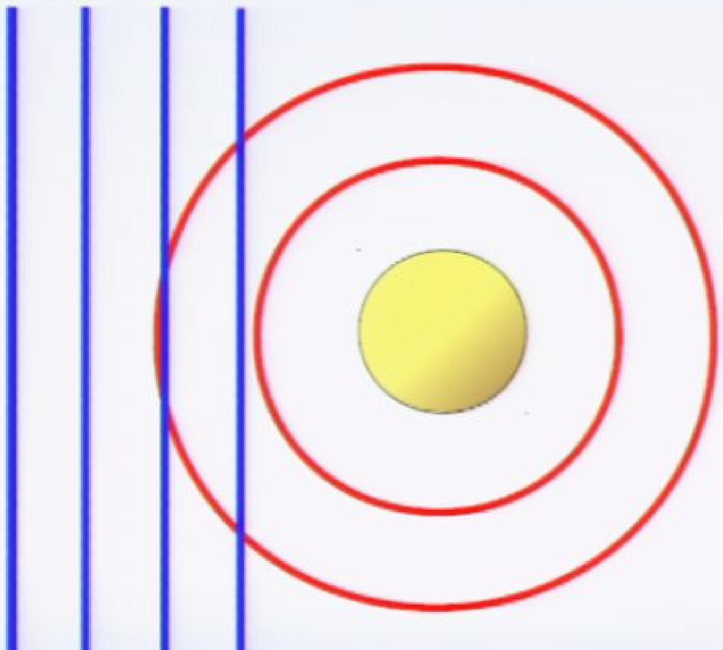

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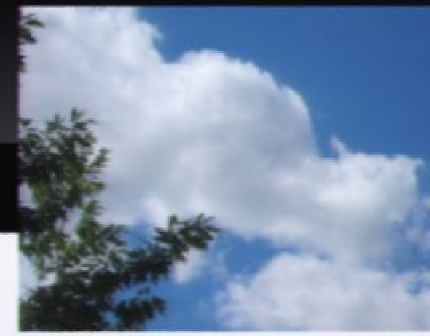

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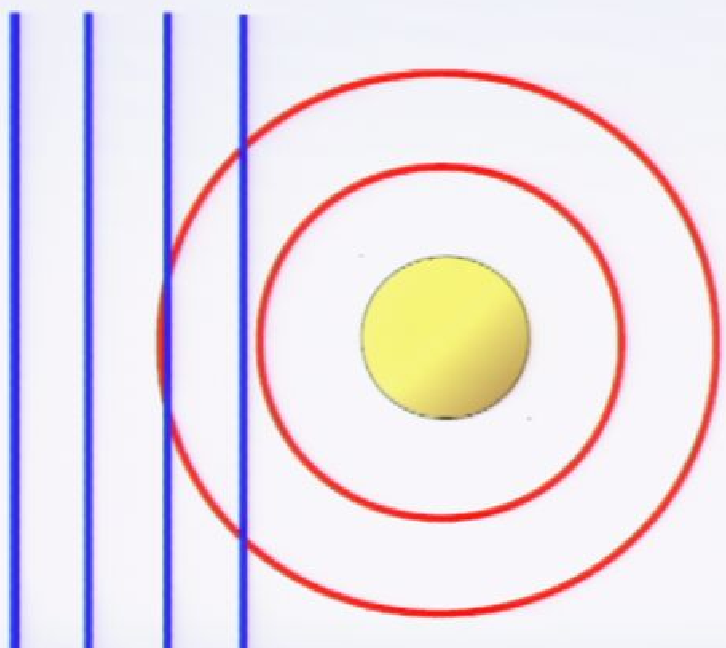

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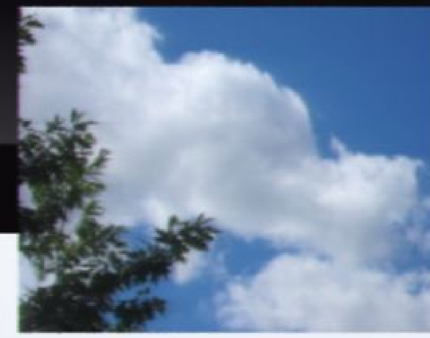

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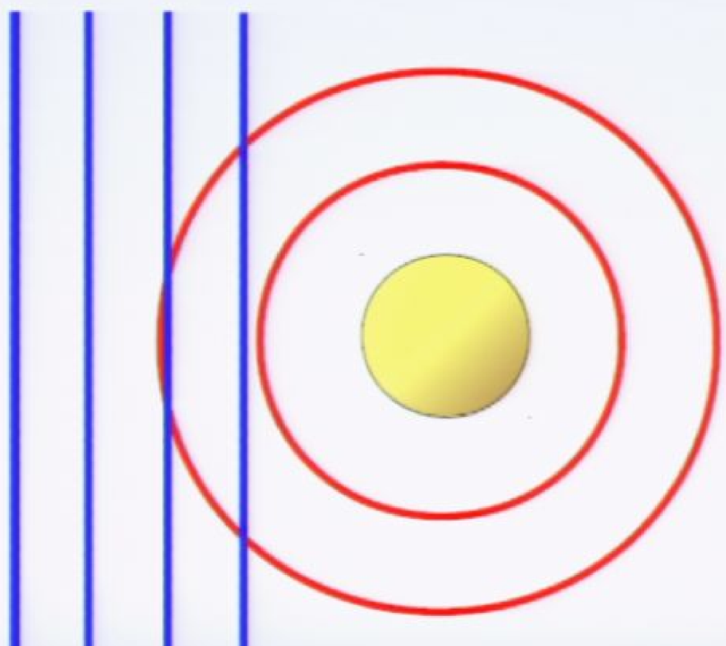

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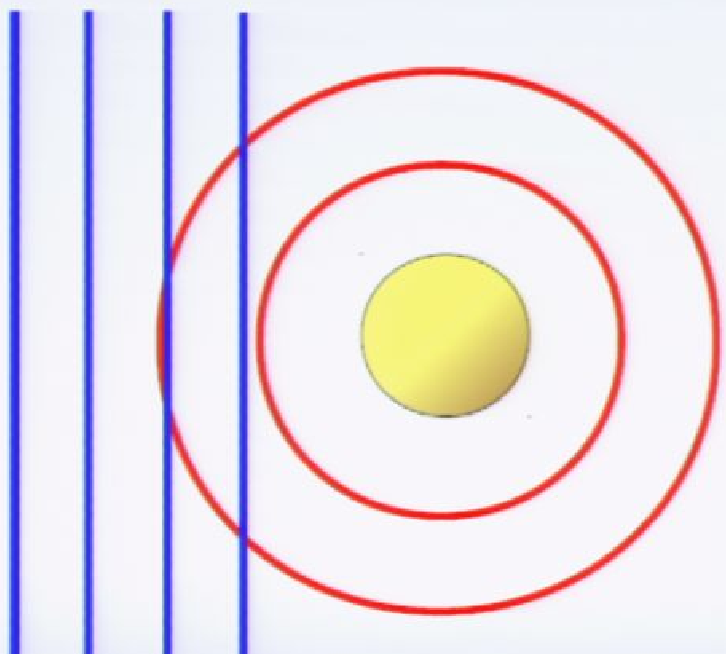

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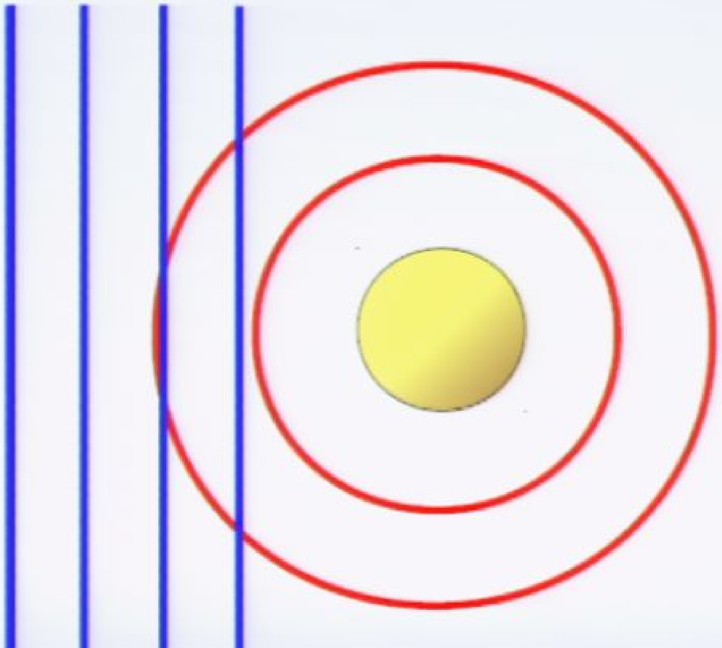

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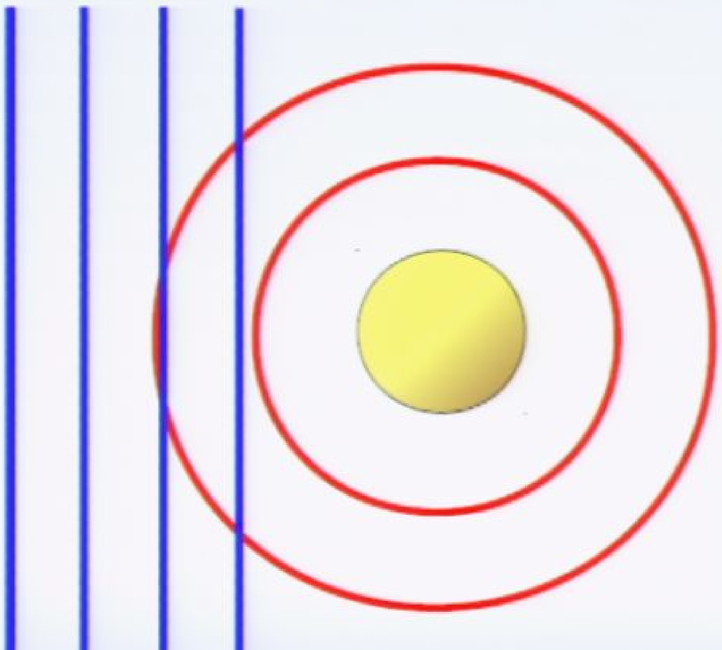

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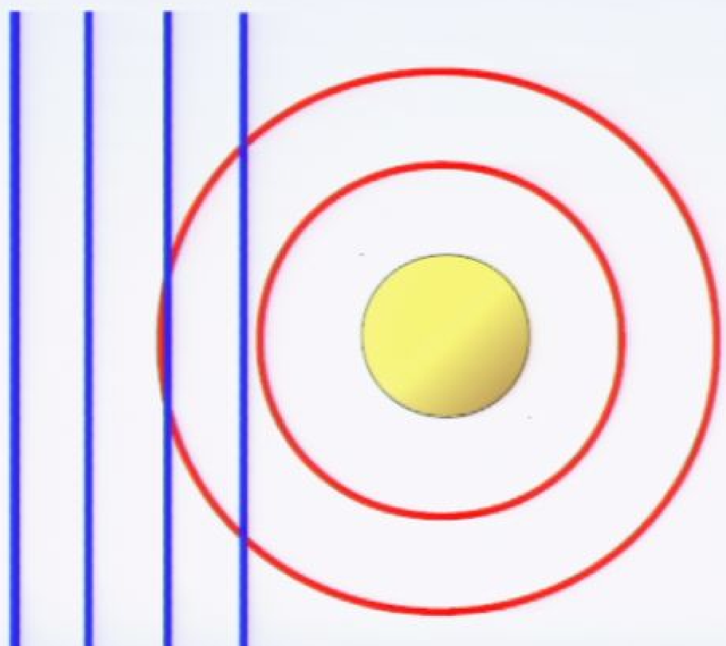

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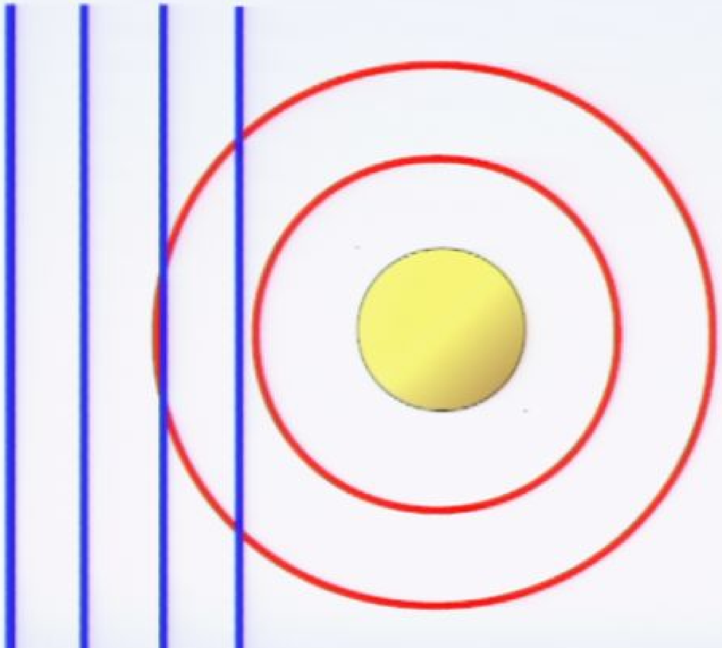

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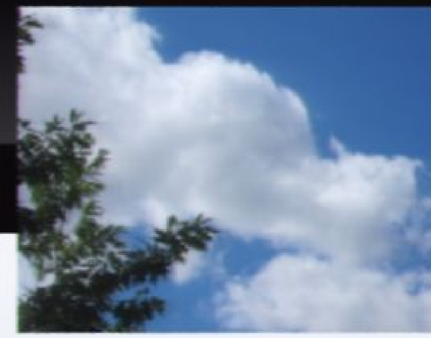

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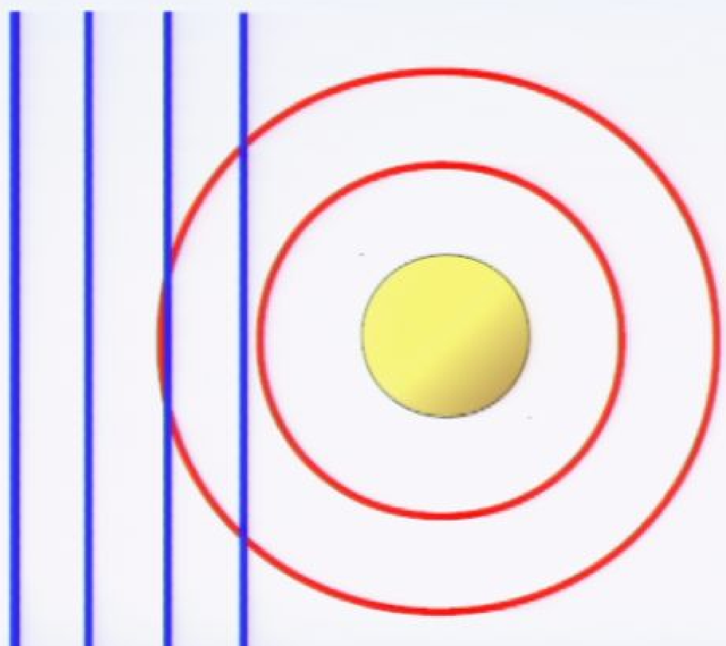

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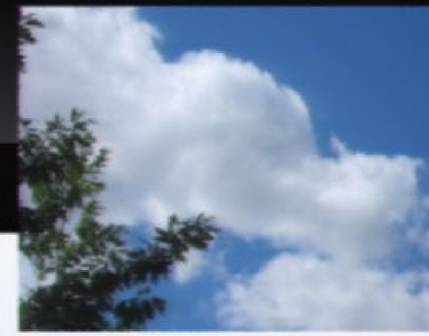

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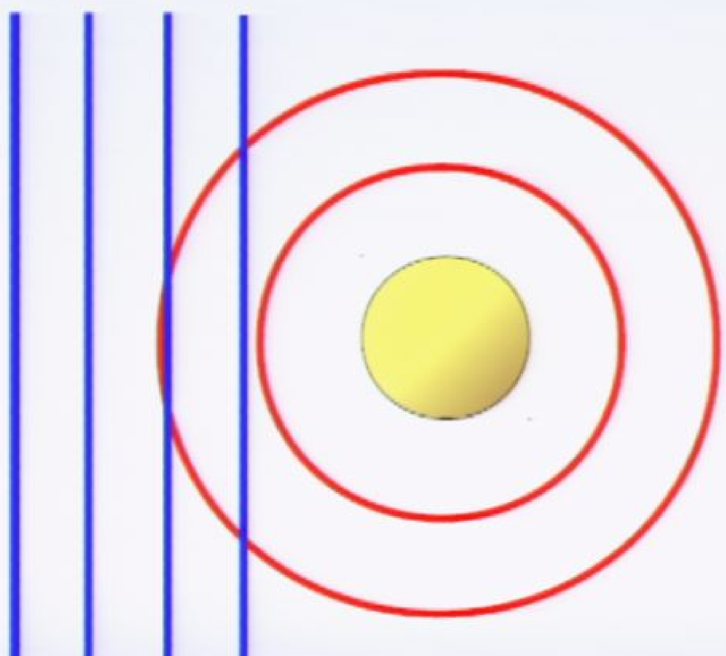

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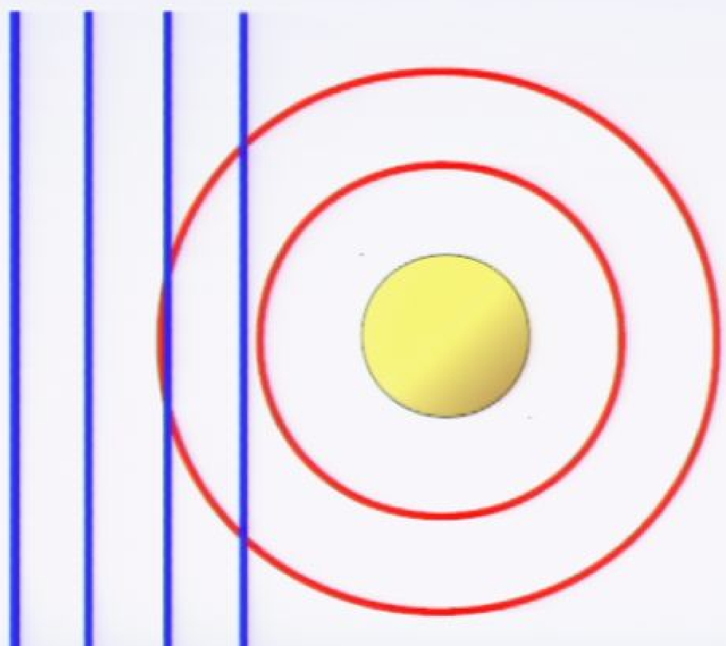

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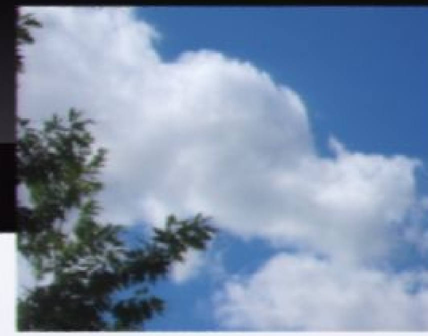

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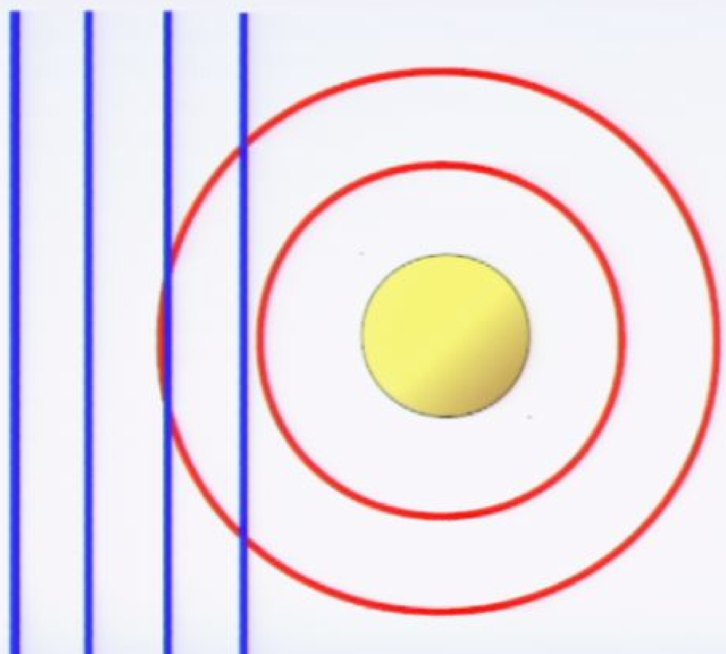

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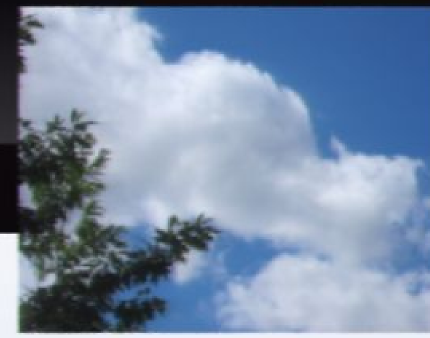

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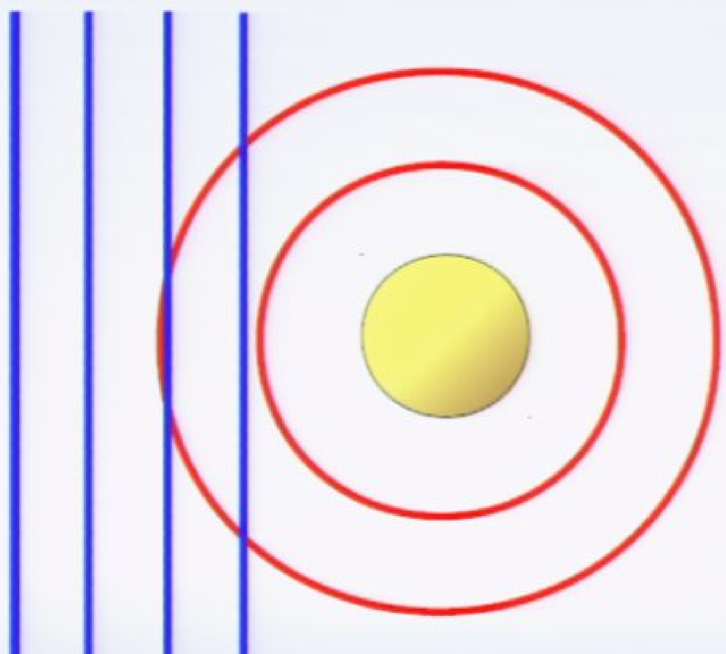

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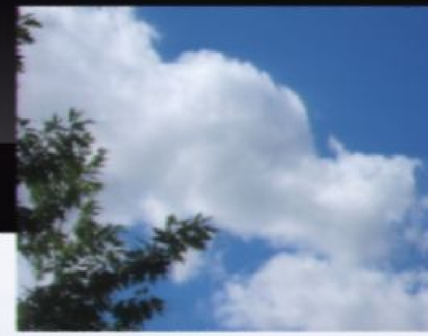

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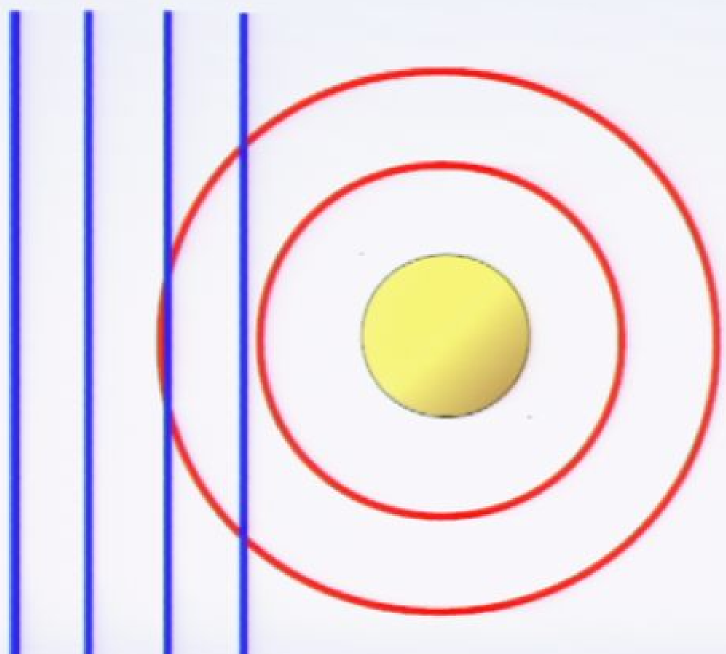

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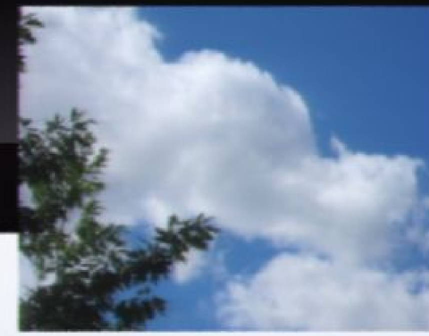

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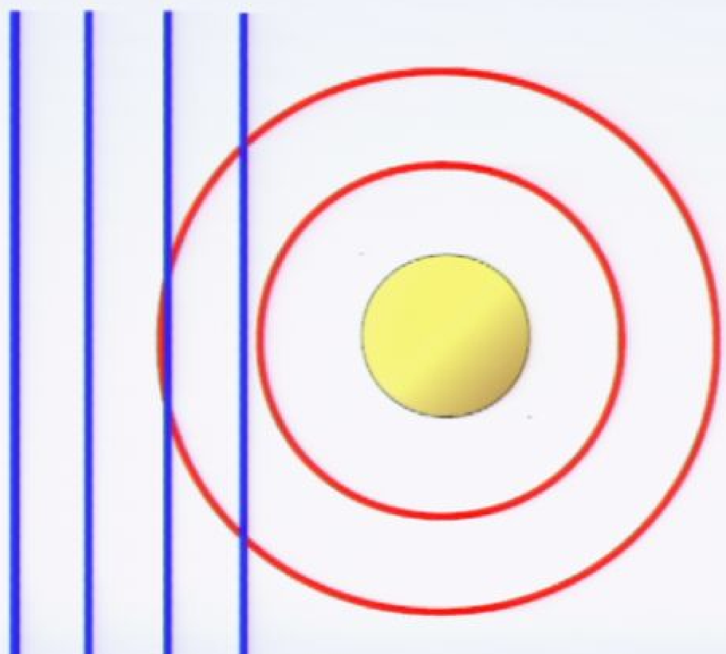

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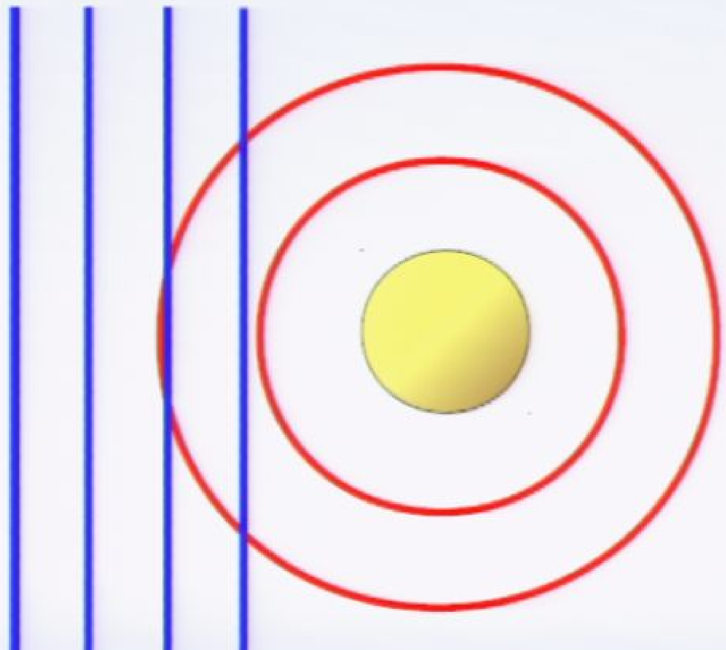

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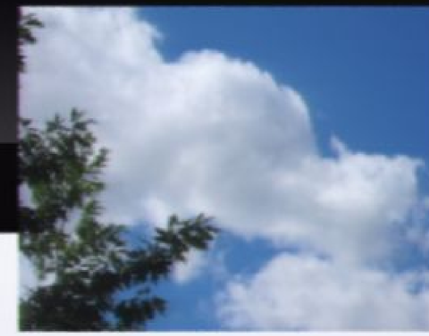

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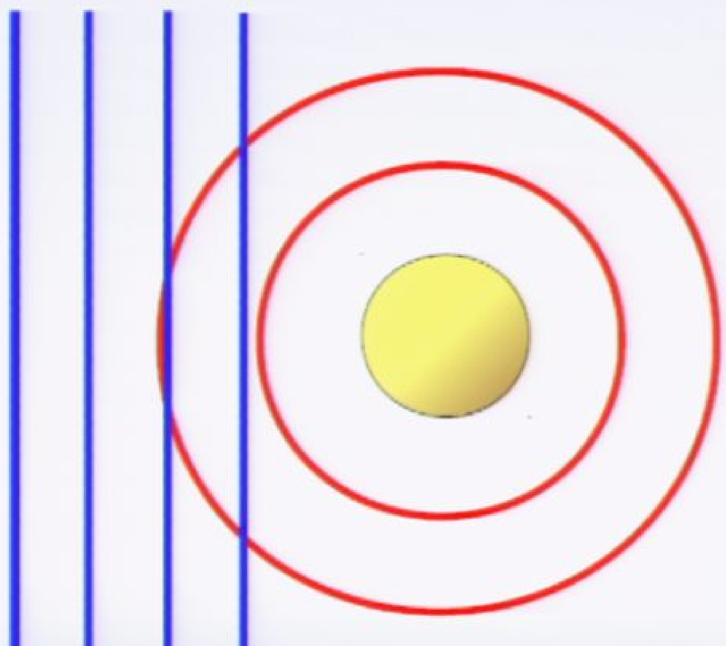

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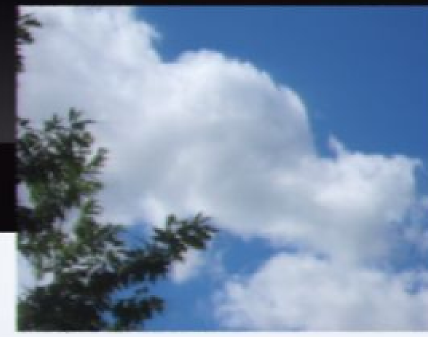

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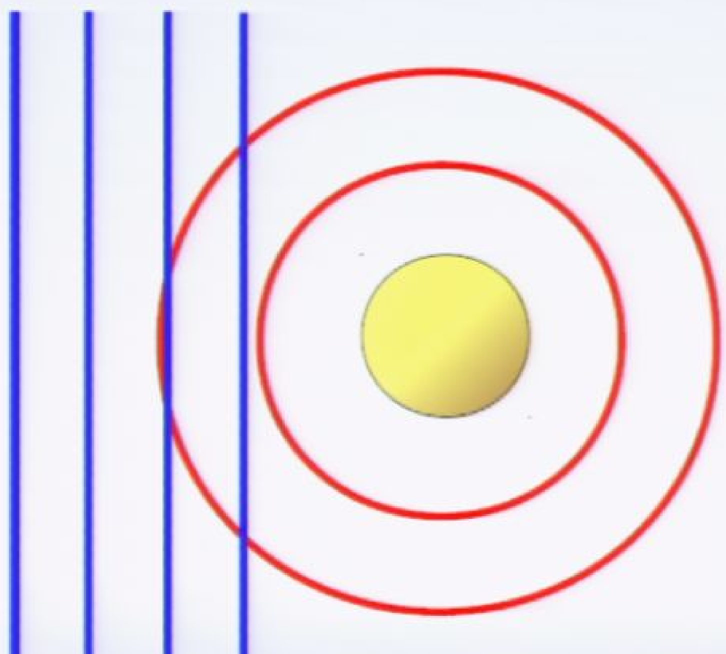

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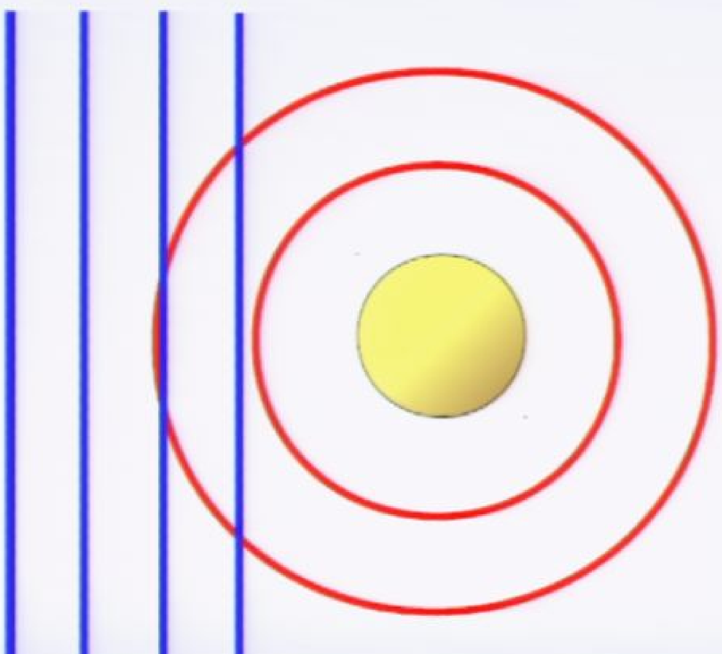

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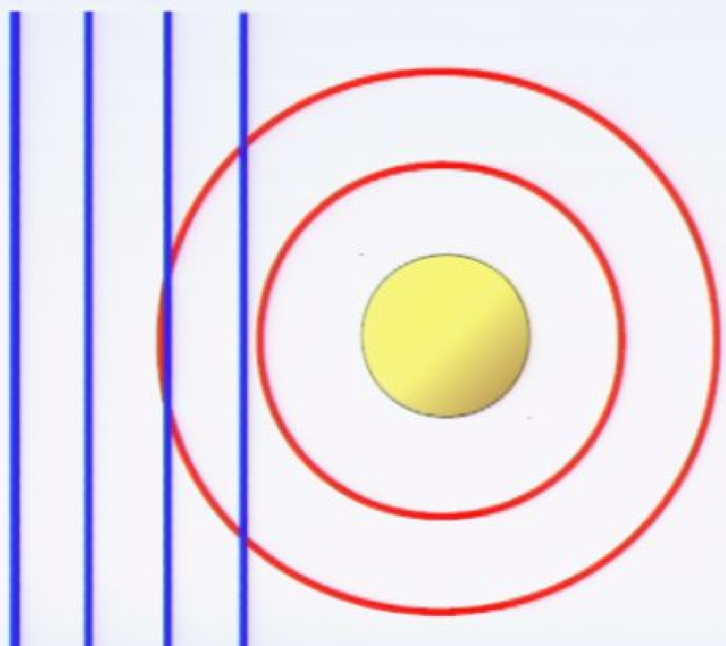

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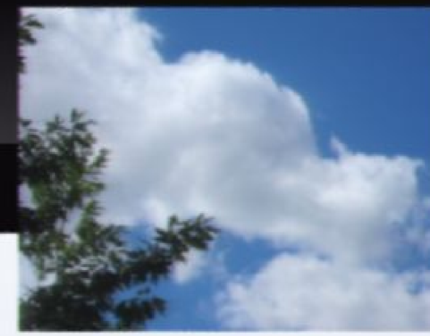

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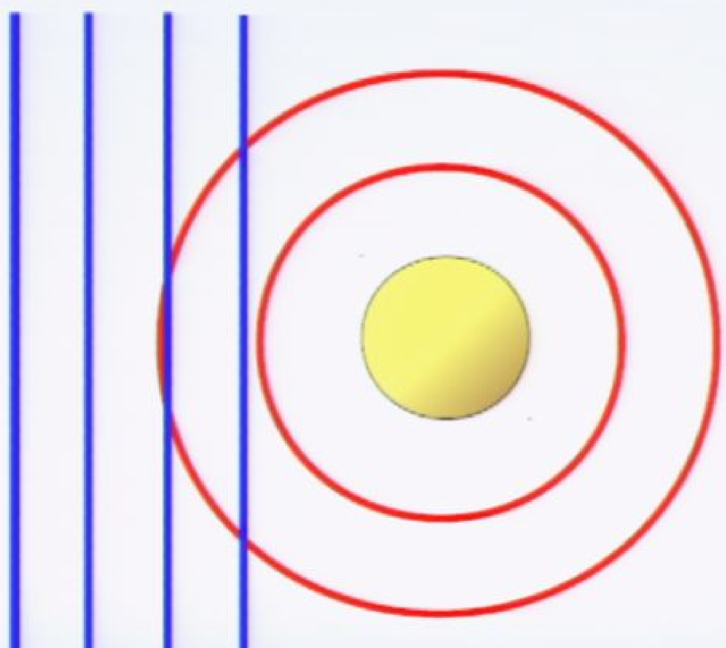

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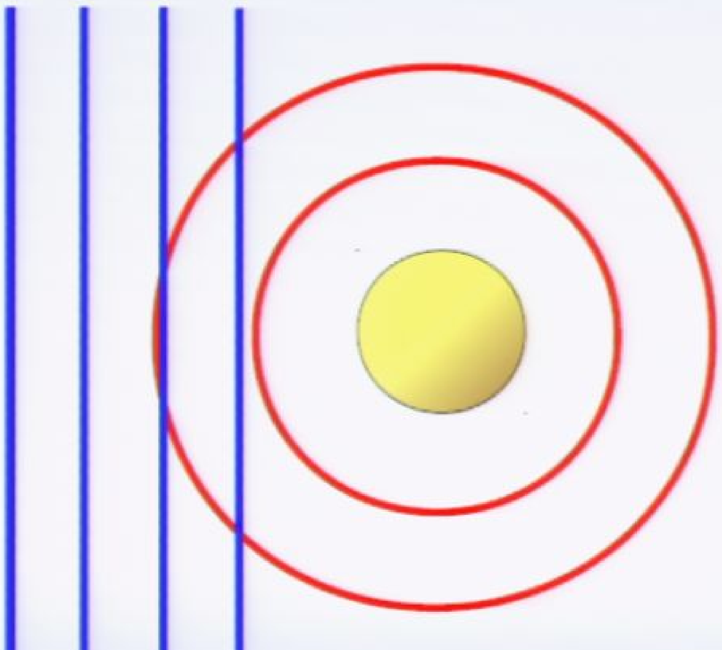

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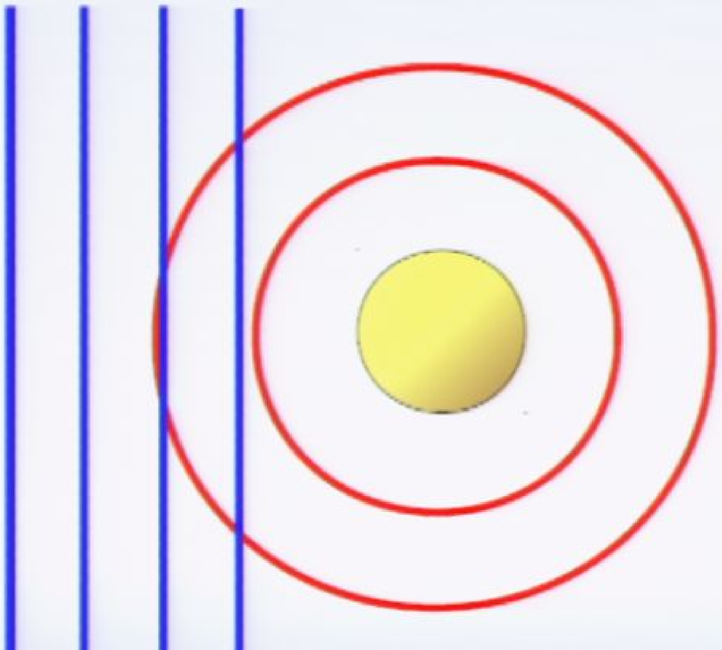

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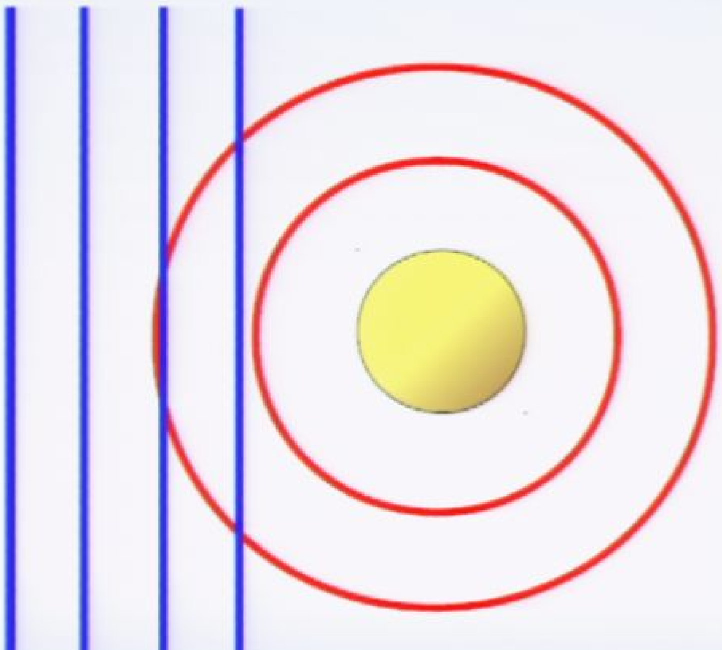

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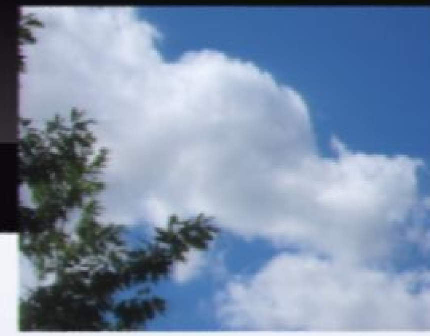

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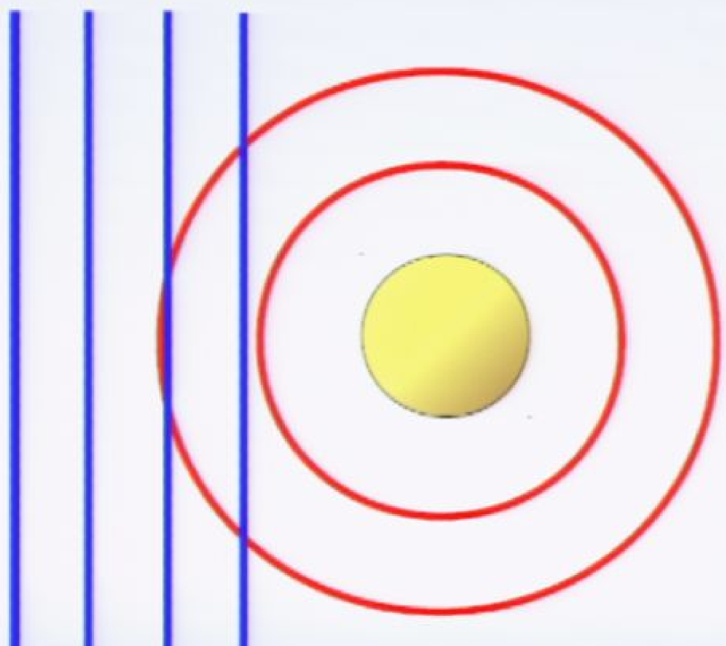

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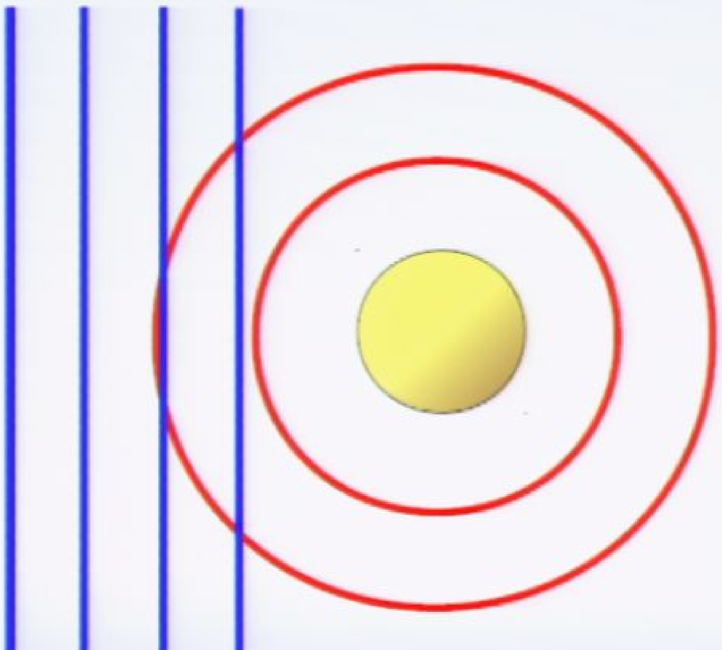

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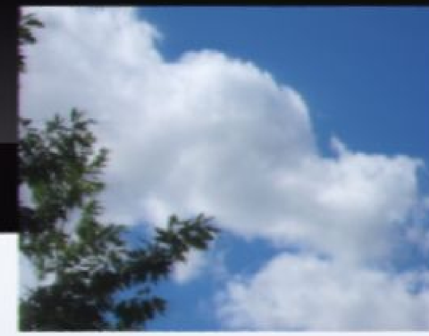

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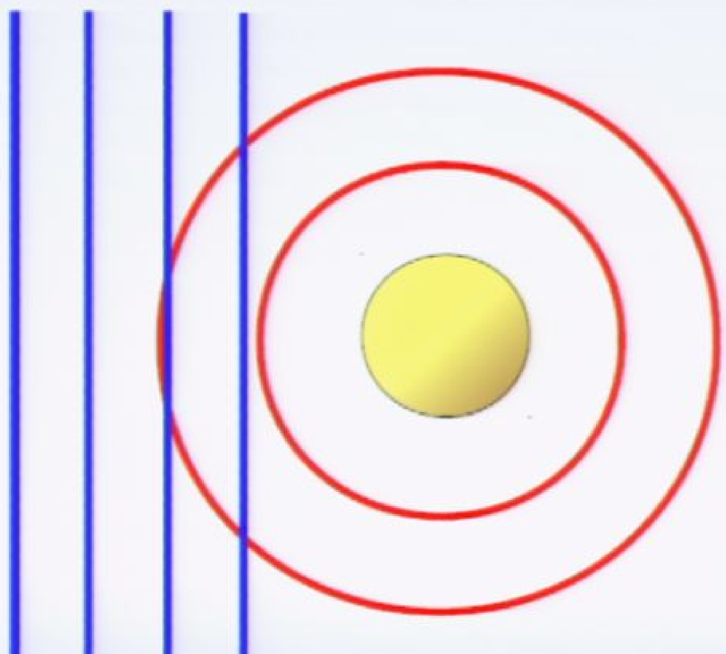

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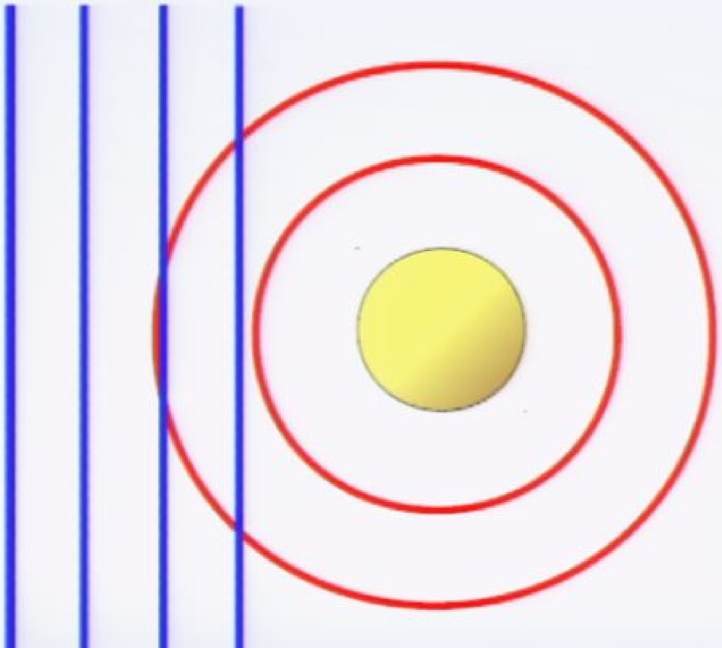

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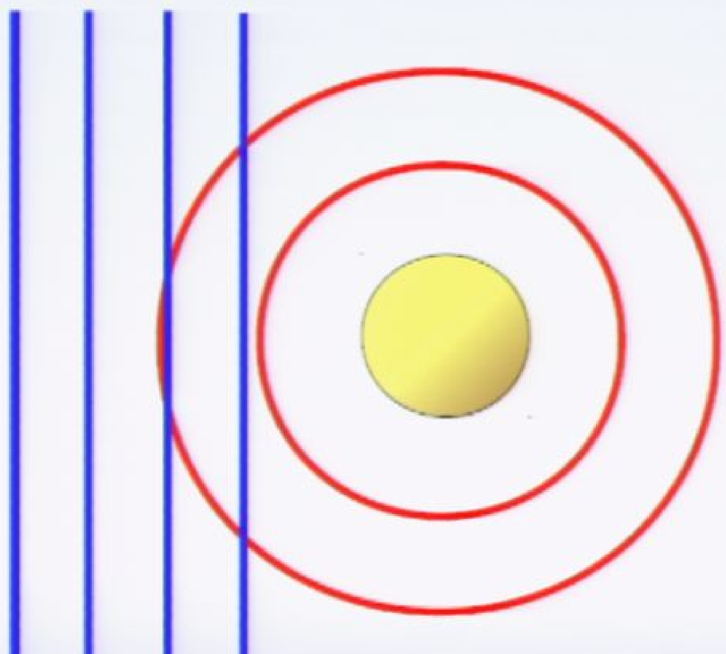

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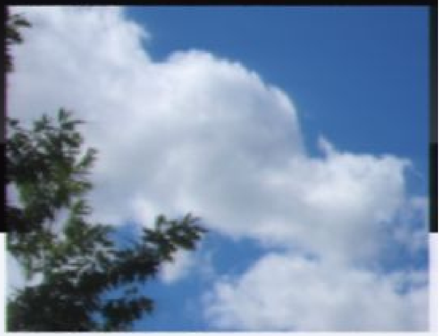

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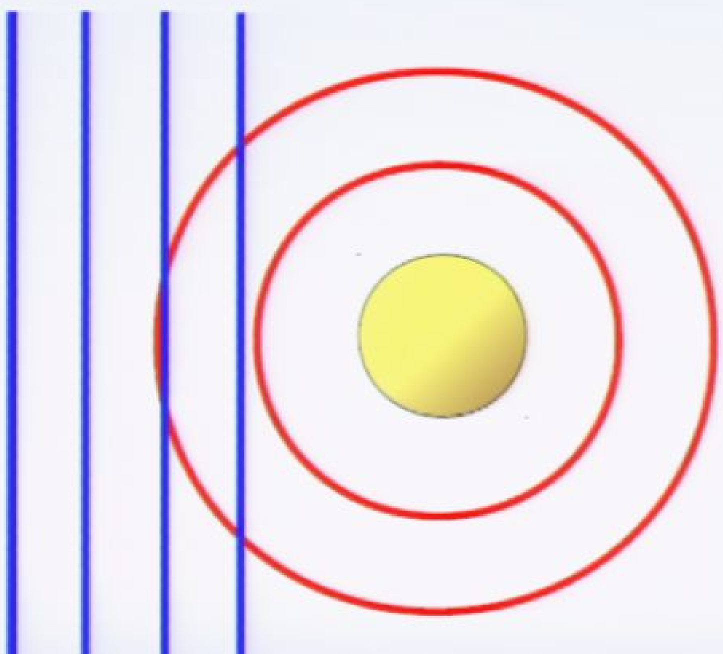

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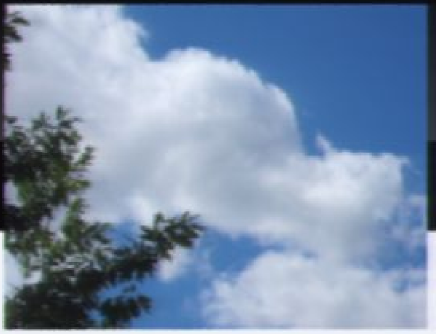

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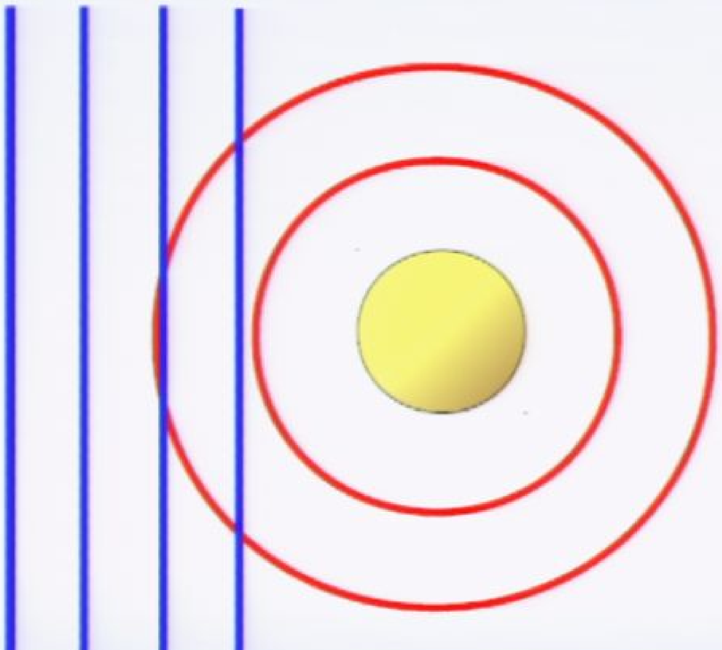

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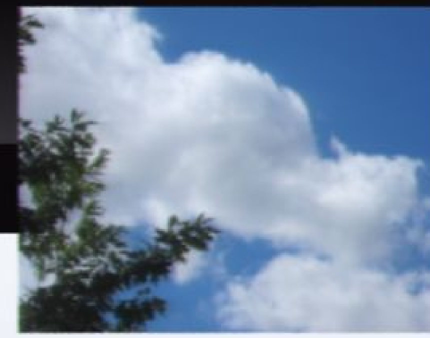

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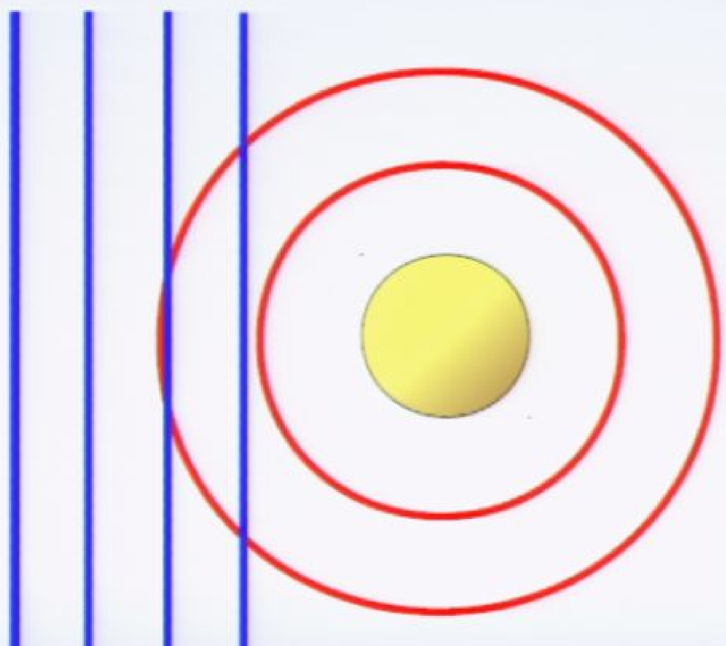

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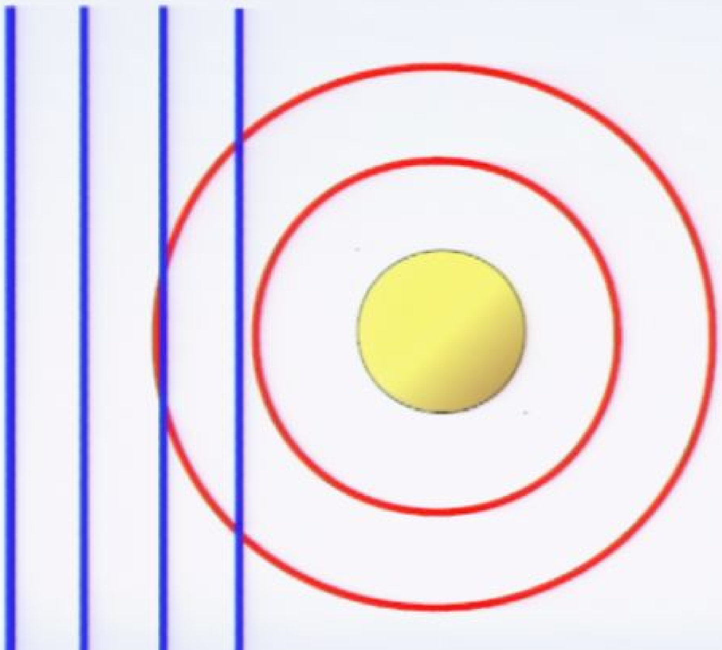

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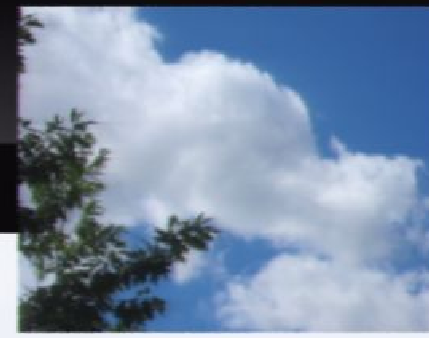

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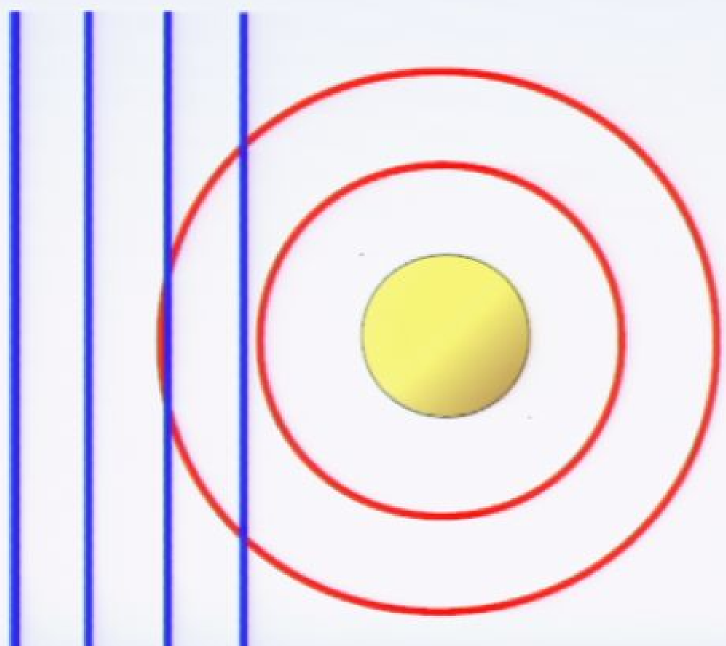

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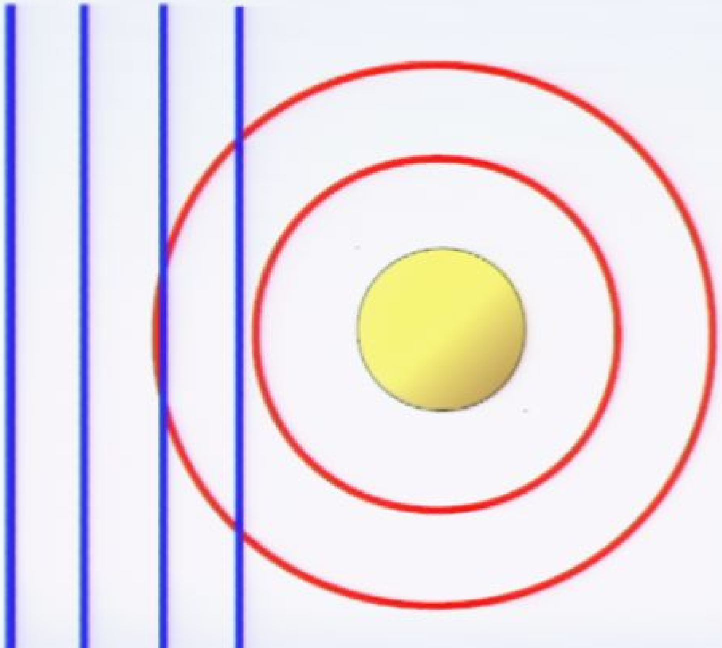

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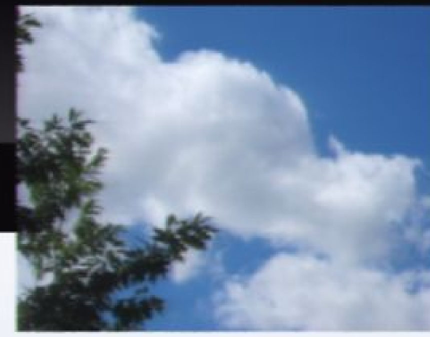

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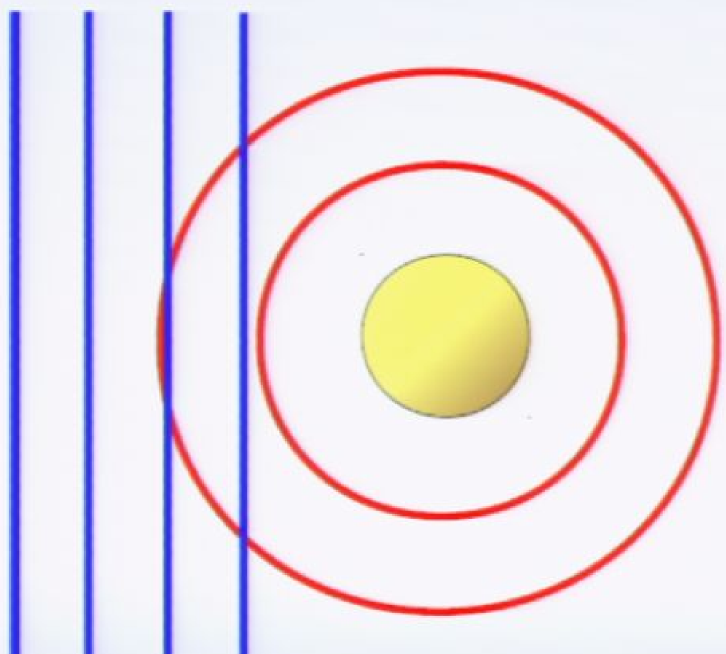

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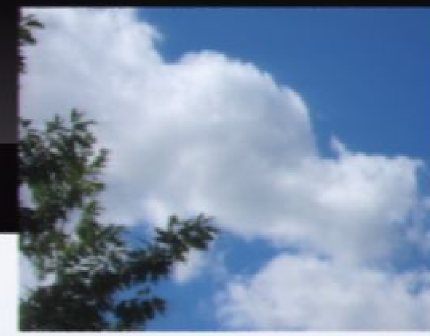

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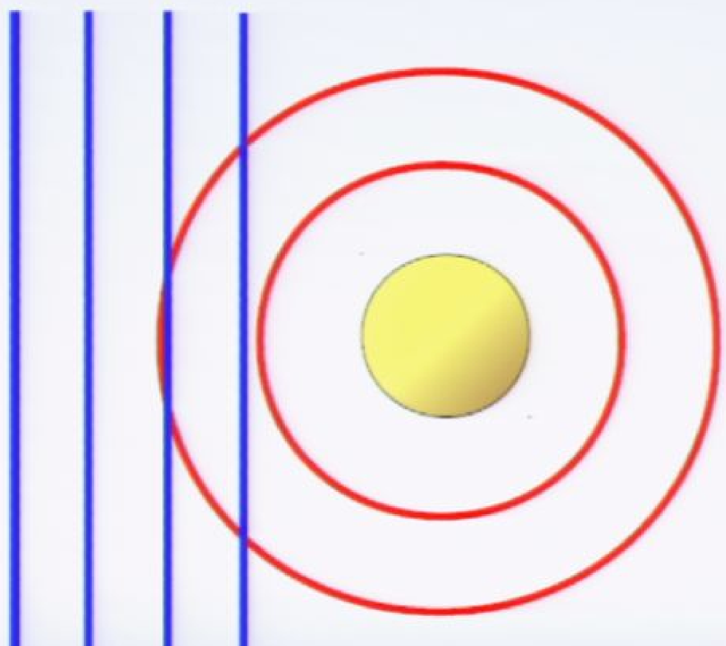

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- Starting point: Maxwell's equations
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- Solution is given as series of Bessel functions

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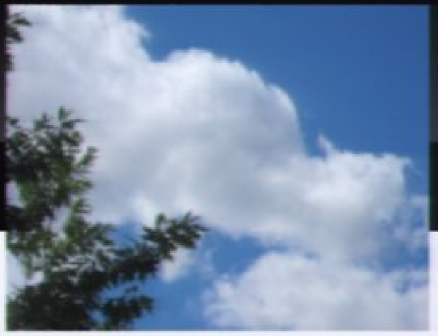

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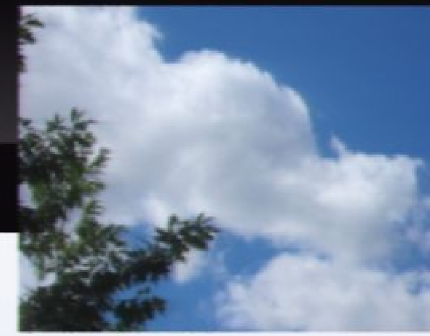

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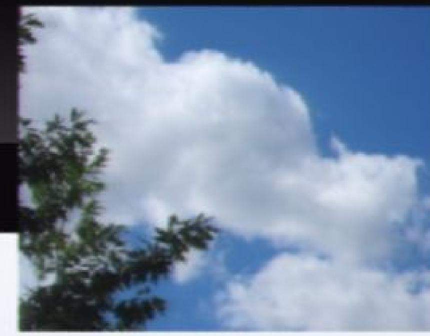

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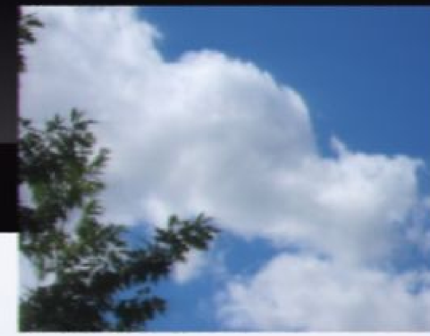

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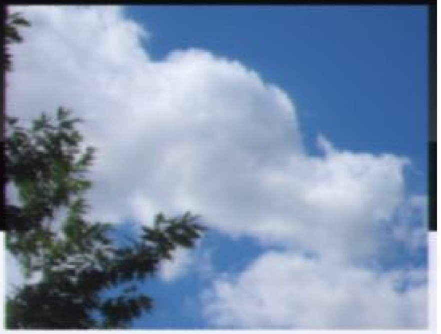

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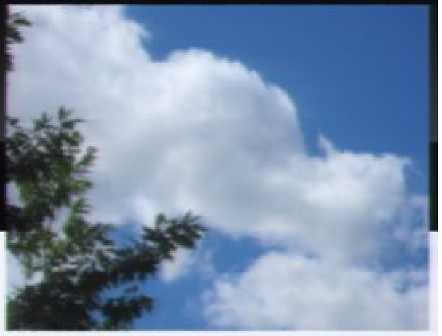

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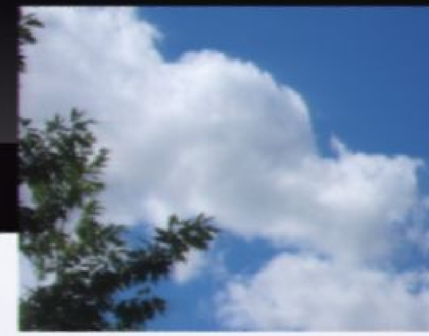

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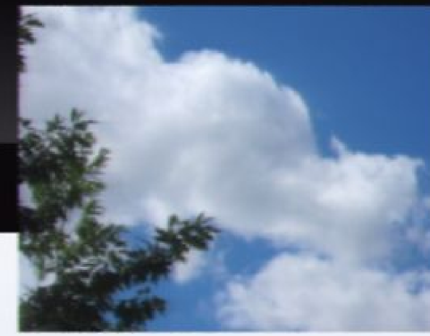

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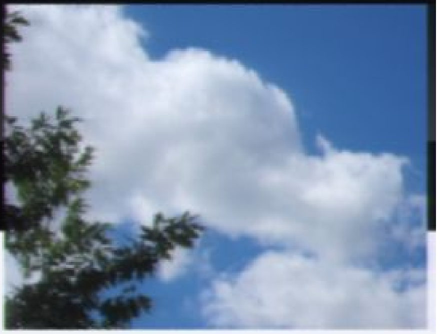

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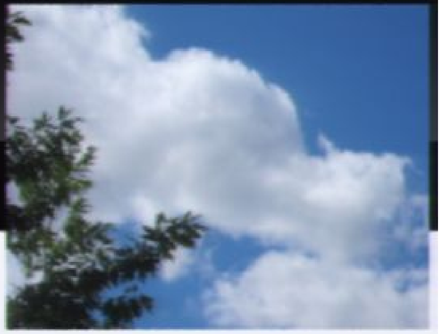

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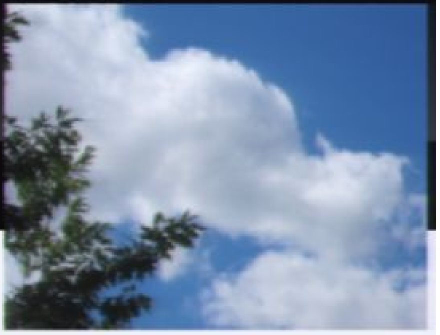

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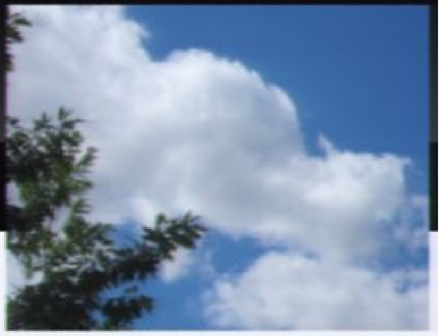

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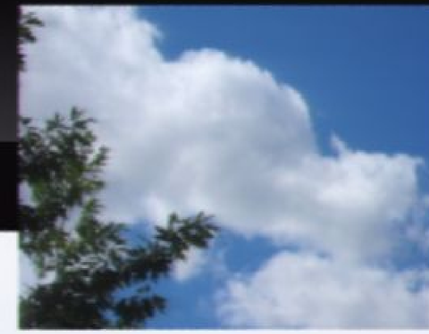

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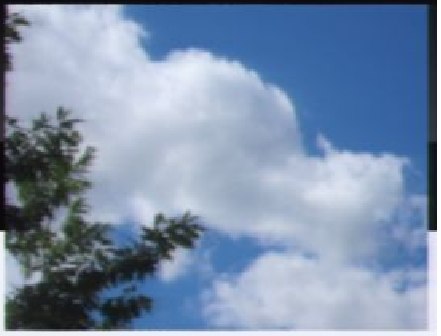

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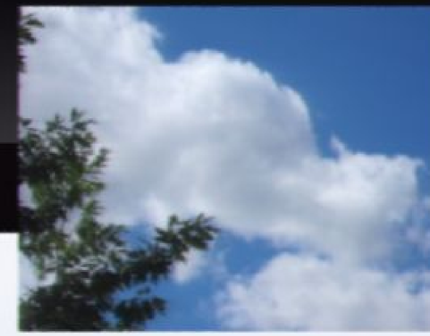

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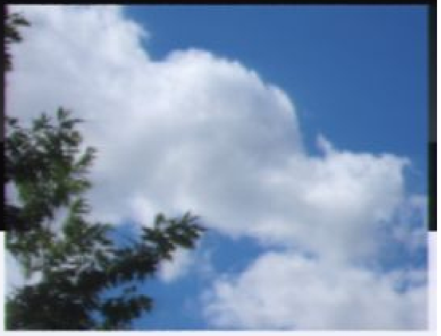

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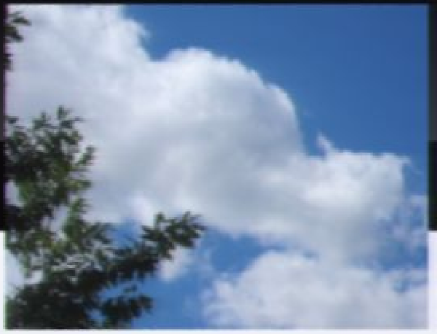

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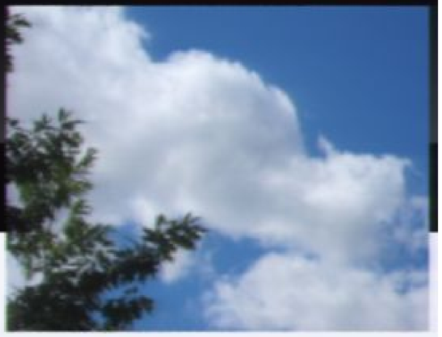

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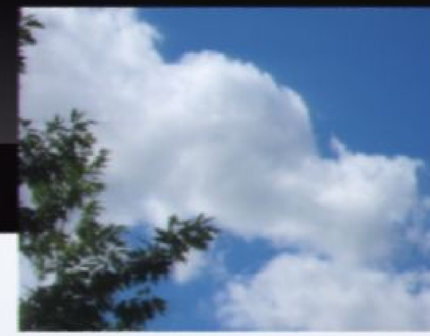

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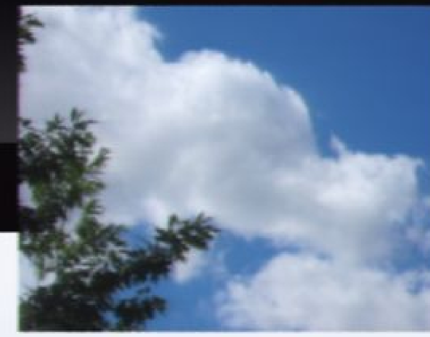

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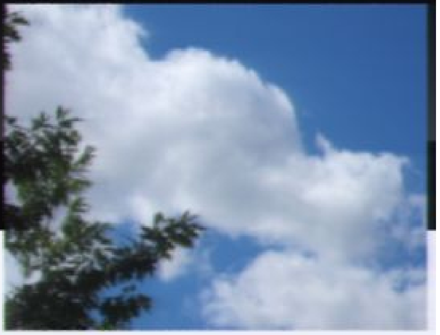

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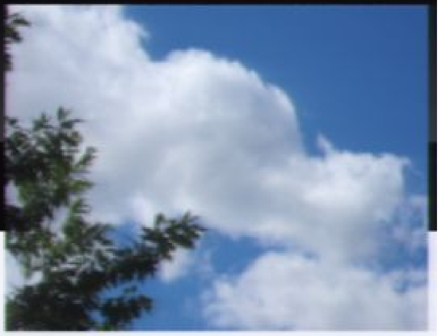

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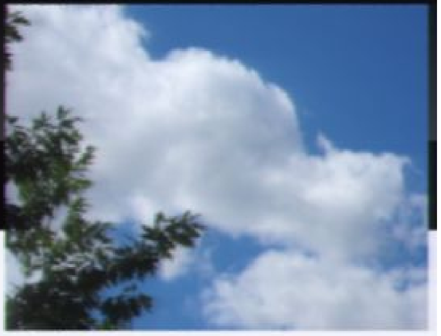

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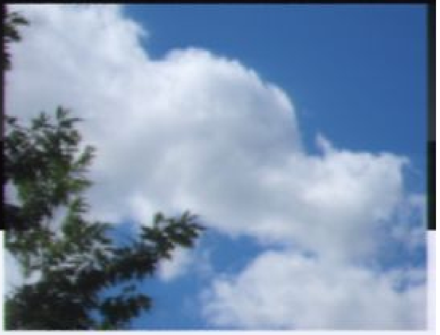

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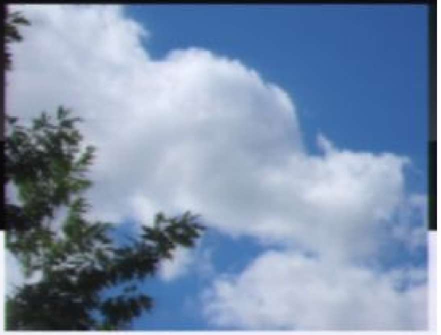

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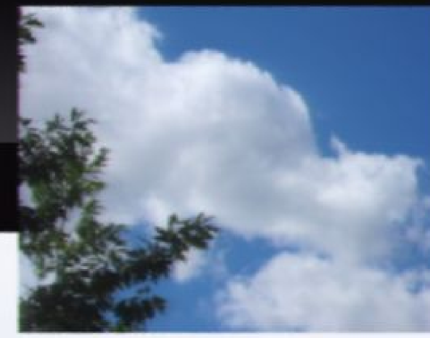

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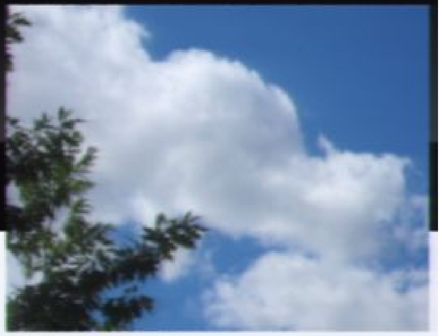

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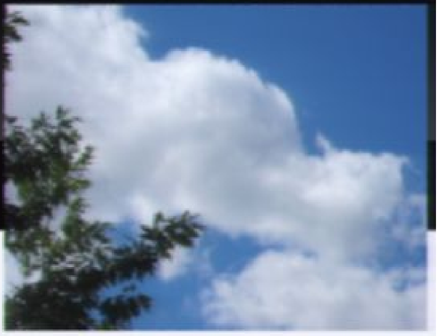

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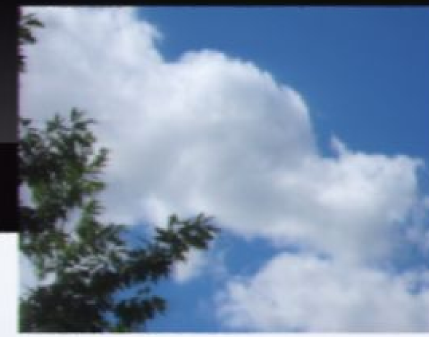

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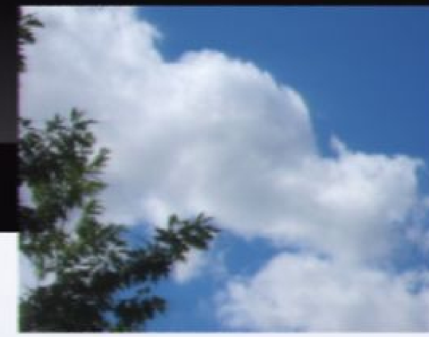

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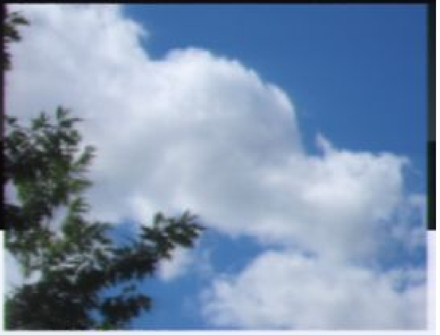

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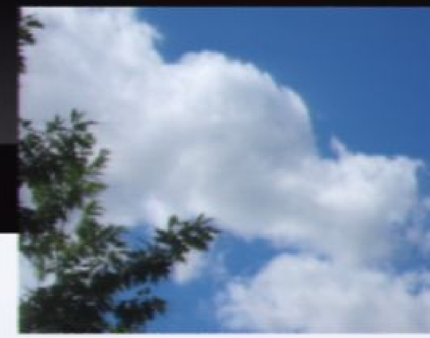

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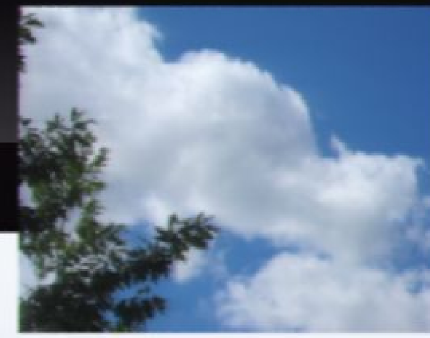

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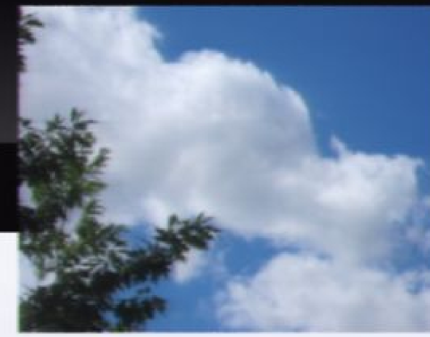

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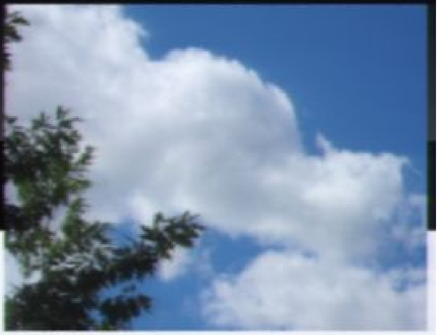

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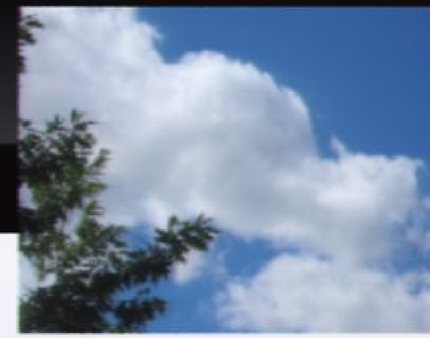

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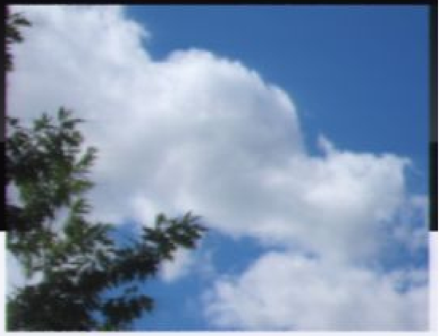

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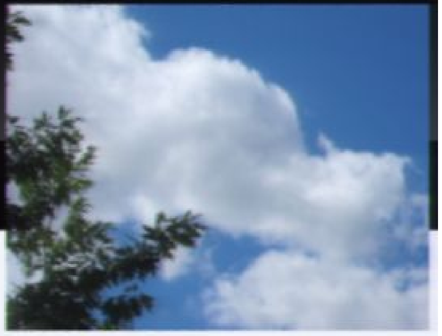

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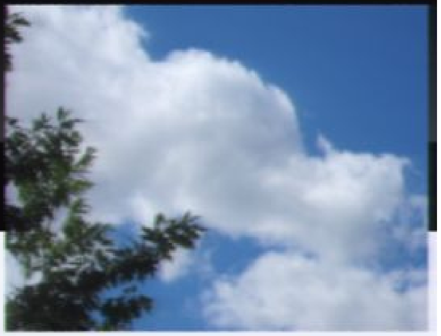

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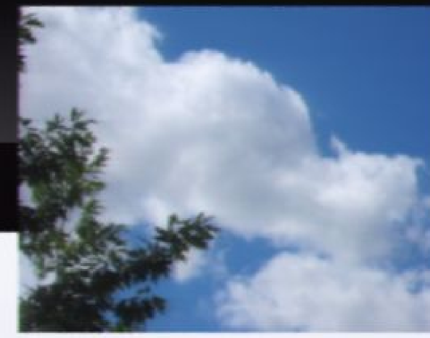

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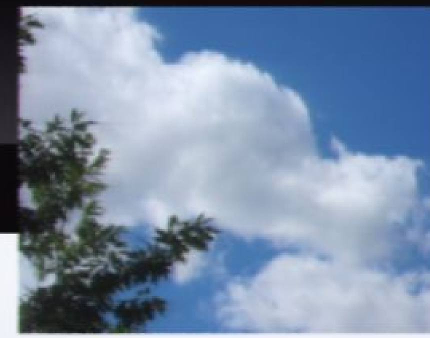

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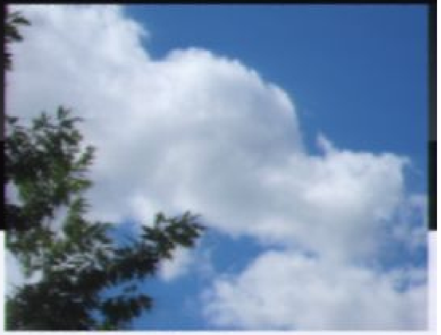

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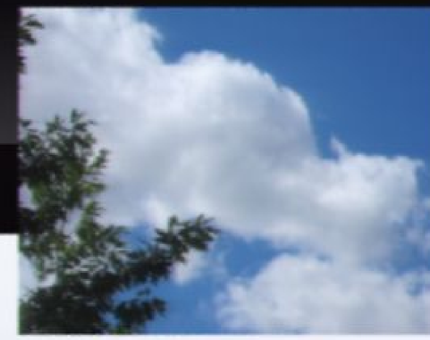

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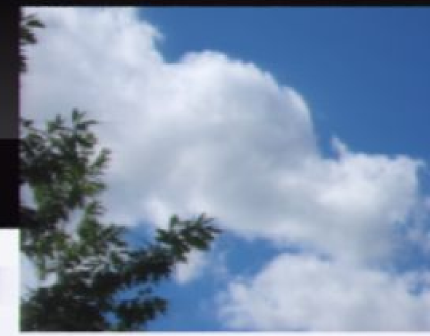

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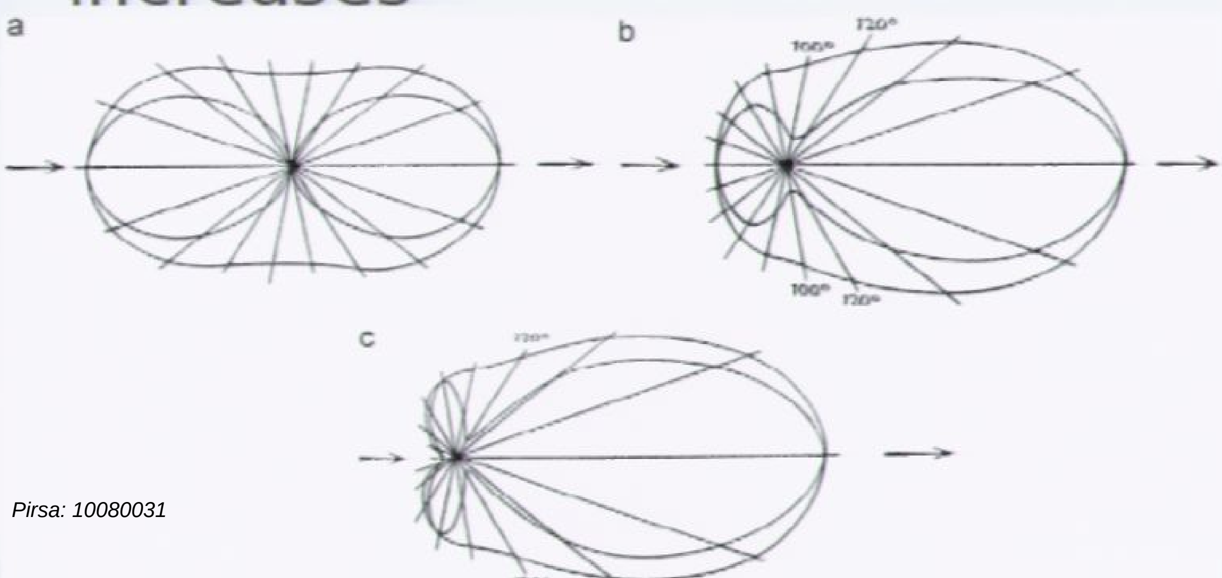
- Particle size increases ⟹ forward scattering increases



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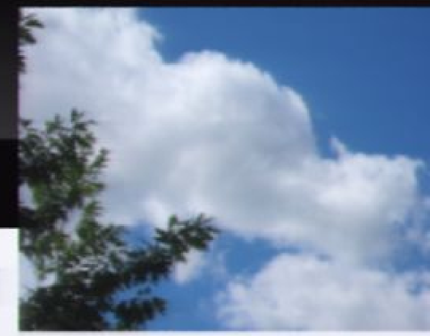

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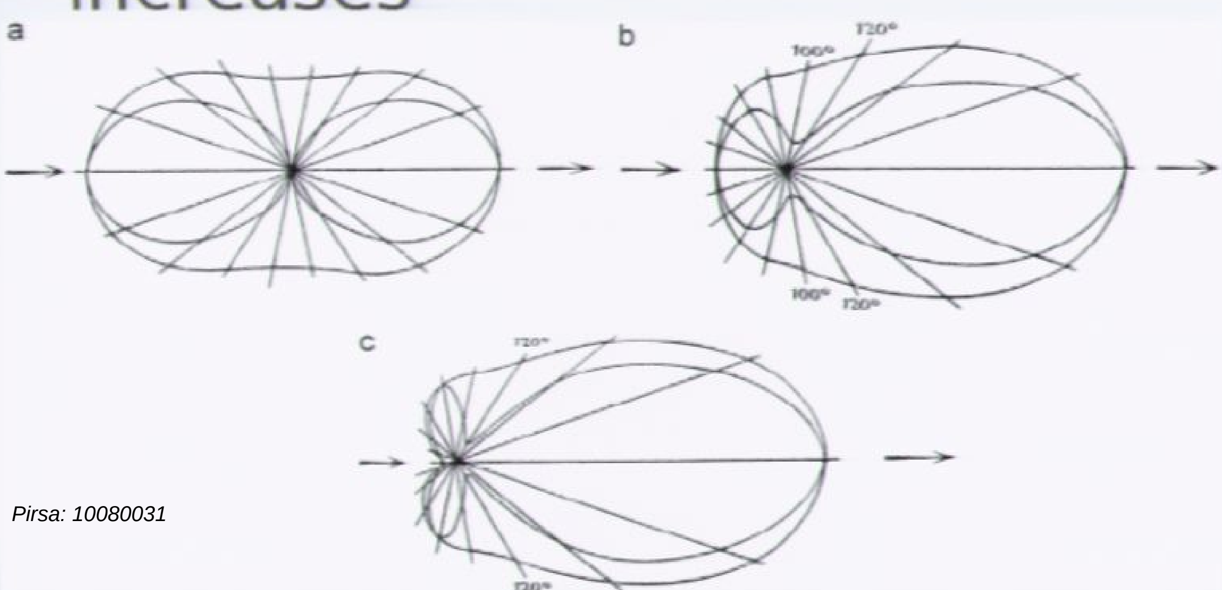

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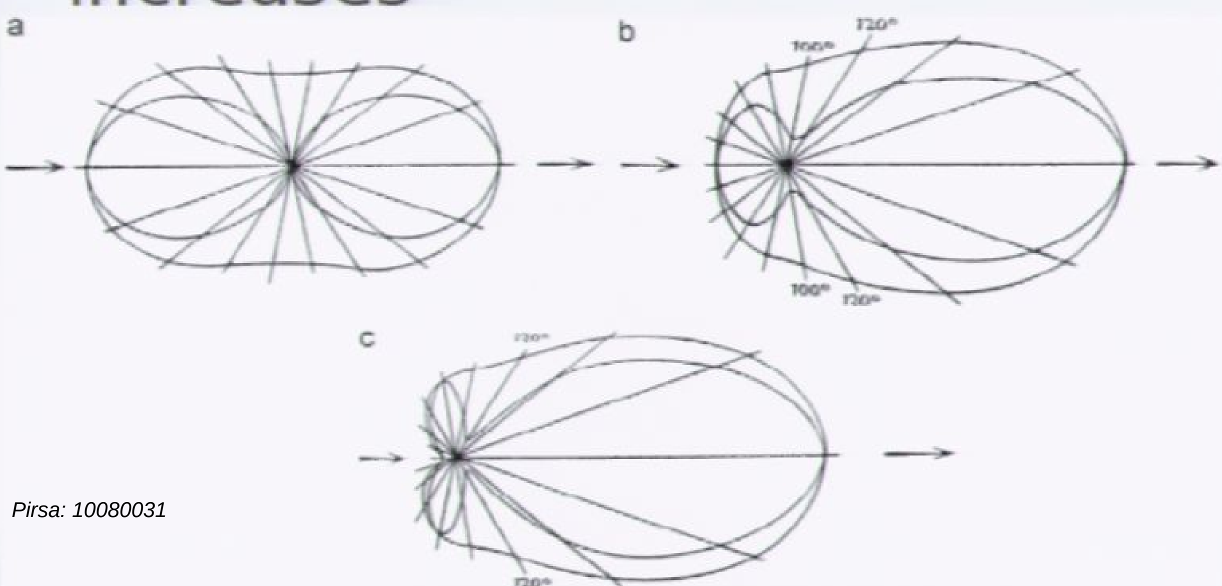

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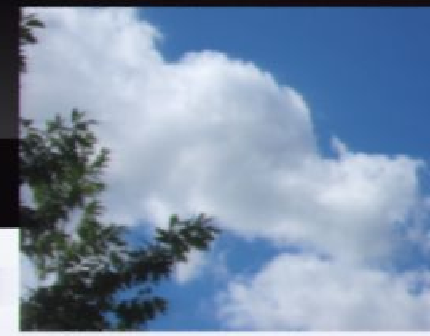

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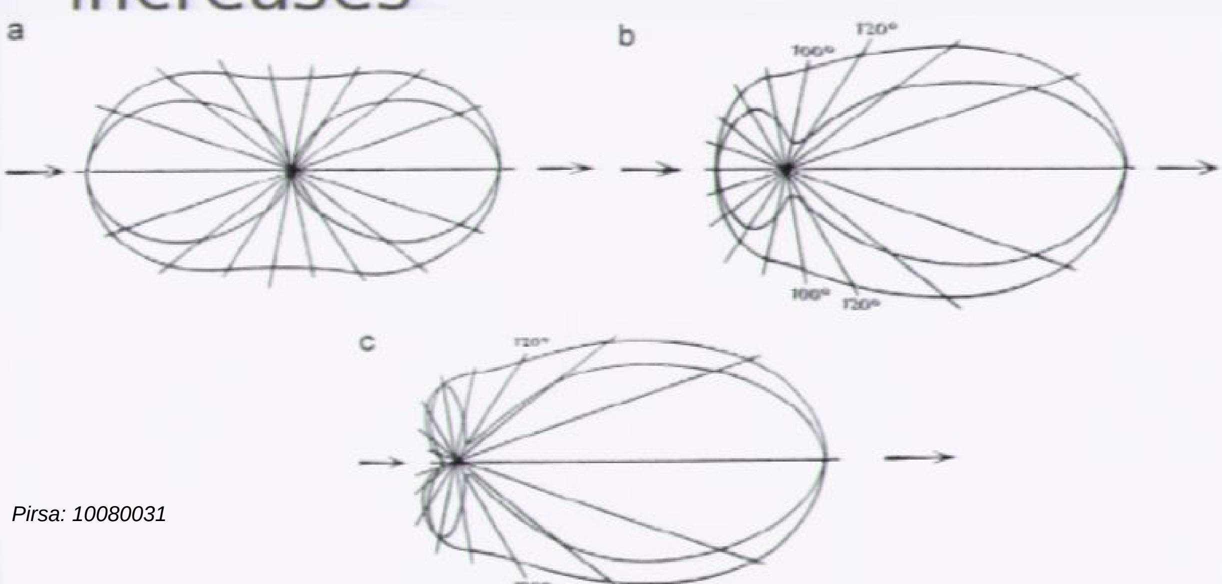

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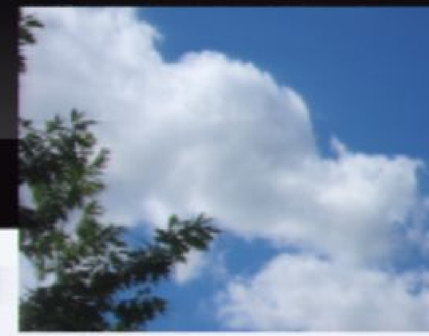

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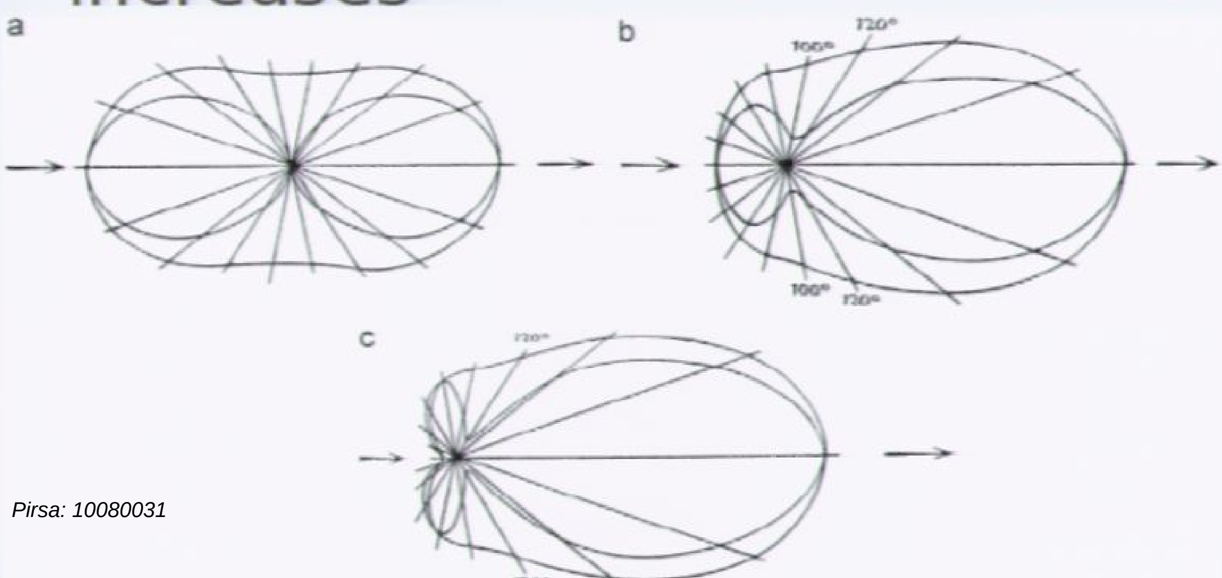

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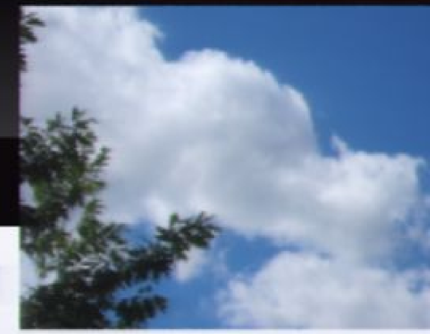

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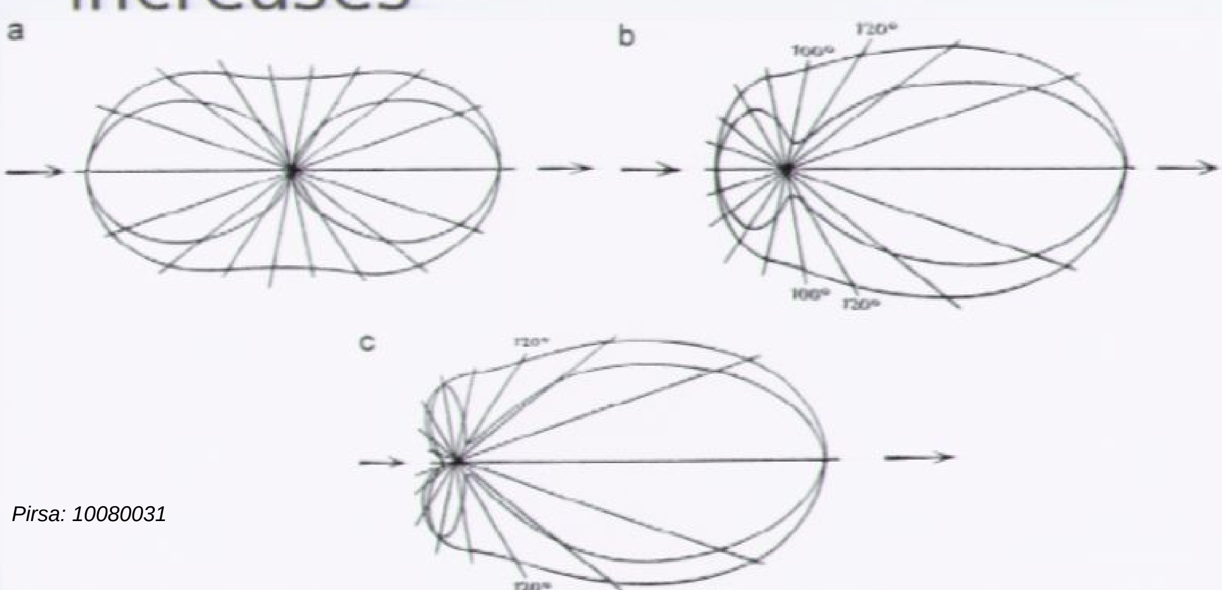

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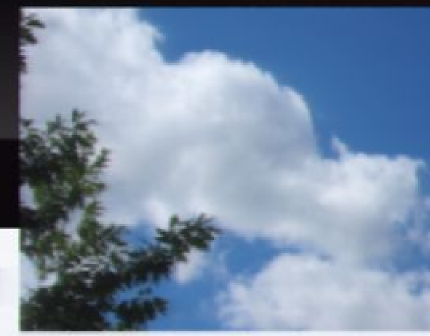

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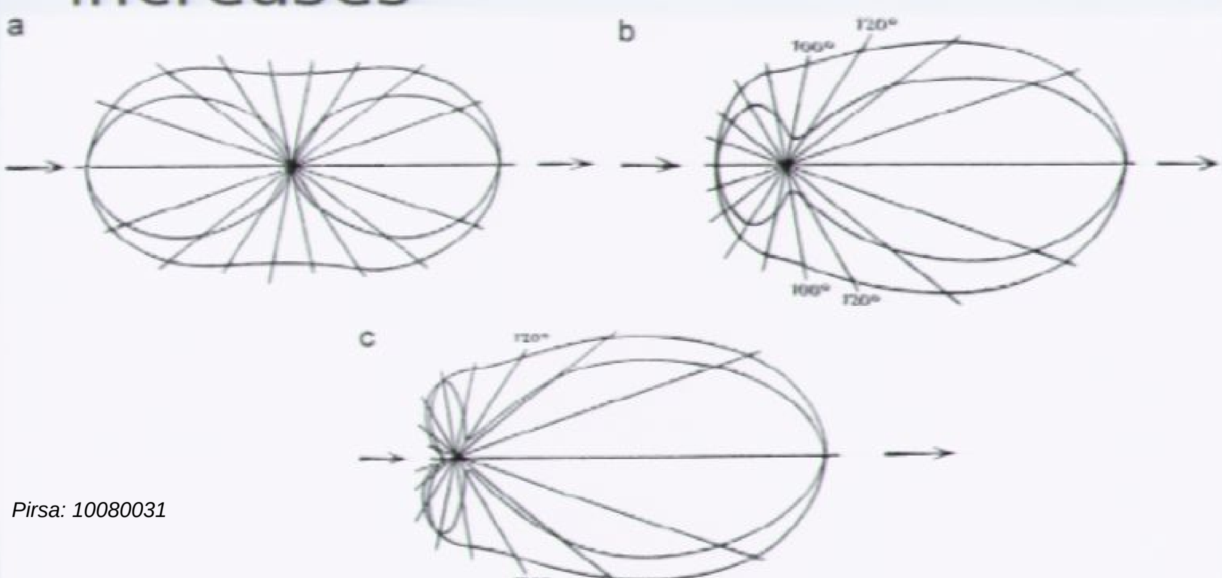

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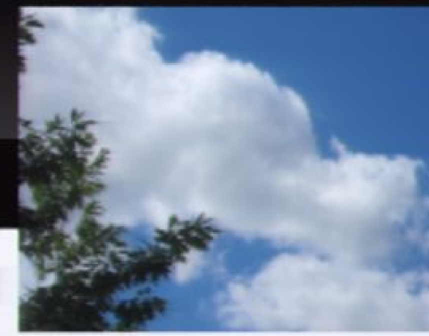

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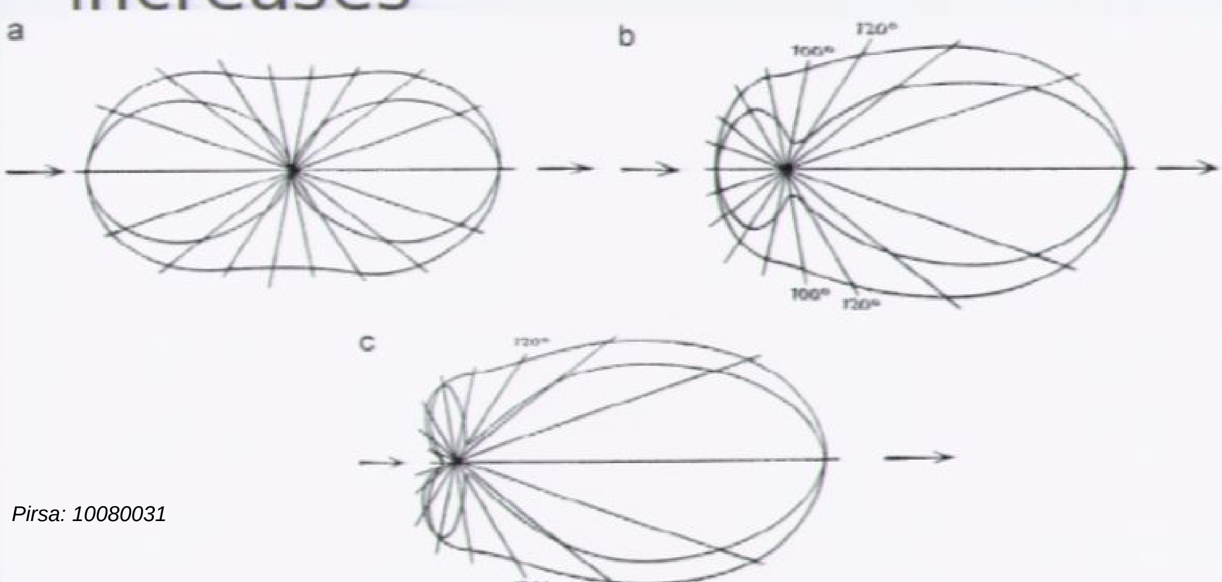

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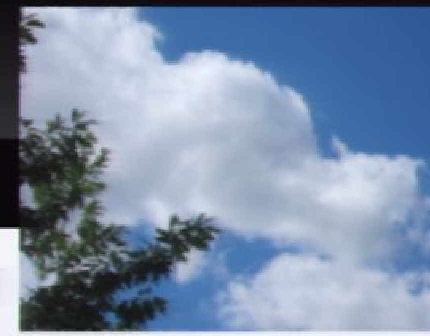

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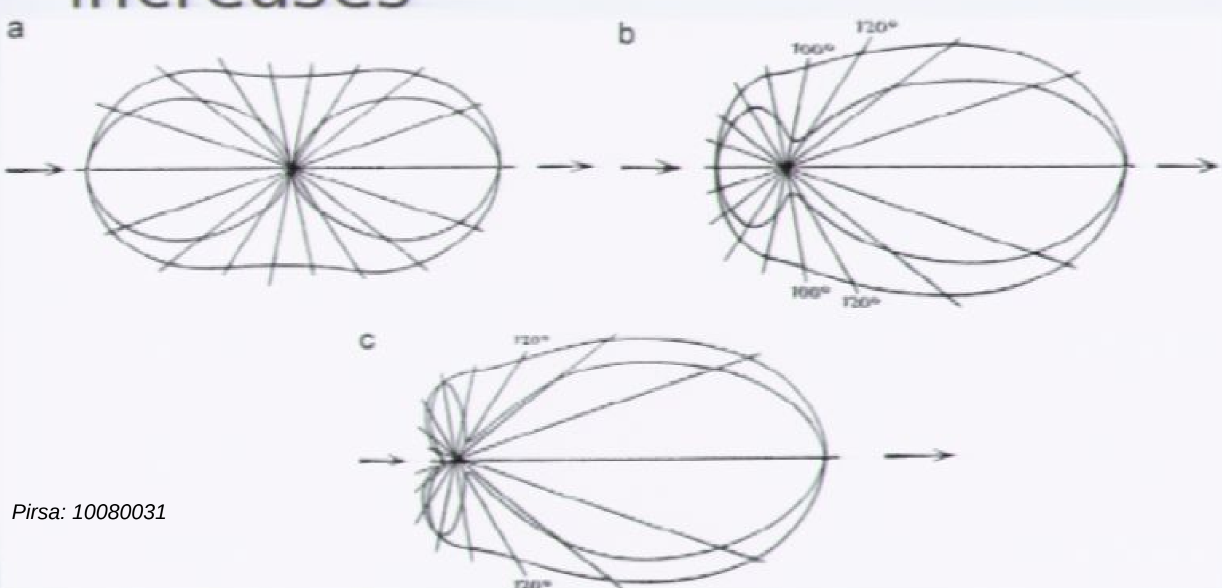

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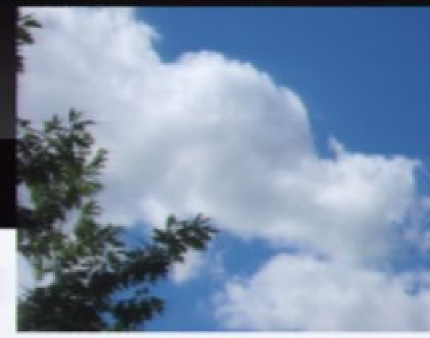

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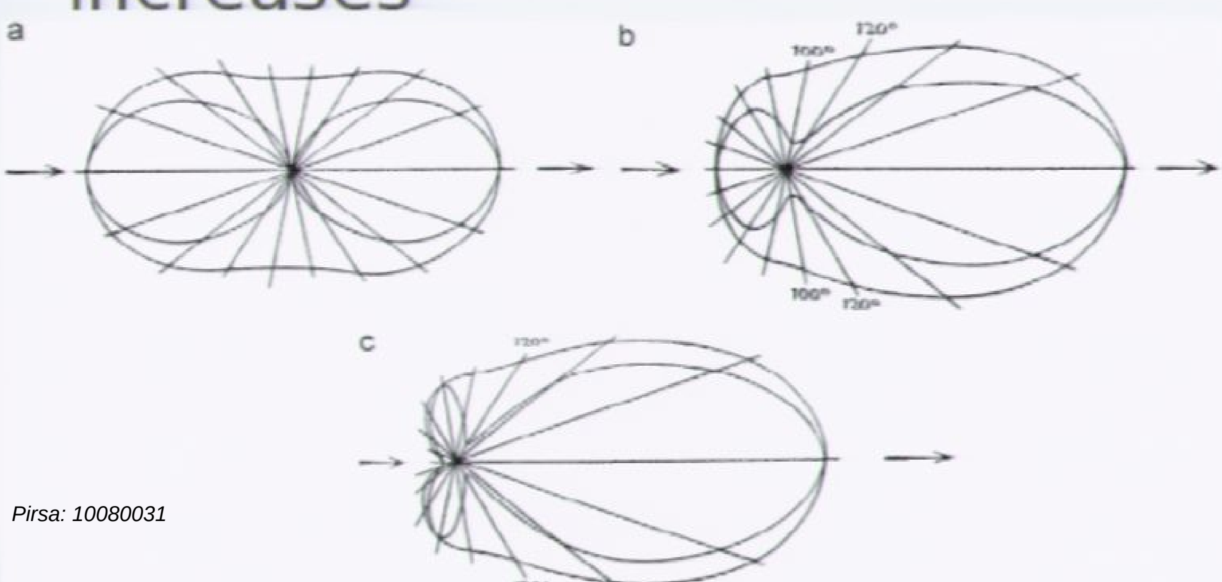

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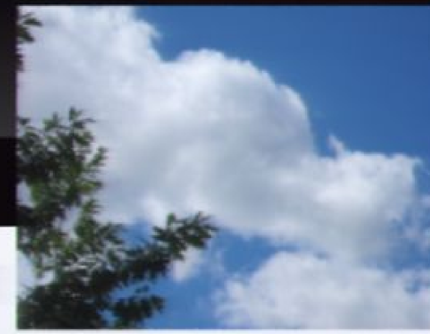

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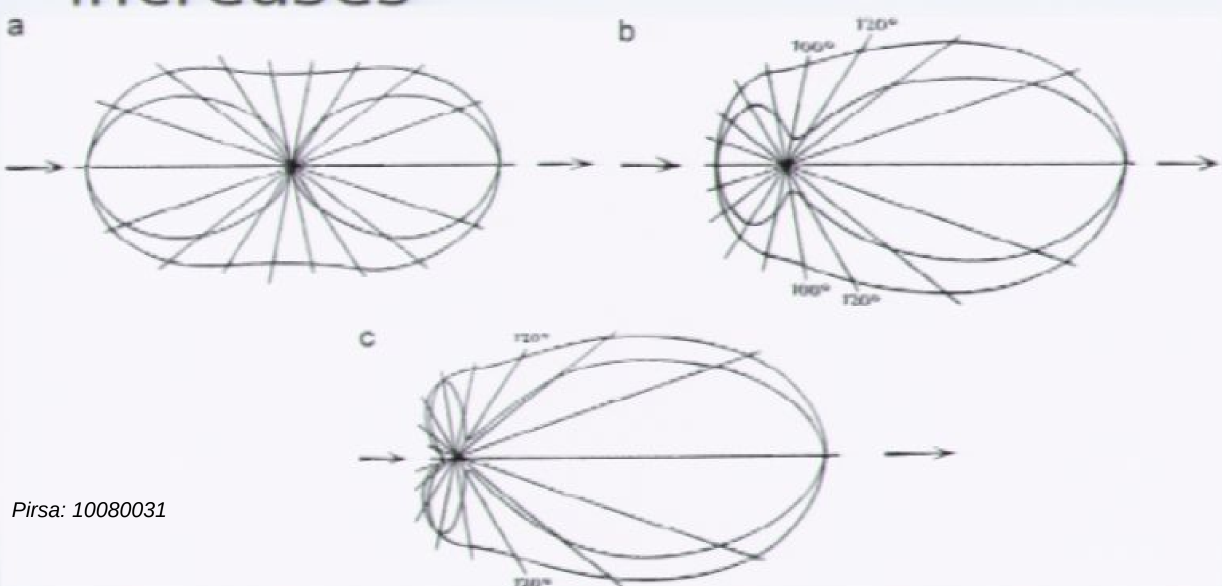

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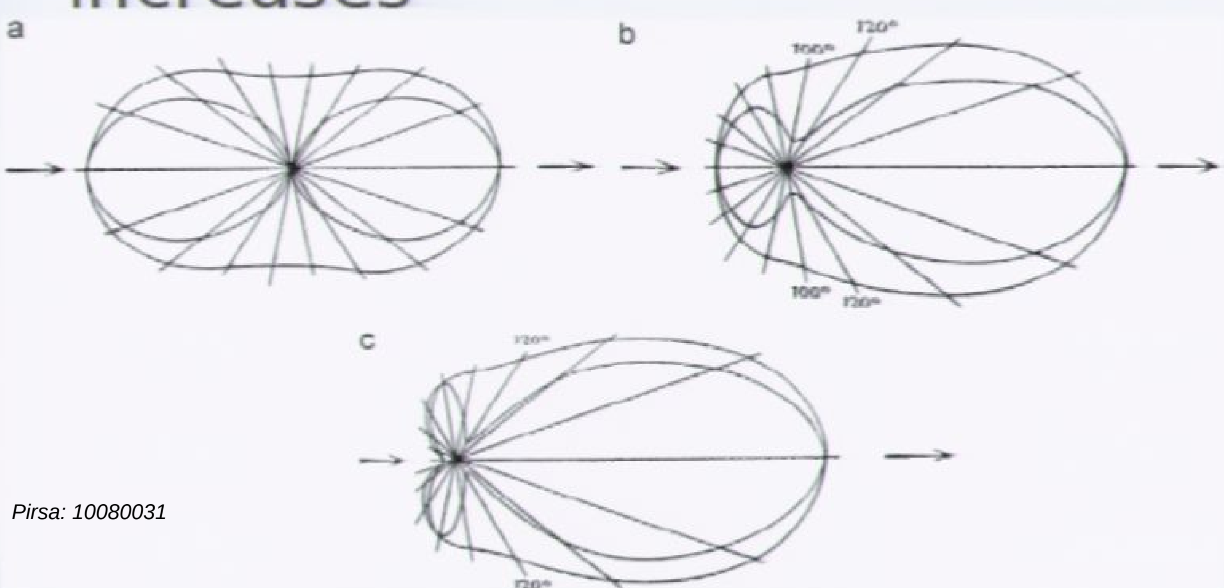

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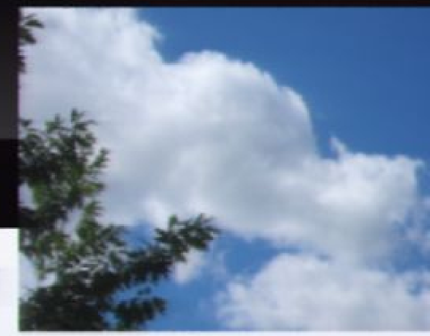

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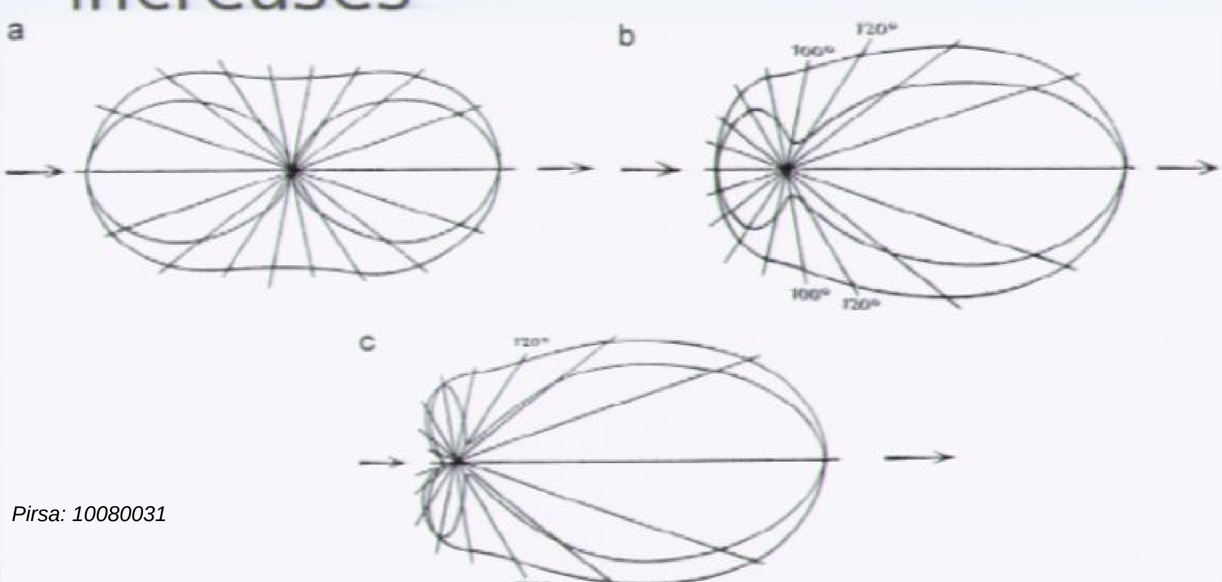

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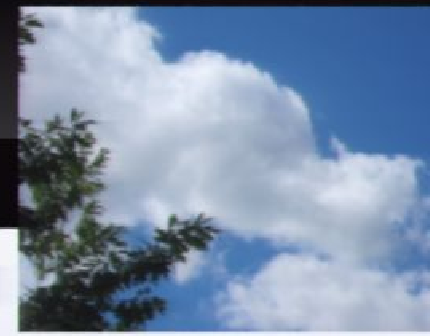

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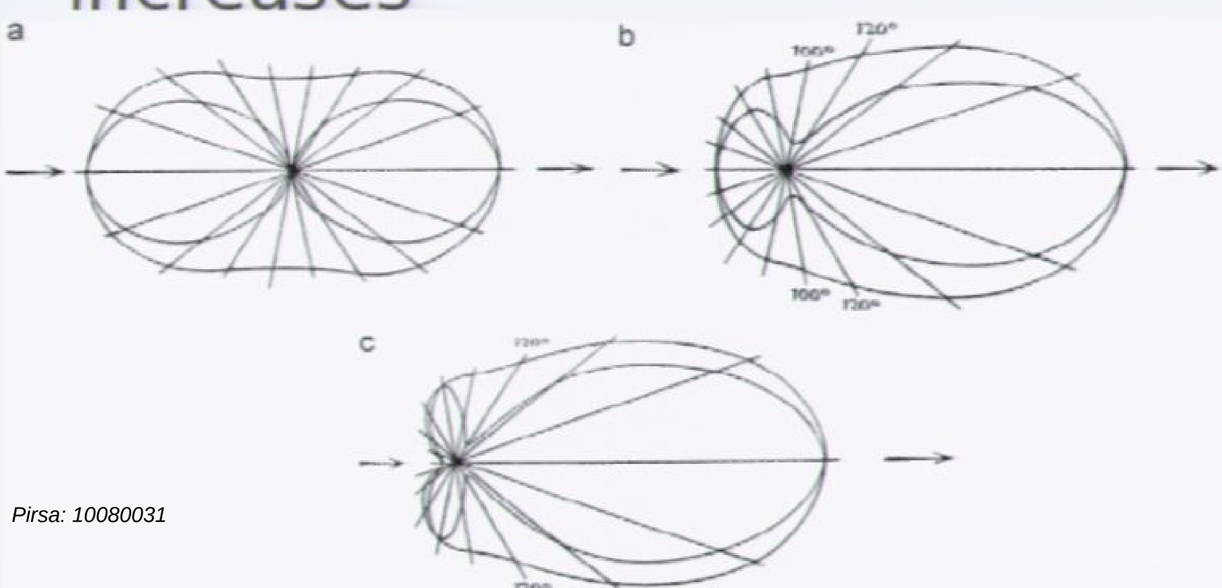

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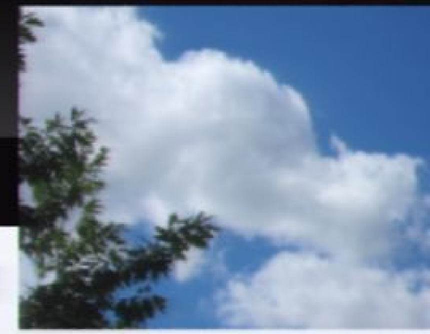

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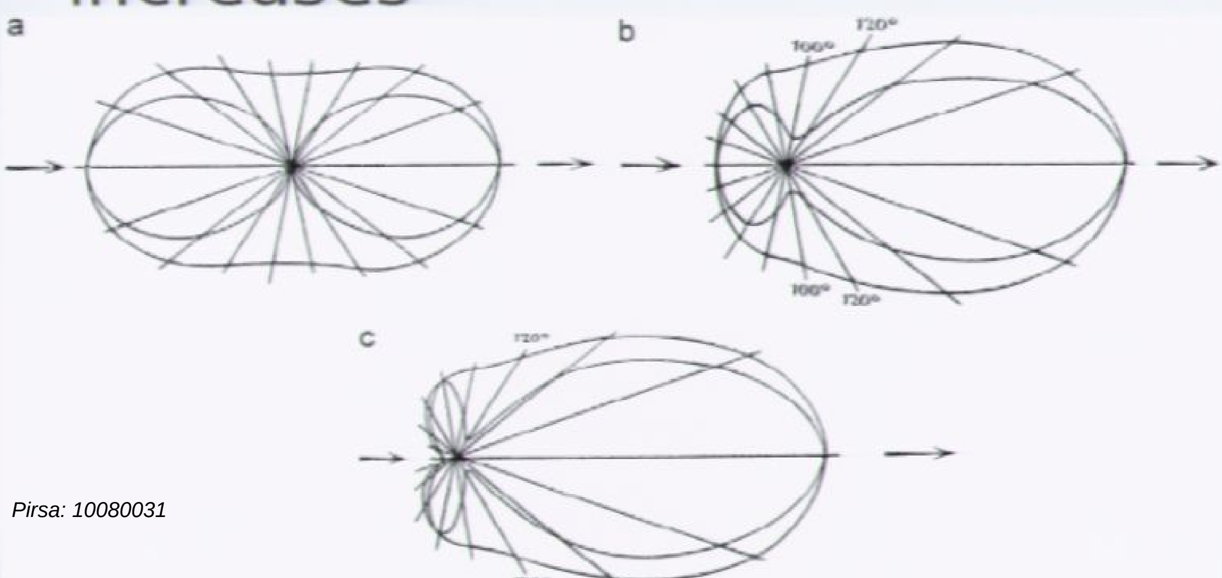

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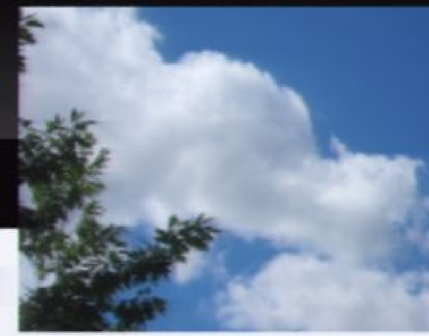

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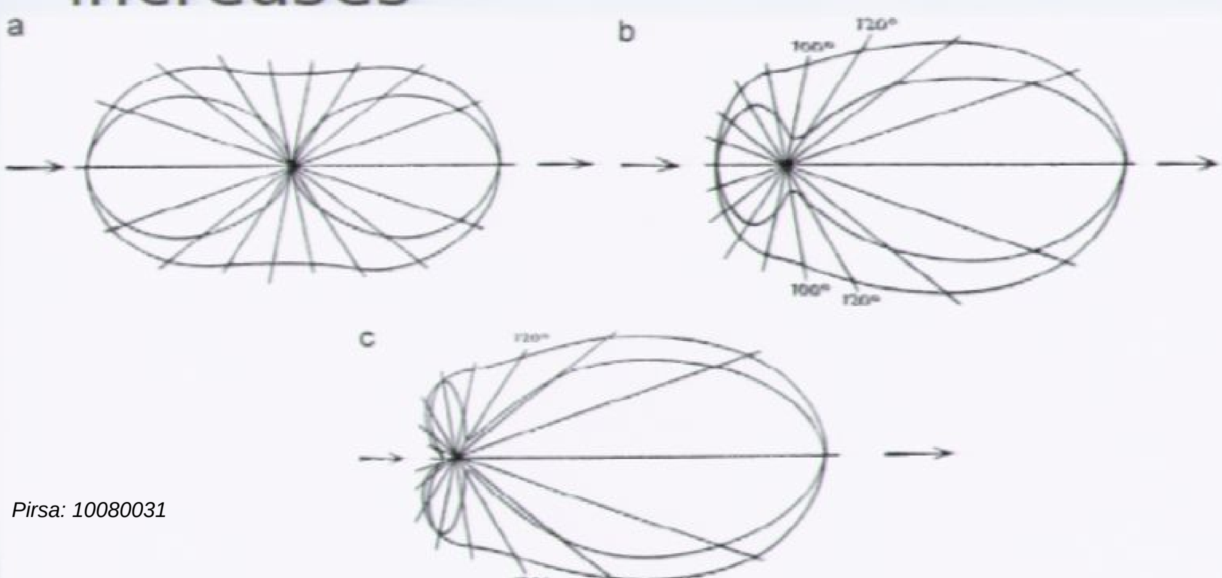

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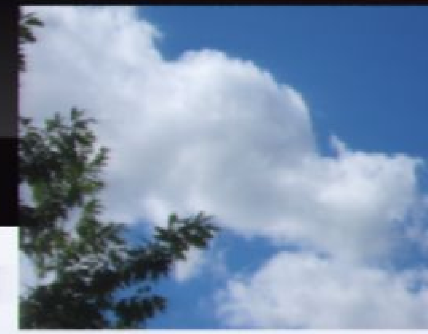

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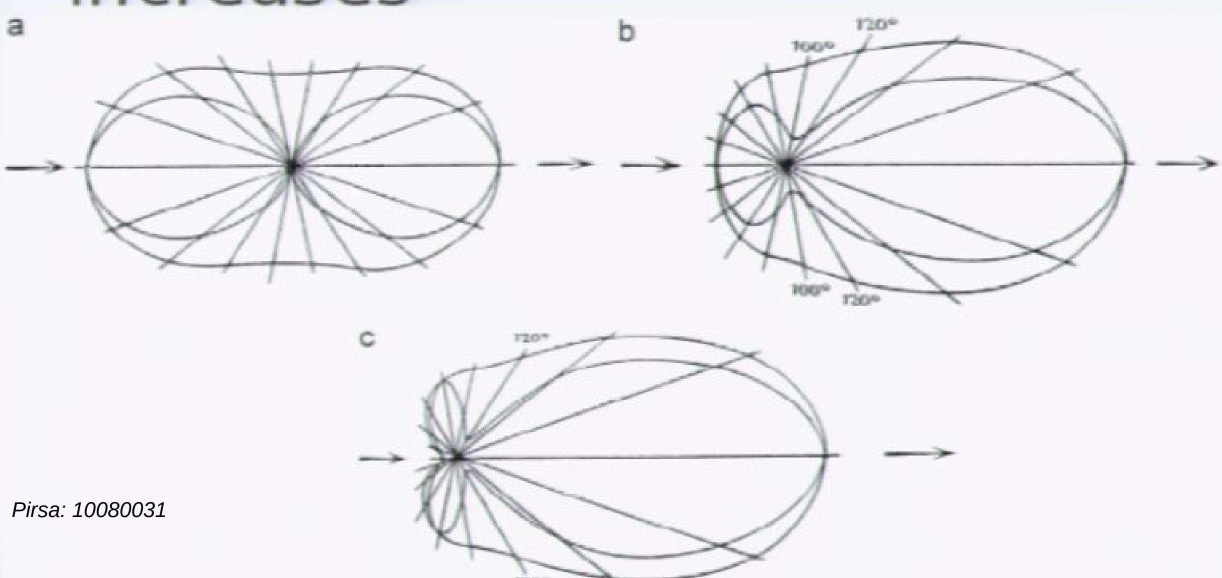

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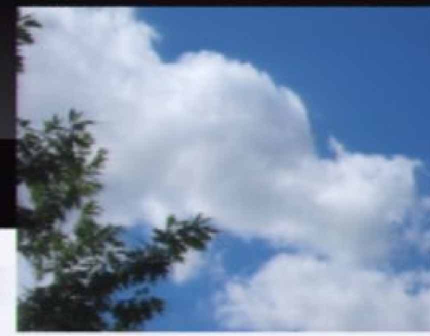

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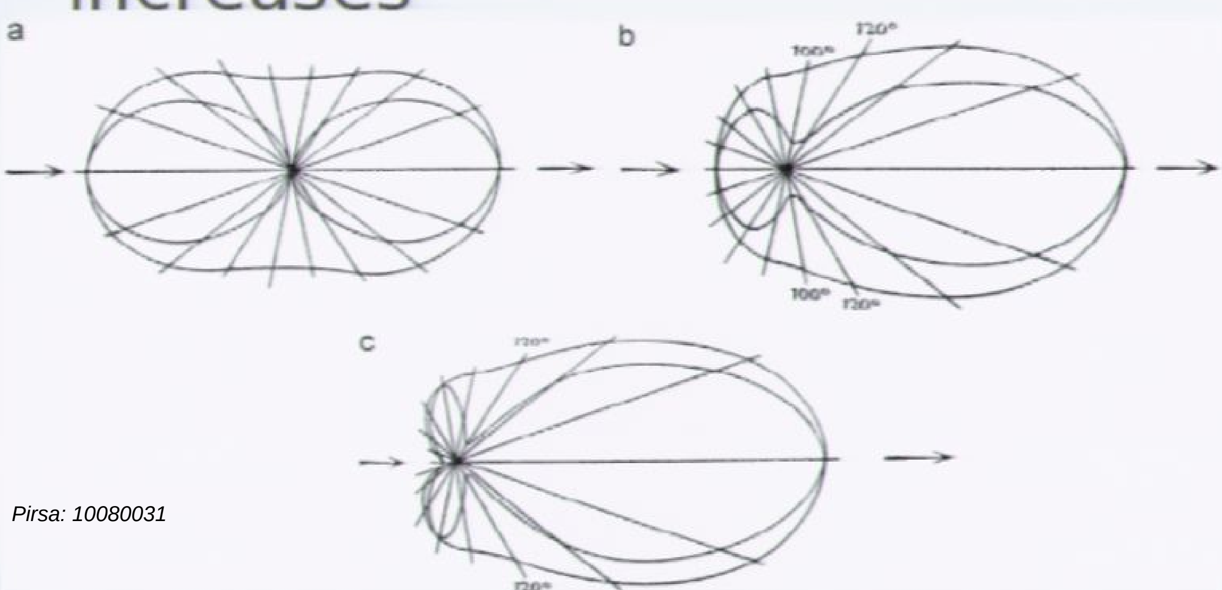

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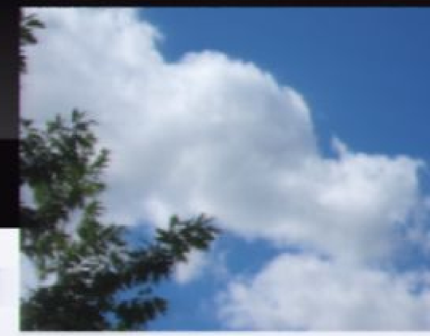

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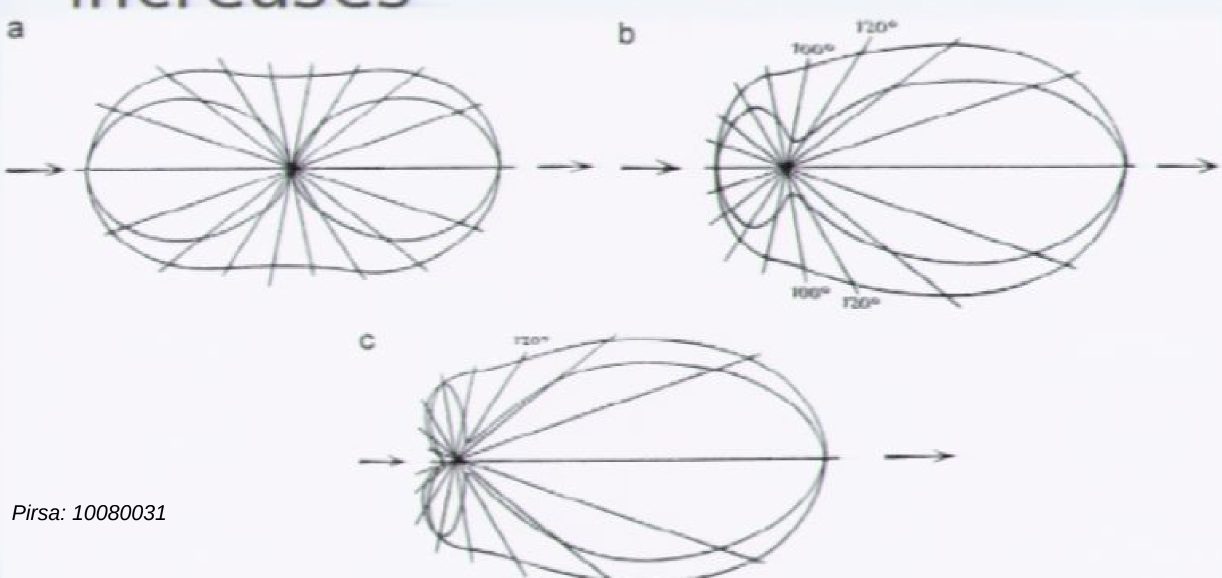

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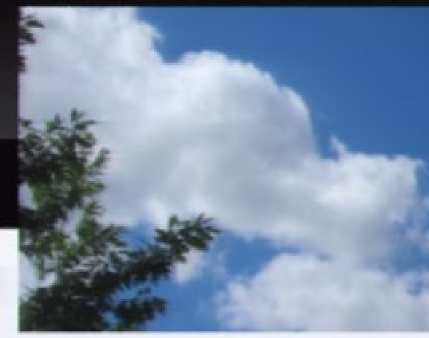

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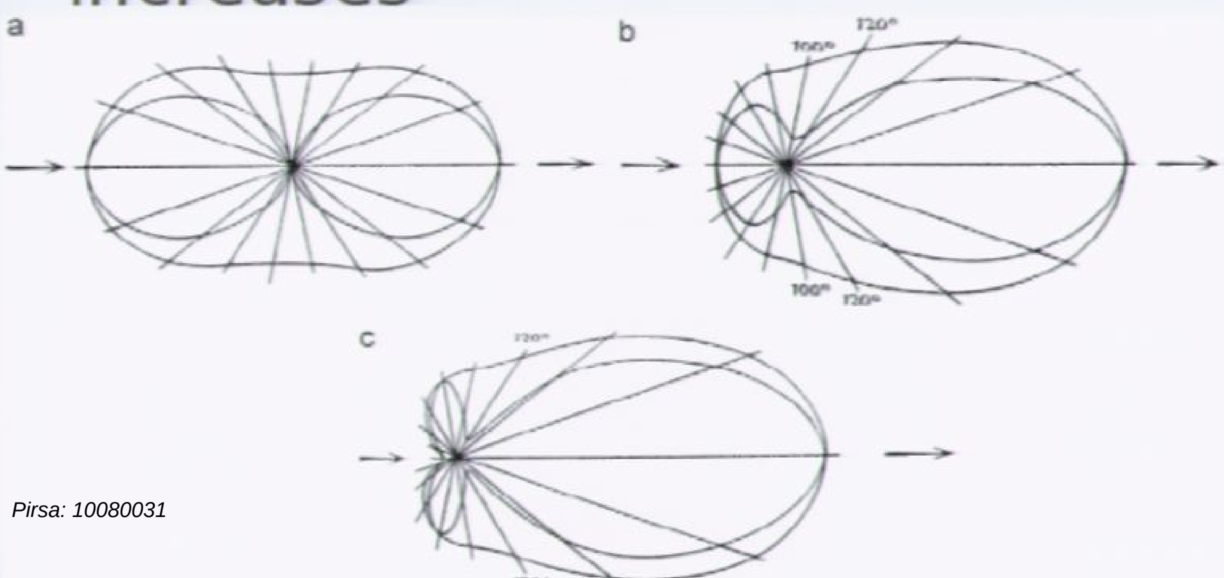

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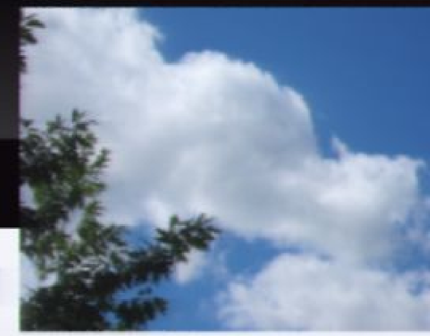
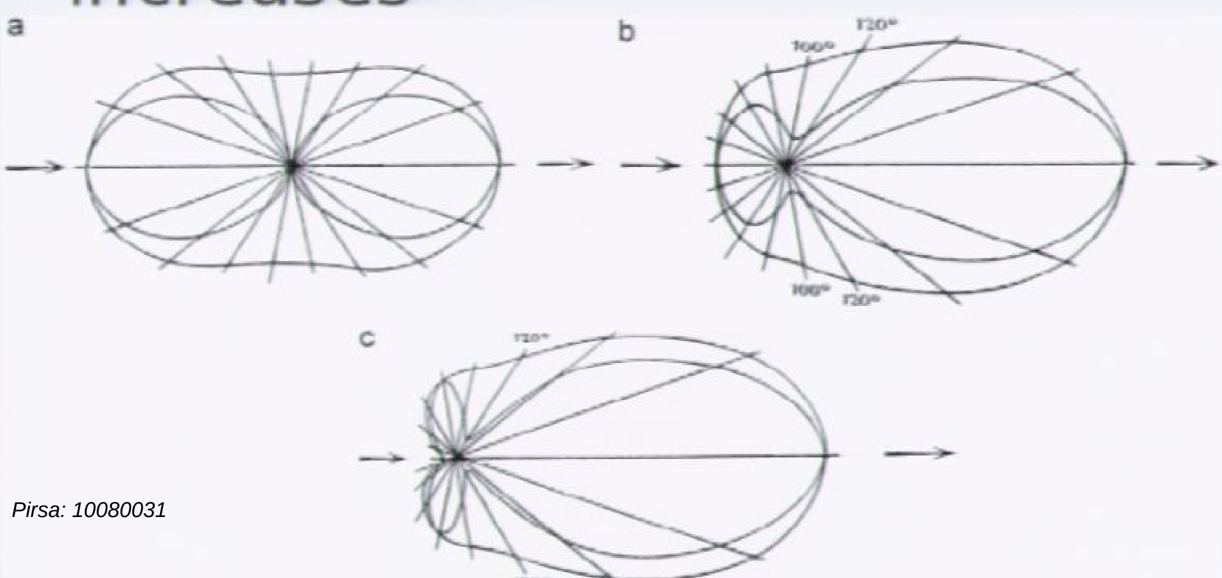


- Point like particles ⟹ $1/\lambda^4$ Rayleigh law
- Particles greater than wavelenght: scattering depends only weakly on λ

Sun light is white, so clouds scatter white light!

- Particle size increases ⟹ forward scattering increases



Polar diagrams:

Incident light: λ=*550 nm*

Particle size:

a) Point like

b) 160nm

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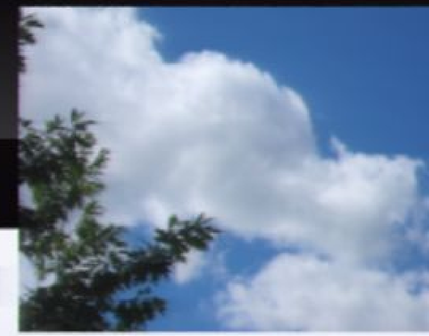

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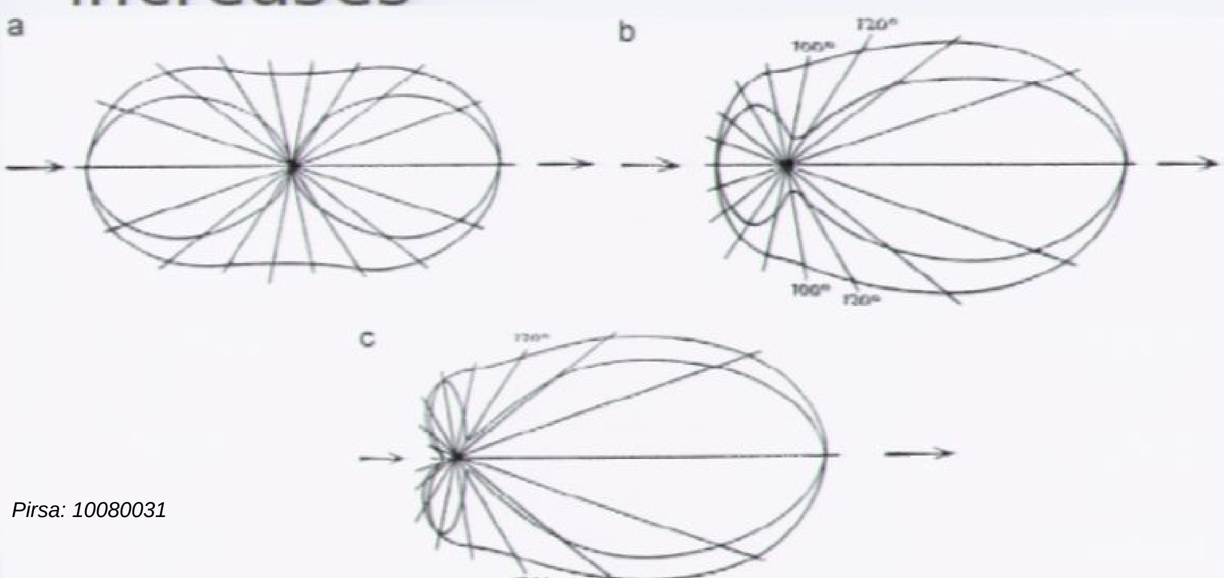

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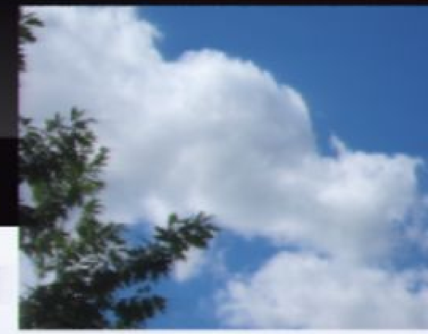

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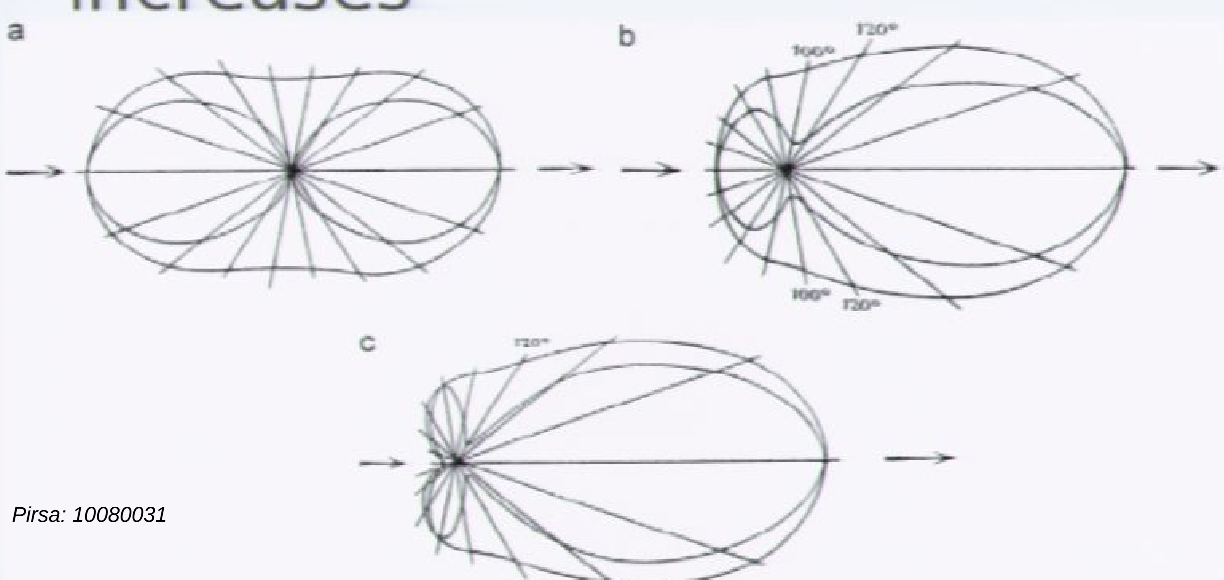

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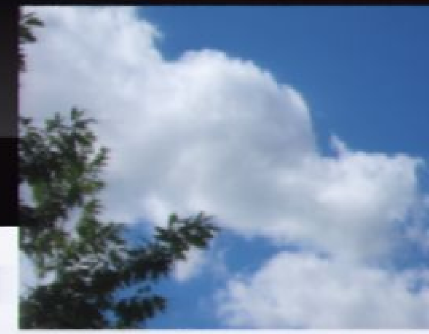

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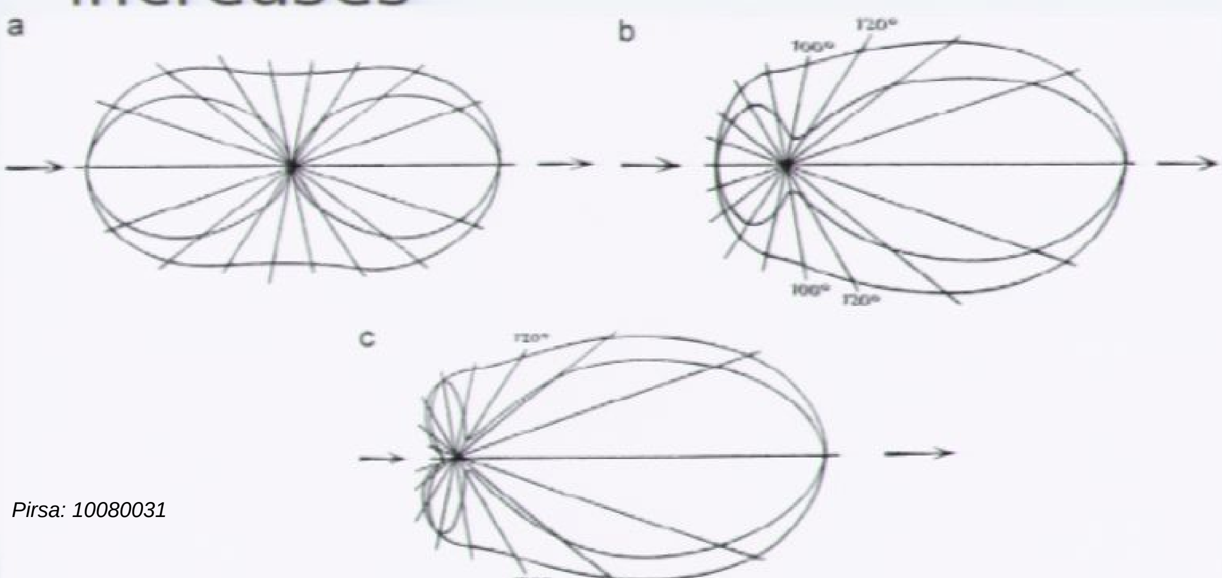

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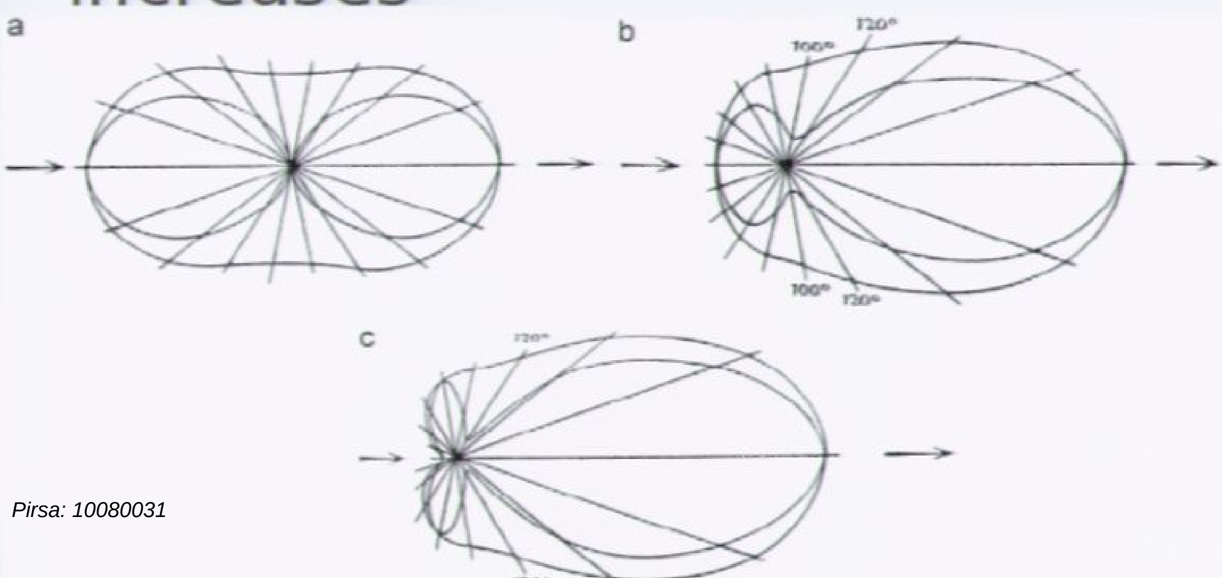

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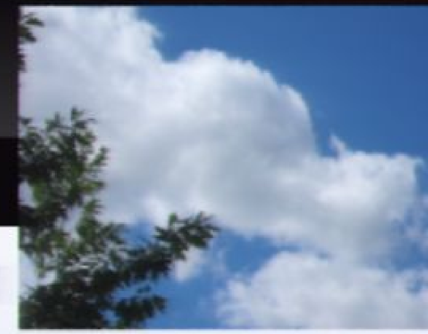

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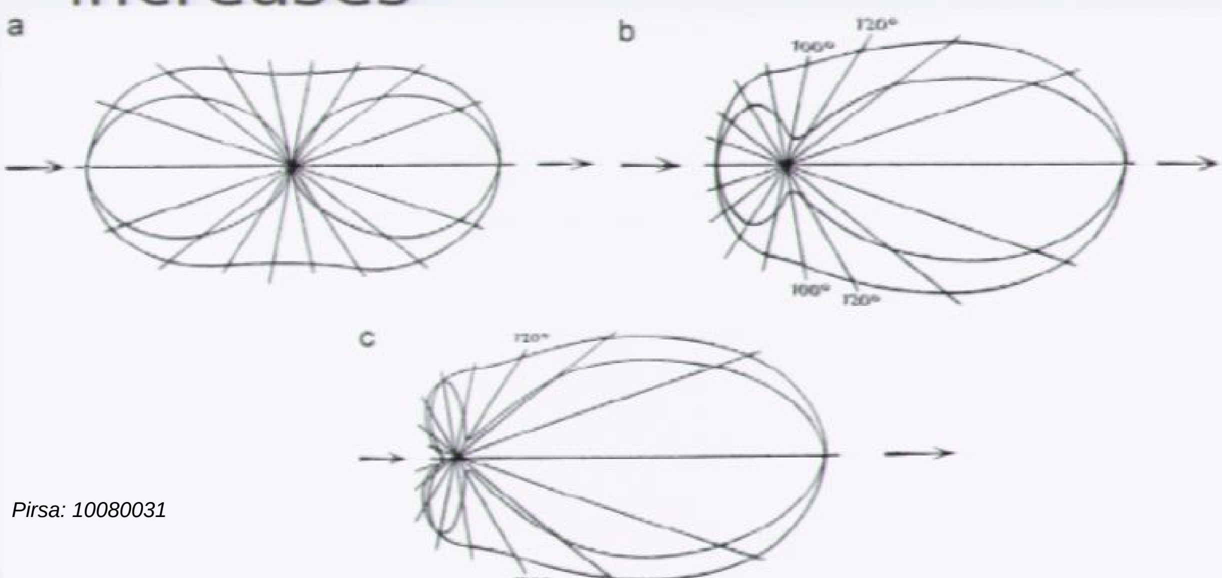

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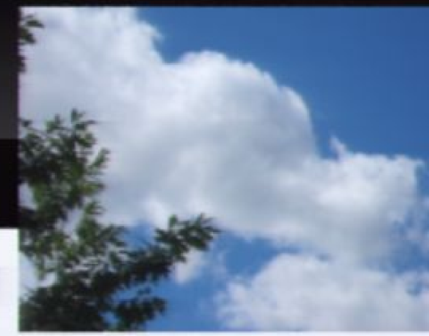

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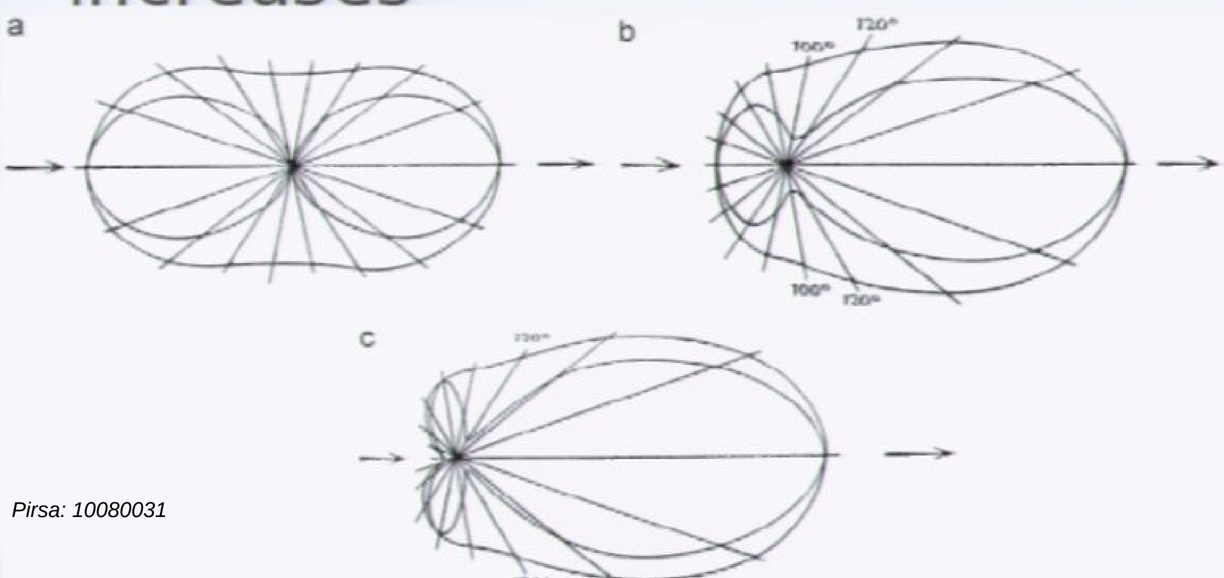

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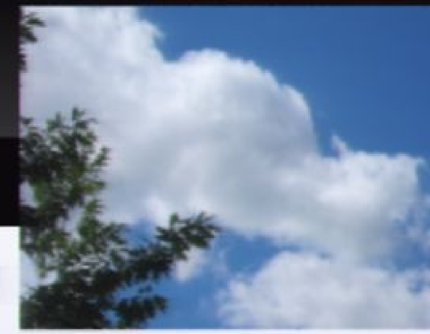

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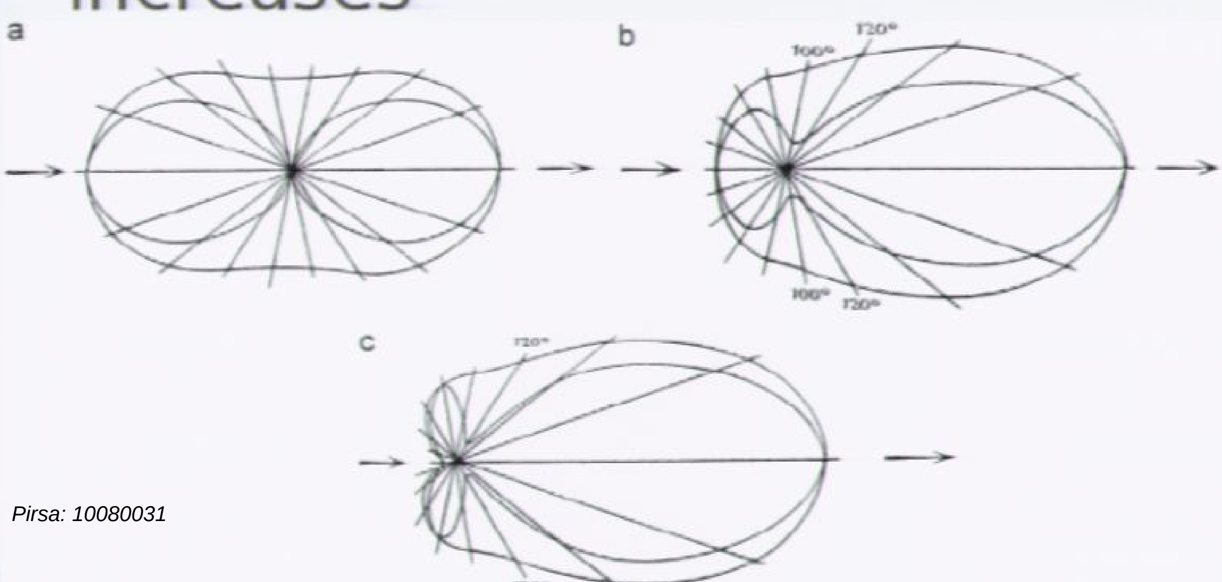

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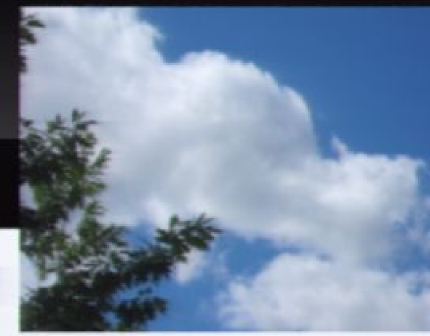

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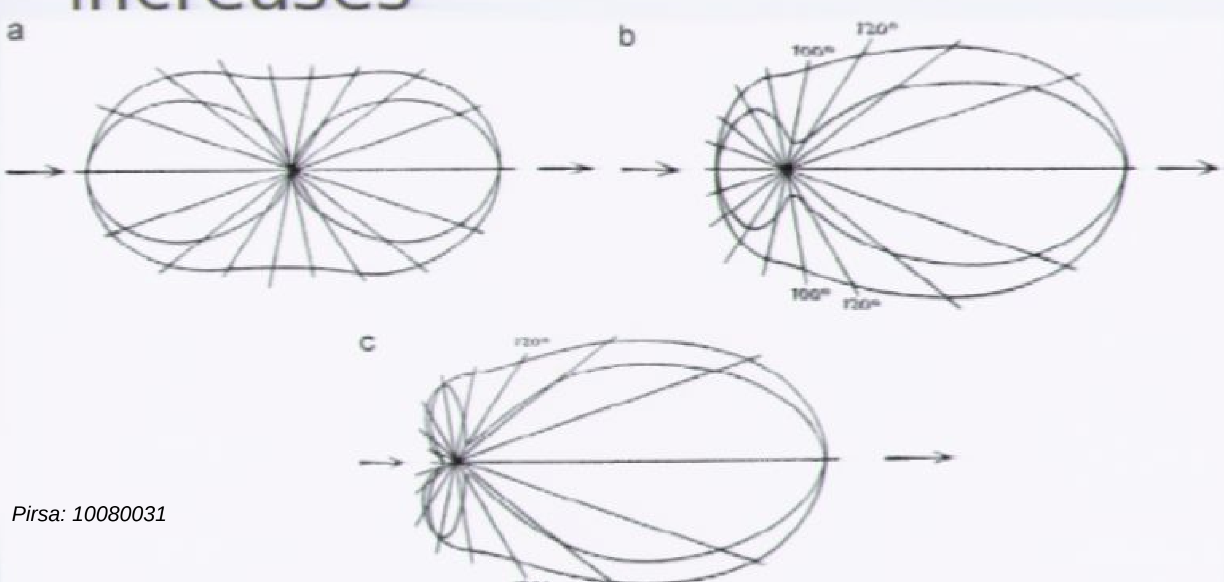

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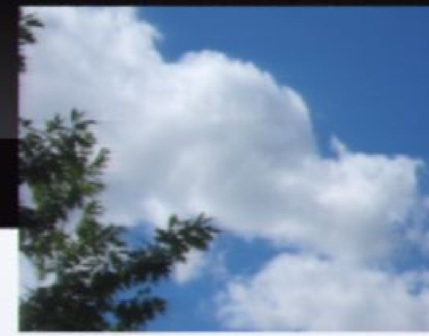
Conclusions



- White colour of clouds is due to Mie scattering
- Mie theory treats scattering by spherical particles of any size
- Mie scattering depends weakly on wavelength, when the particle size is larger than wavelength
- For water droplets all light is scattered almost in the same

⇨ Clouds are white

Outline

- Stay-on-tab - What it is and a little bit of history
- Leverage and levers - The physics and examples of levers
- The scored lid - Comments on the lid of a soda can
- Summary

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Figure: *The stay-on-tab*

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Figure: *The pull-tab (Wikipedia)*

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- Simple desing - cheap and easy to fabricate

Figure: *The stay-on-tab*

Leverage

"Give me a lever long enough and a fulcrum on which to place it, and I shall move the world"

- Archimedes

$$\tau = \mathbf{r} \times \mathbf{F} \qquad (1)$$

where τ is the torque vector, $\mathbf{r}$ is the displacement vector and $\mathbf{F}$ is the force vector

- Lever amplifies the force you excert on the can

Classes of levers

- Class 1: The fulcrum is located between the applied force and the load

Figure: *Scissors (Wikipedia)*

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Figure: *Wheelbarrow (Wikipedia)*

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- Class 2: The load is situated between the fulcrum and the force
- Class 3: The force is applied between the fulcrum and the load

  Davidovits, Paul (2008), Physics in Biology and Medicine, Third edition

Figure: *Tweezers (Wikipedia)*

- The stay-on-tab is a class 1 lever

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- Lets assume that the force is perpendicular to the ring pull

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- The stay-on-tab is a class 1 lever
- Lets assume that the force is perpendicular to the ring pull
- $r_1 \approx 20$ mm and $r_2 \approx 5$ mm $\Rightarrow$ force is quadrupled
- But wait! There's more!

Figure: *The stay-on-tab*

- The lid is scored to make things easier

Figure: *The scored lid (Wikipedia)*

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Summary

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Summary

- The stay-on-tab has taken us through:
  - Archimedes (lever)
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  - Modern engineering
- Above all: human curiosity and ingenuity

perimeter scholars international

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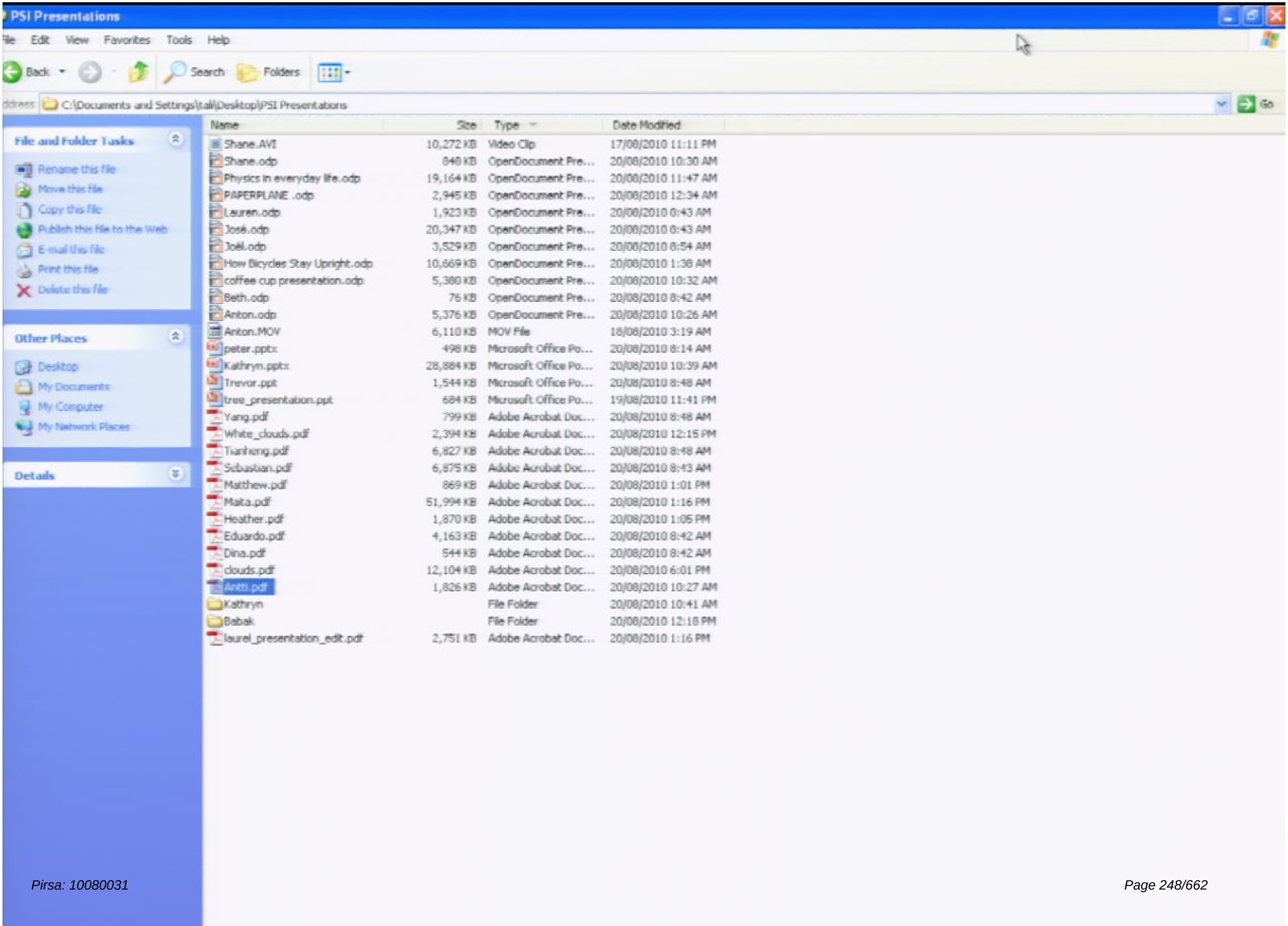
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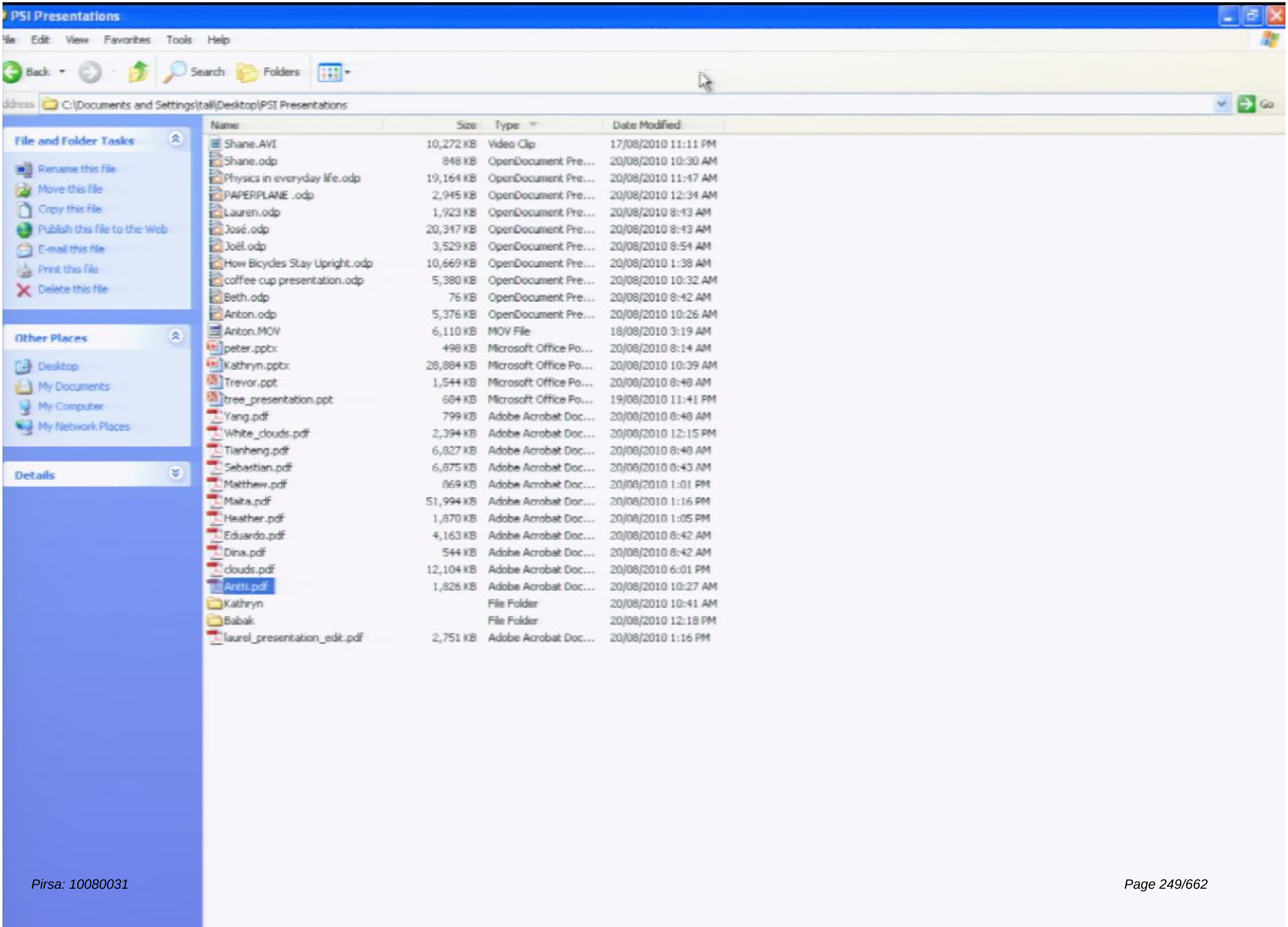
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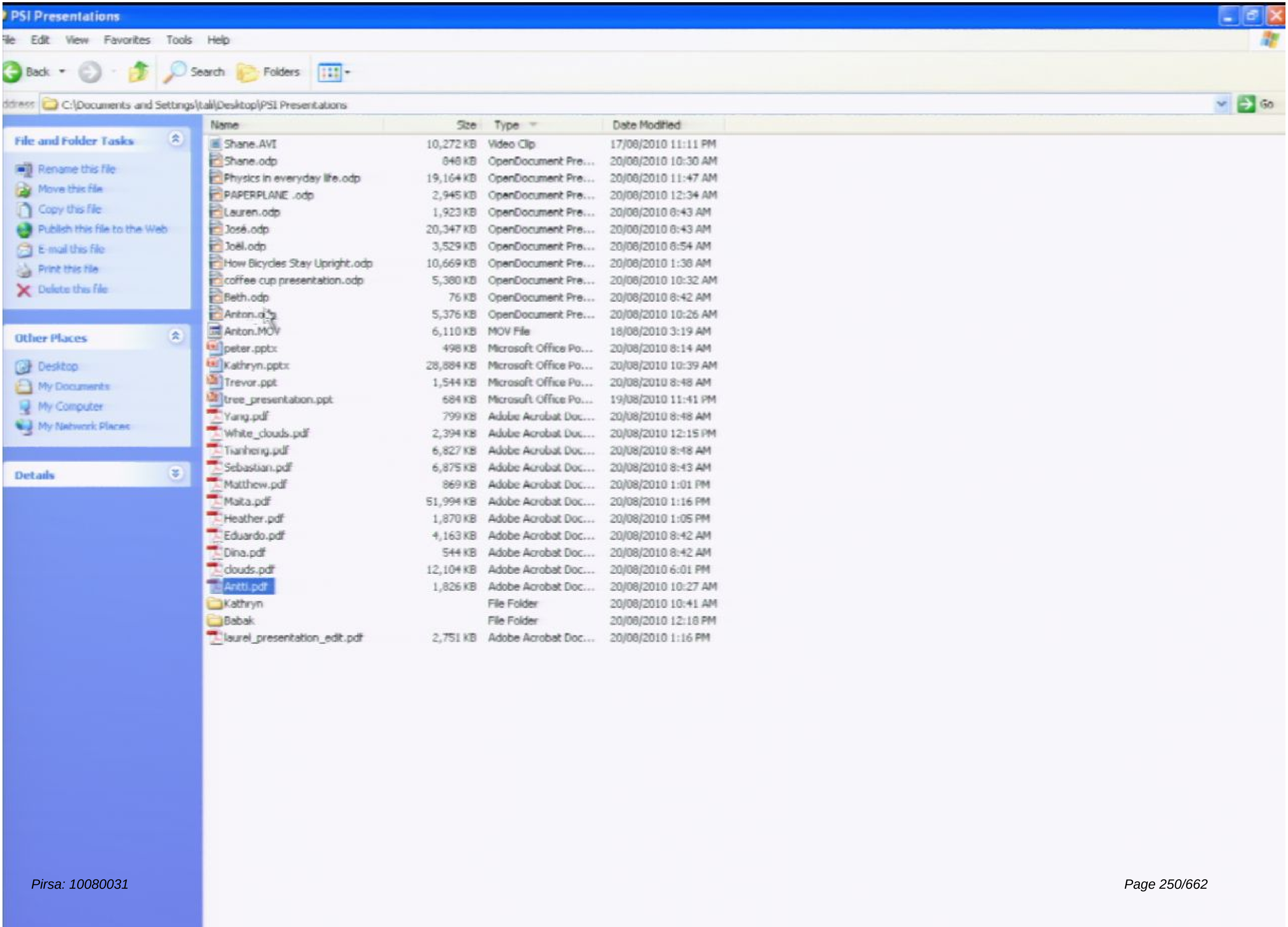

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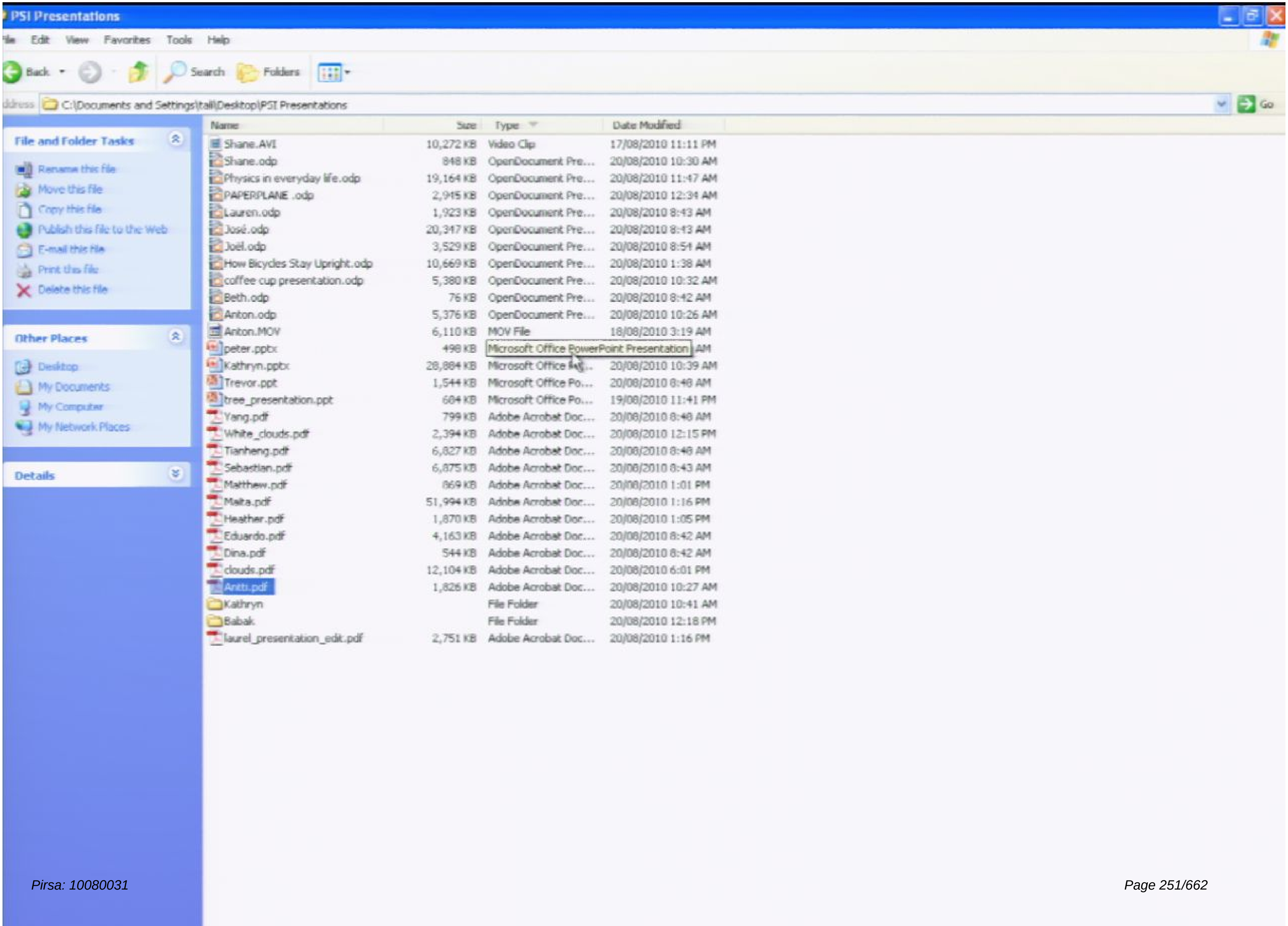
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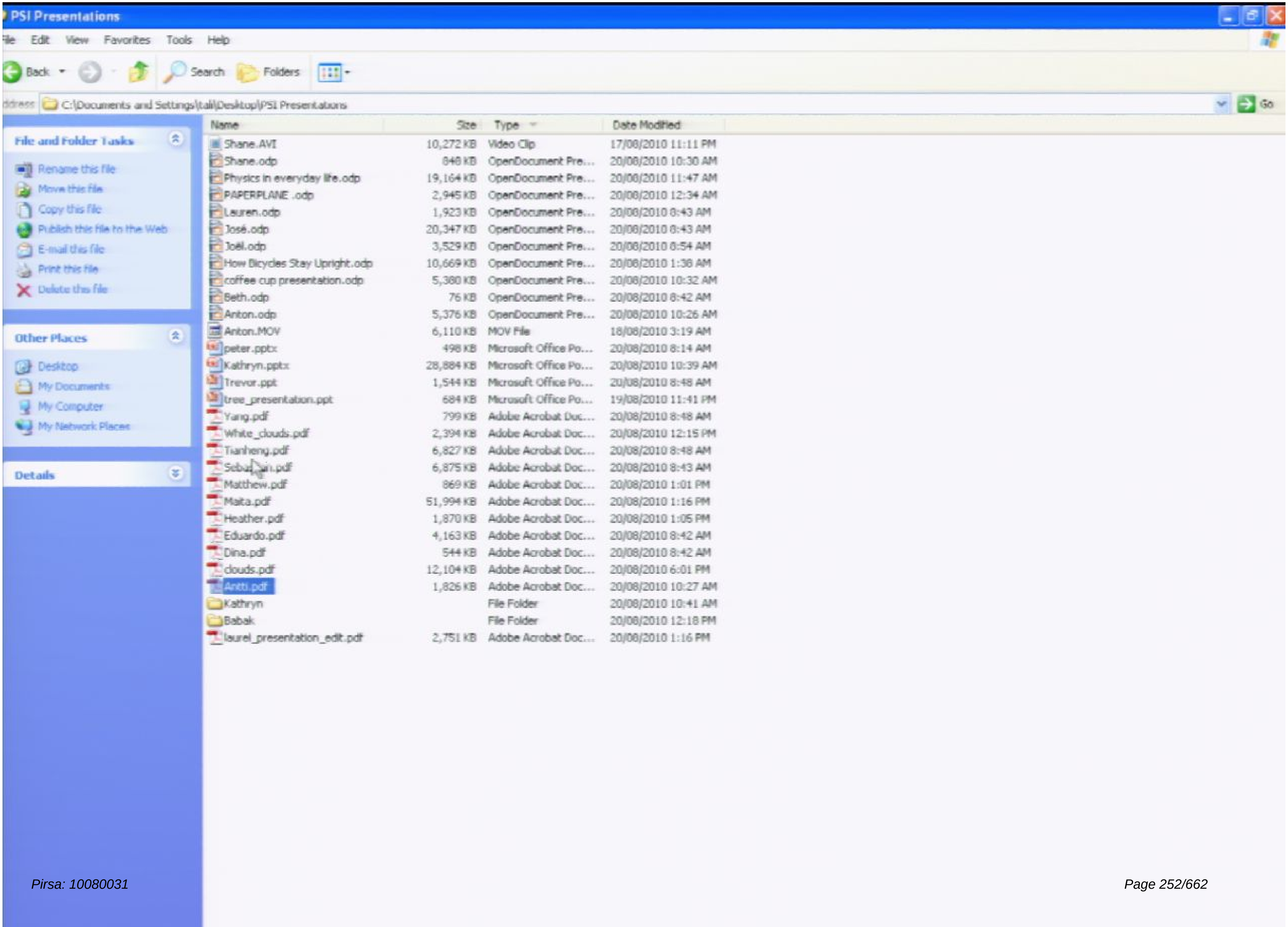
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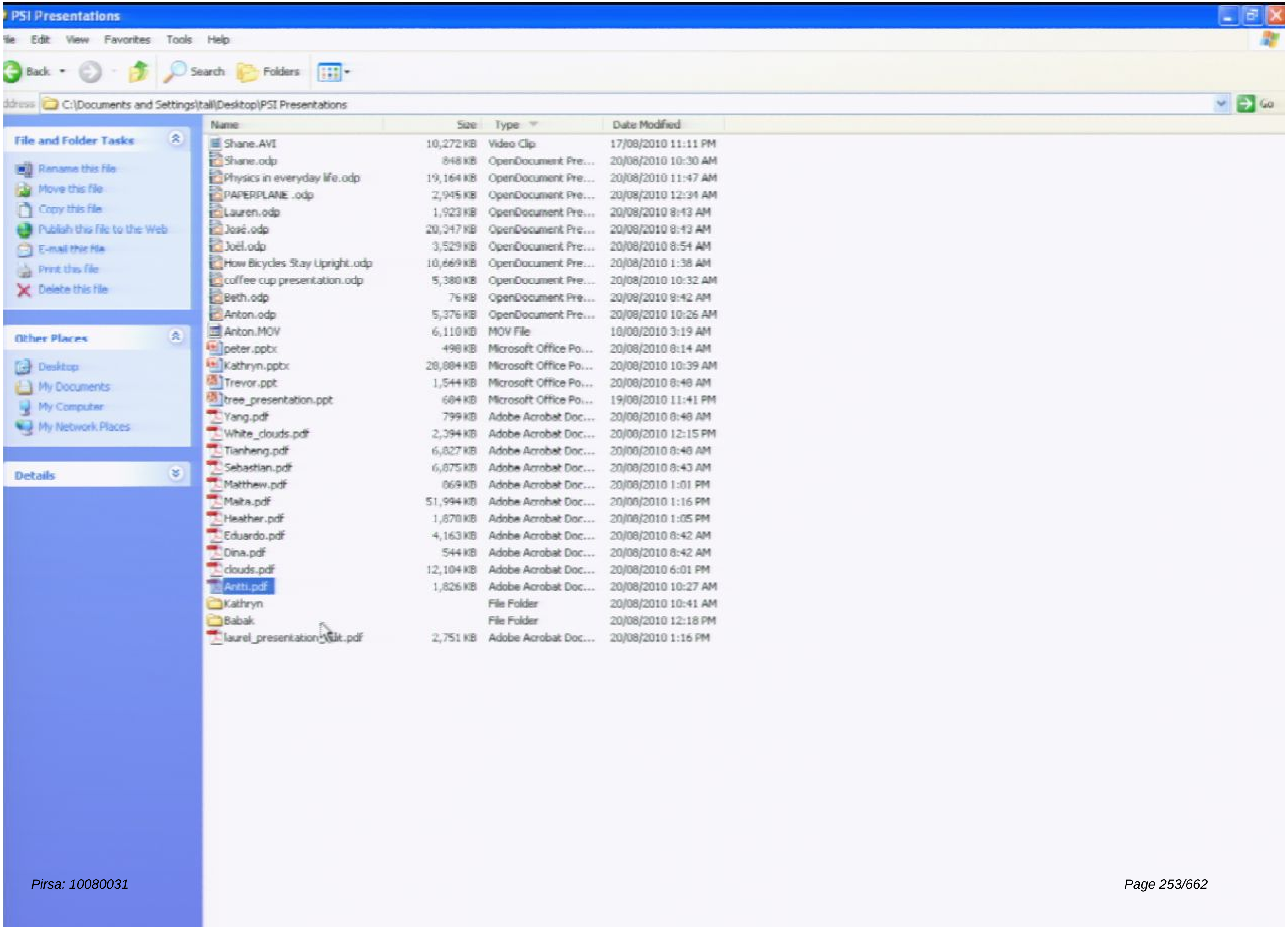
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How Bicycles Stay Upright

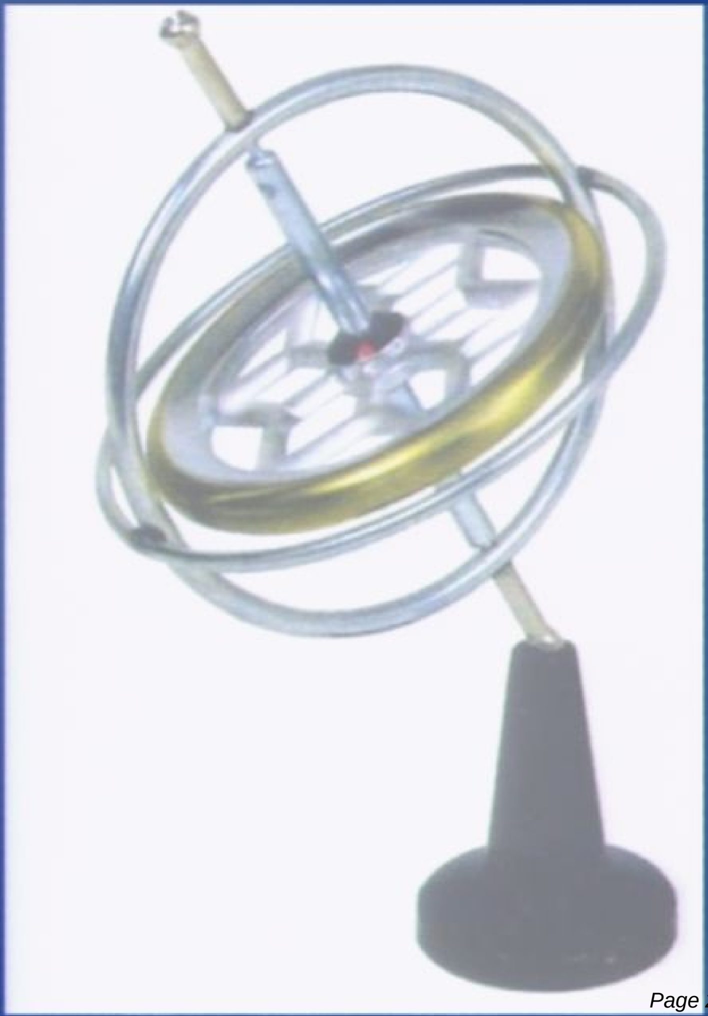
Maeve Manion-Fischer
Perimeter Scholars International

Outline

- Can you explain how a bicycle works?
- Possible Explanations
- Experimental Tests
- Unexpected Effects

Possible Explanations

- Centrifugal force
- Gyroscopic Motion
- A rolling hoop stays upright because of gyroscopic forces, shouldn't a bicycle wheel be similar?



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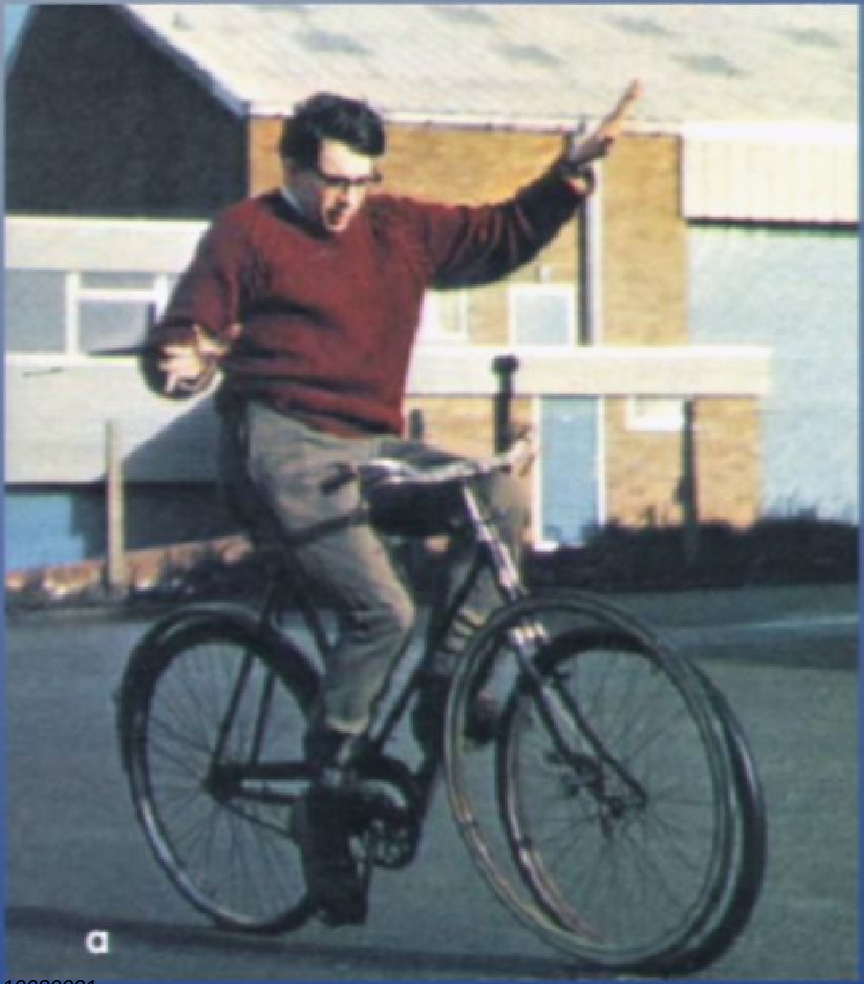
Testing the Hypothesis



- Riderless normal bicycle will stay upright for awhile (centrifugal forces not enough to explain this)
- When riderless, this bicycle will fall over immediately.

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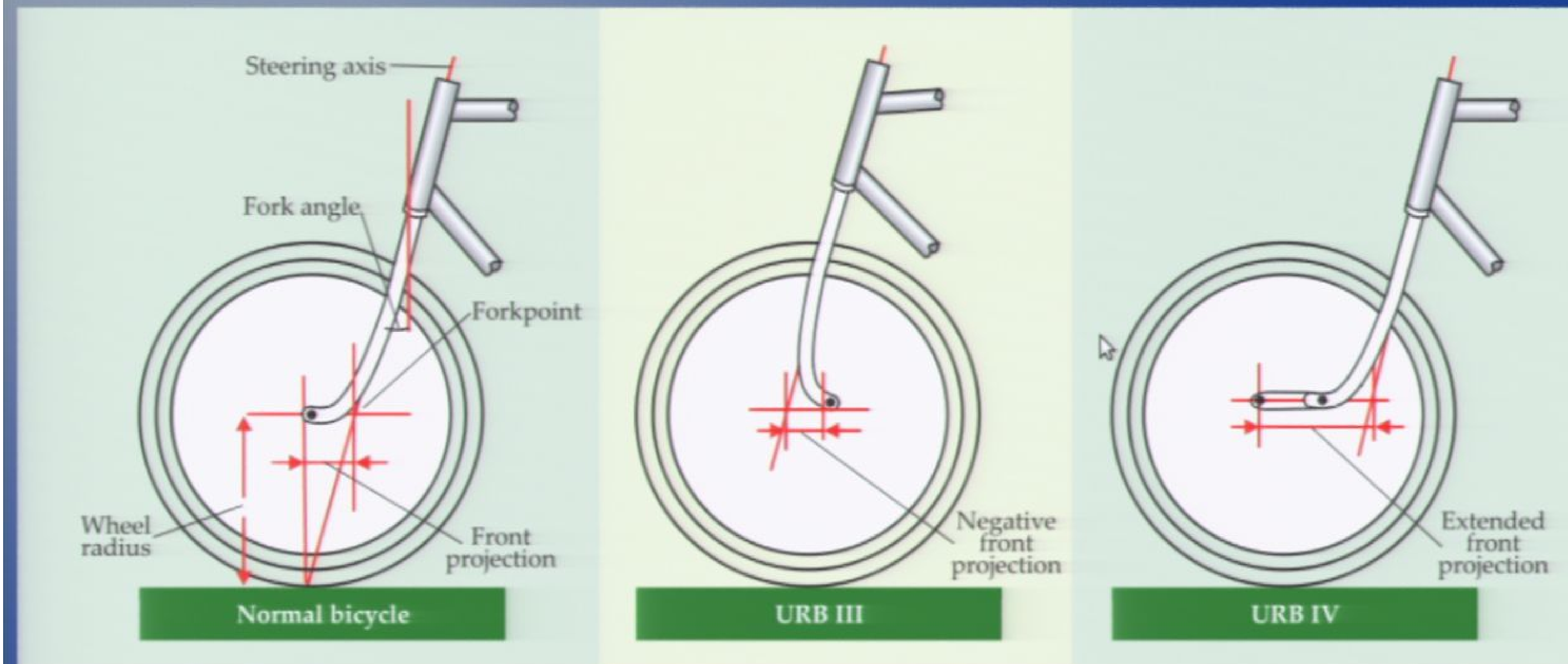

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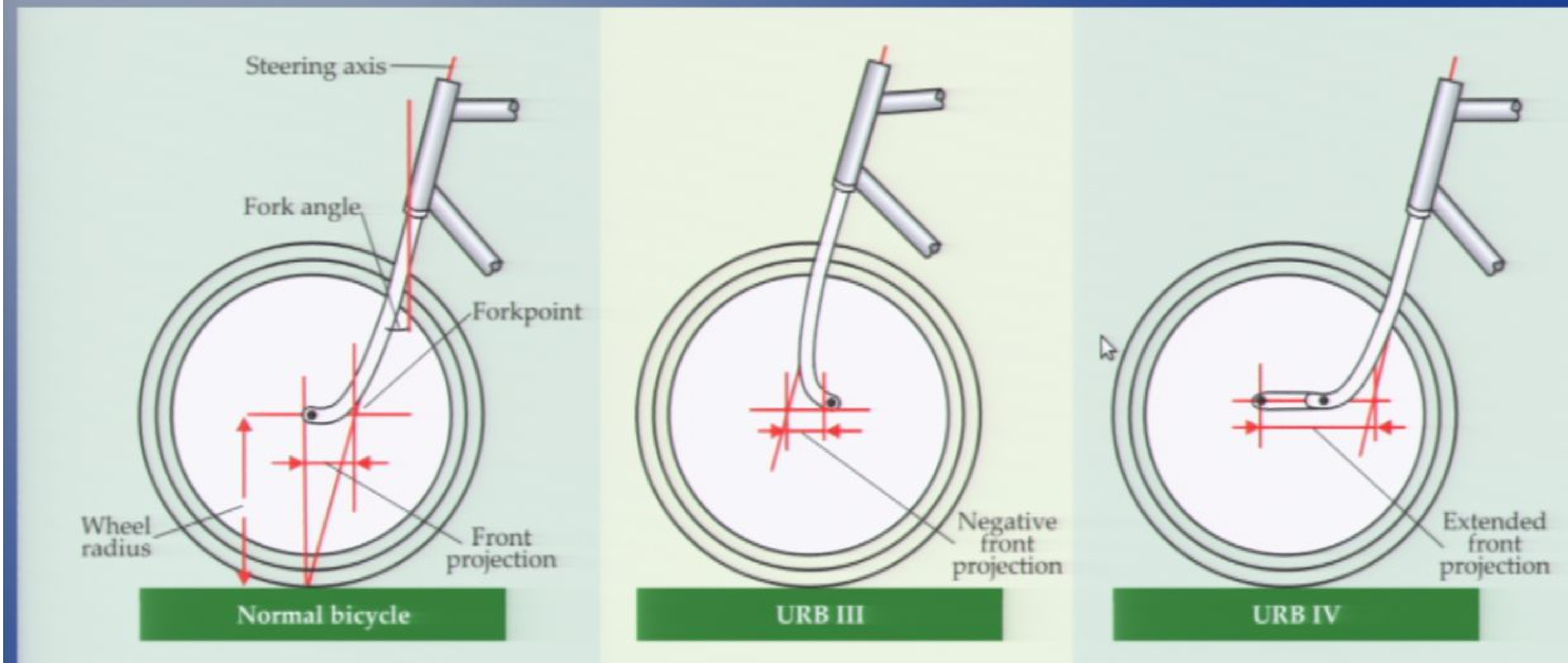

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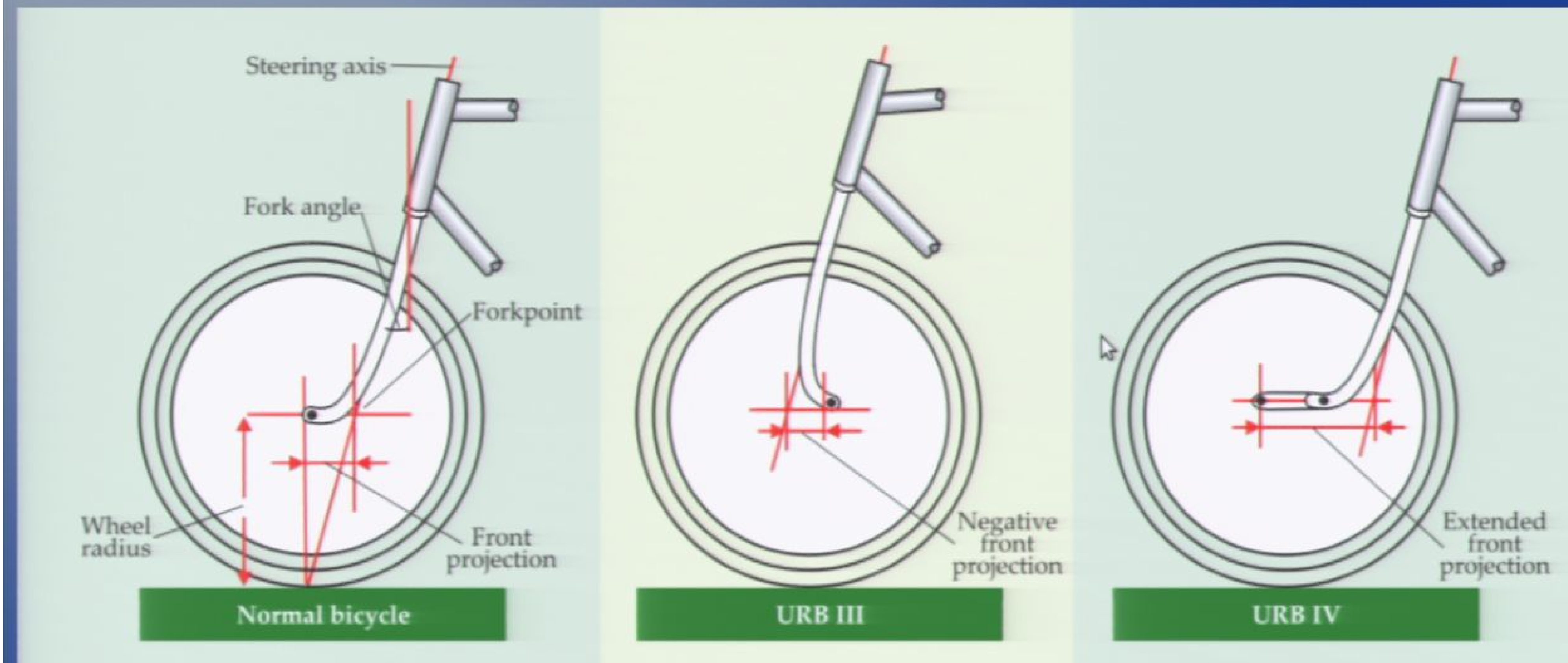

Conclusions

- Explanations that immediately come to mind do not explain the motion of a bicycle
- The stability of bicycles is best explained by both the structure of the steering mechanism and castoring forces.

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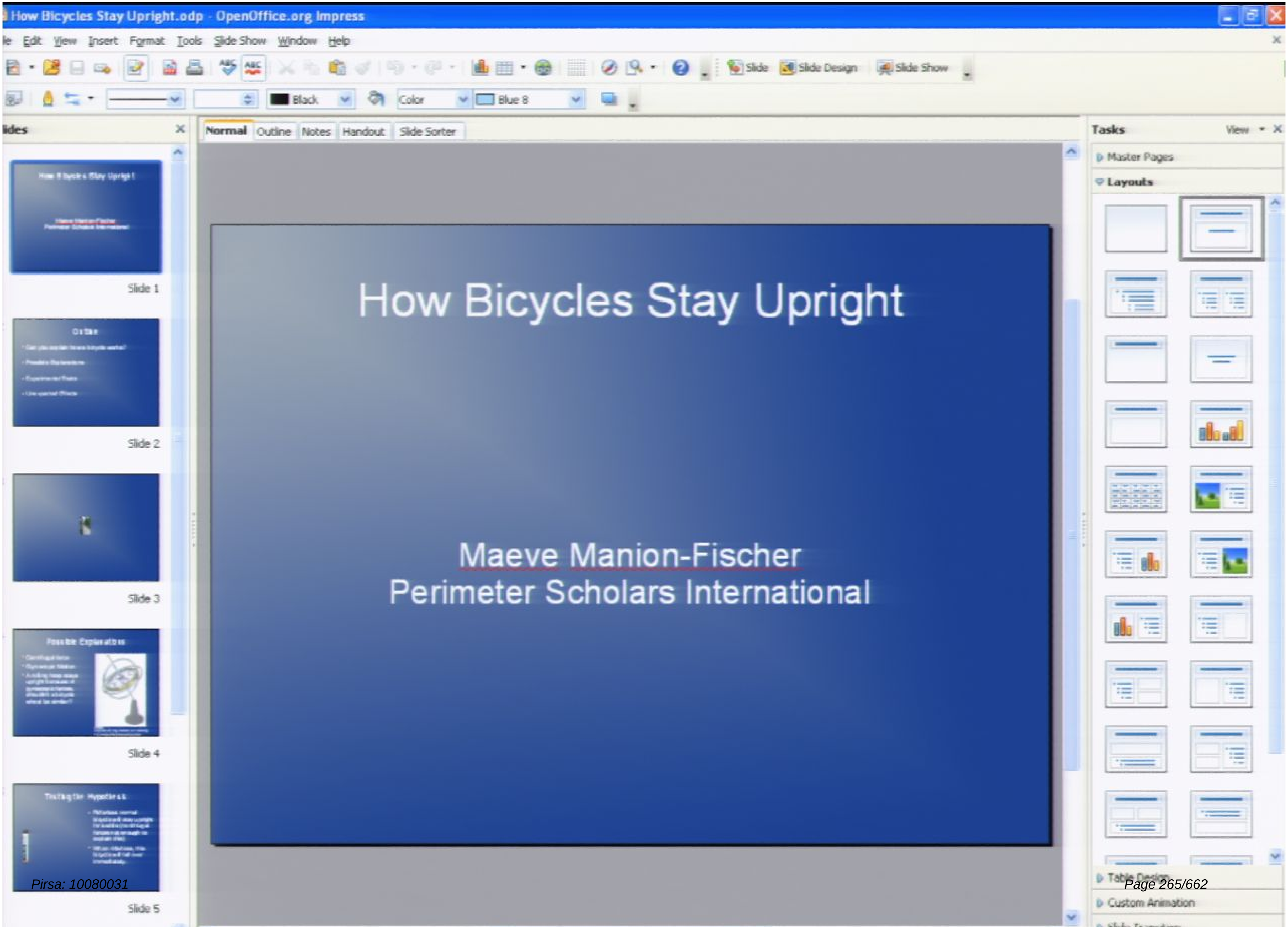
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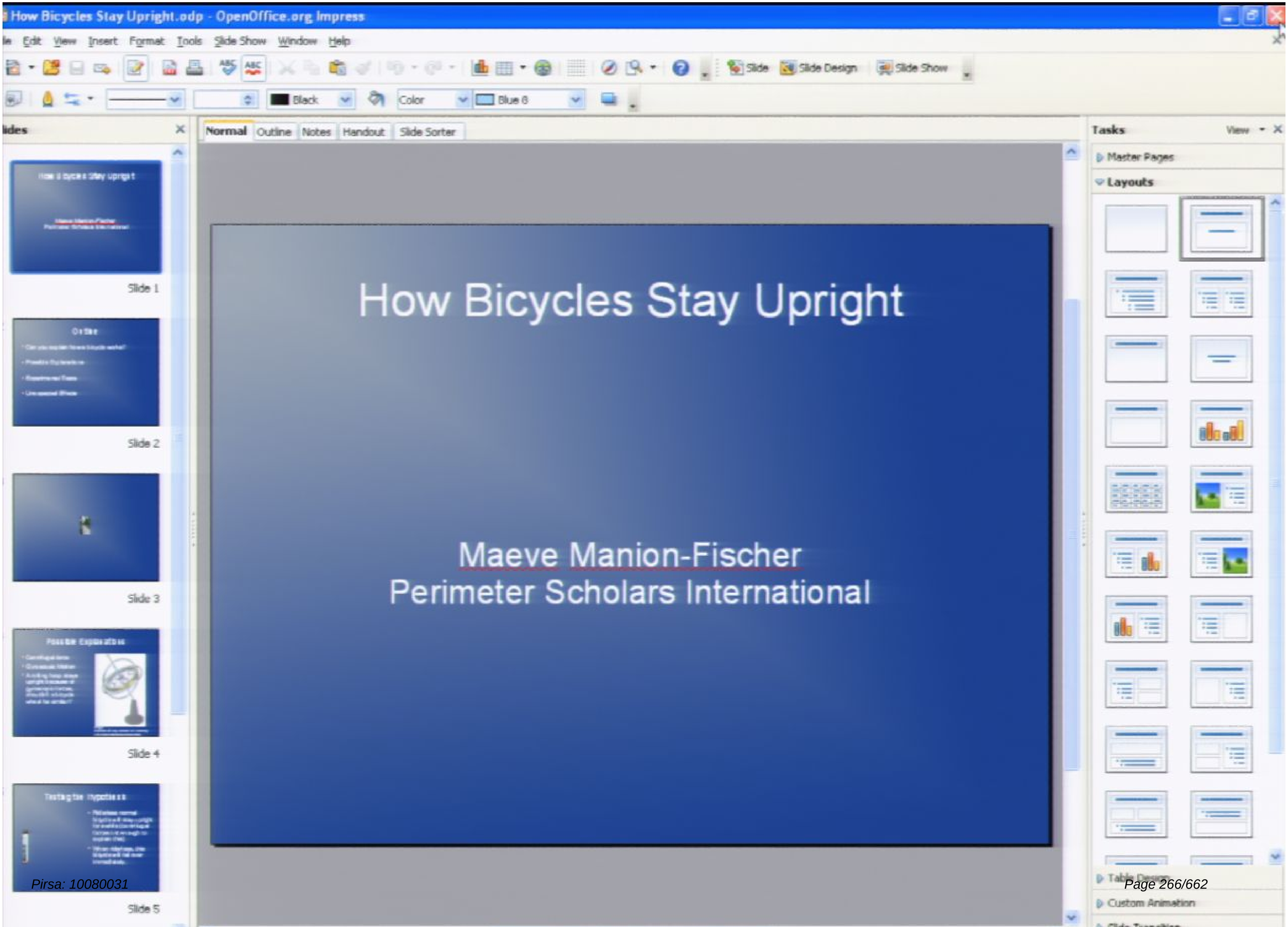
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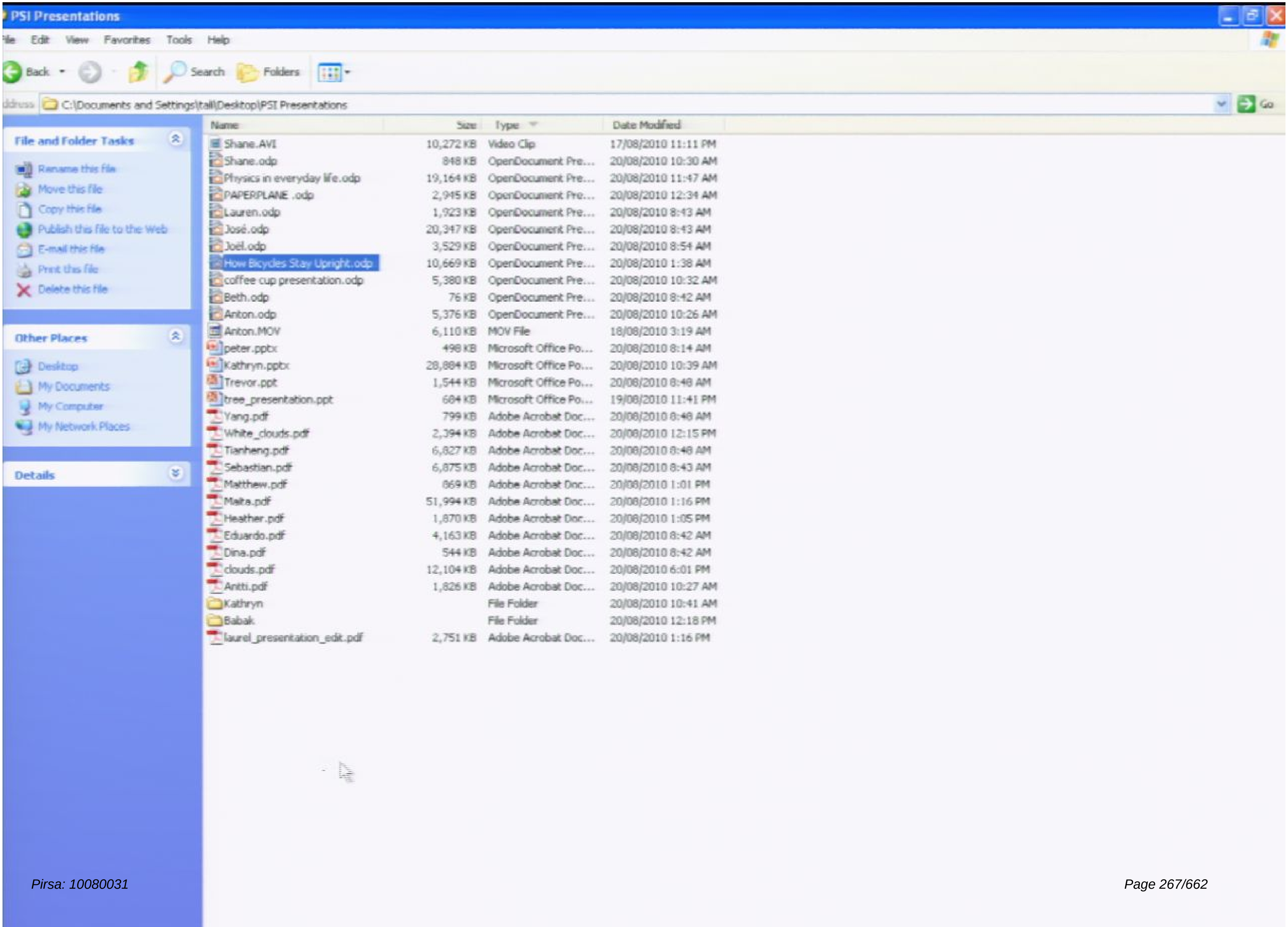
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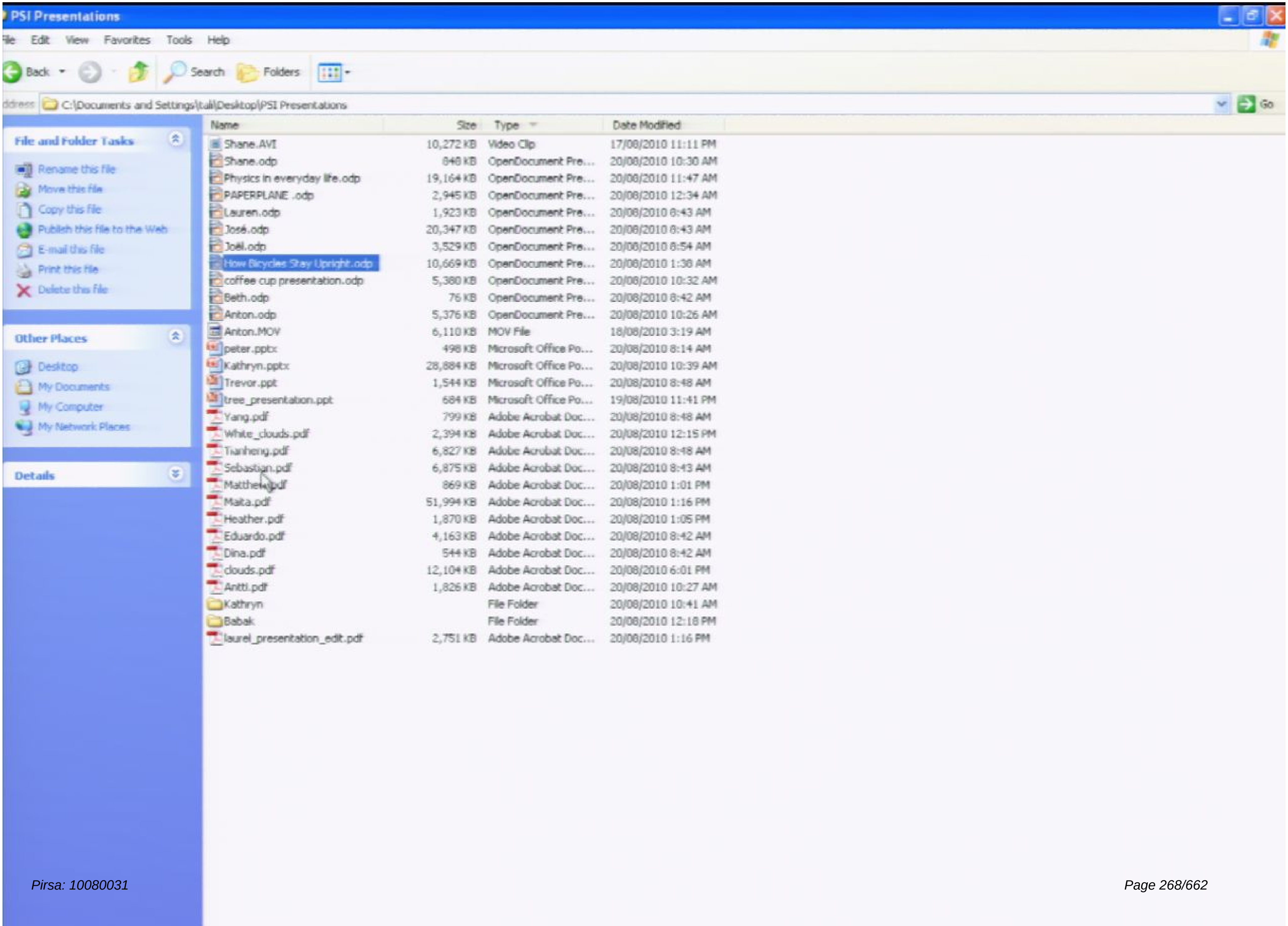
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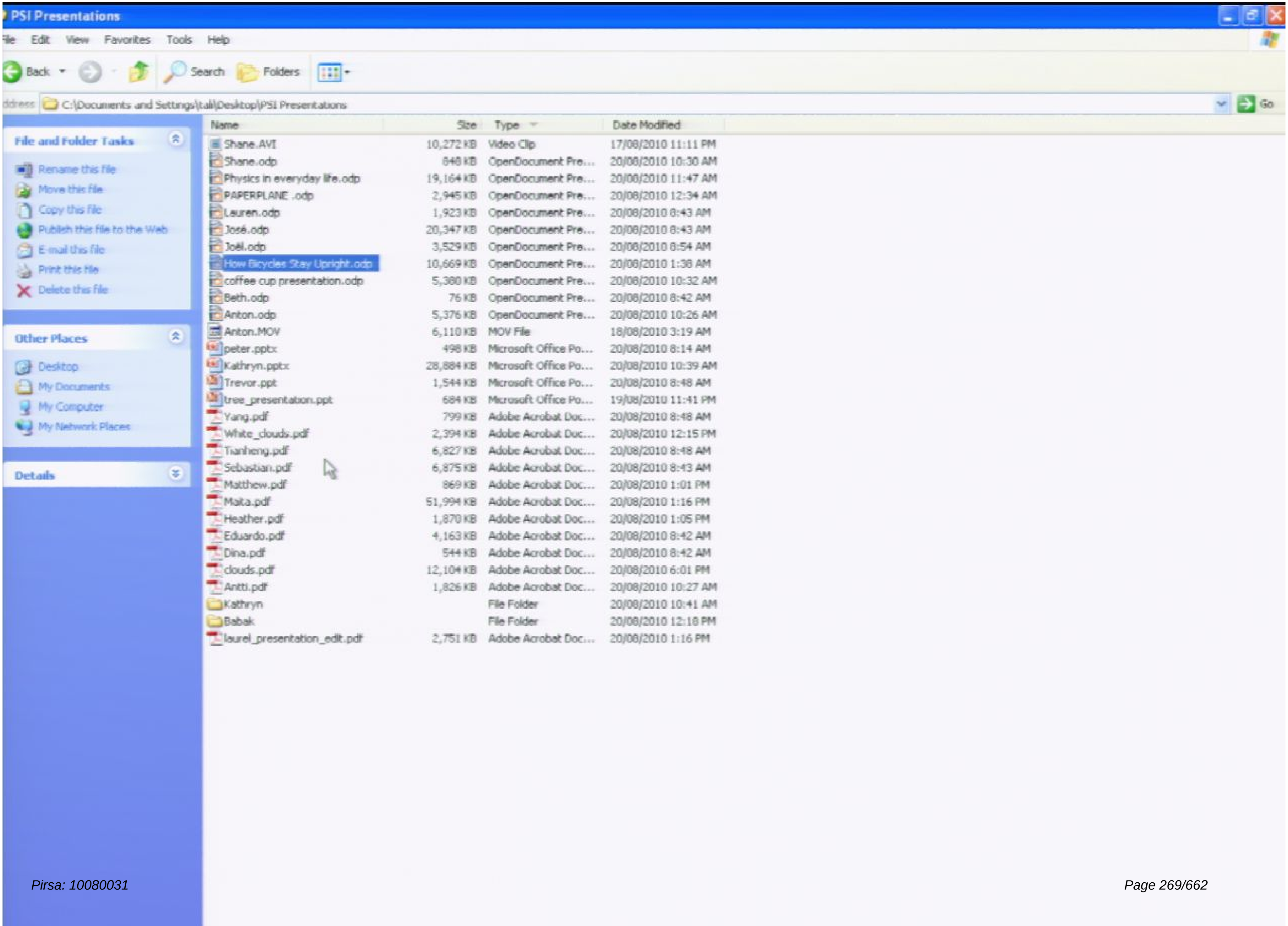
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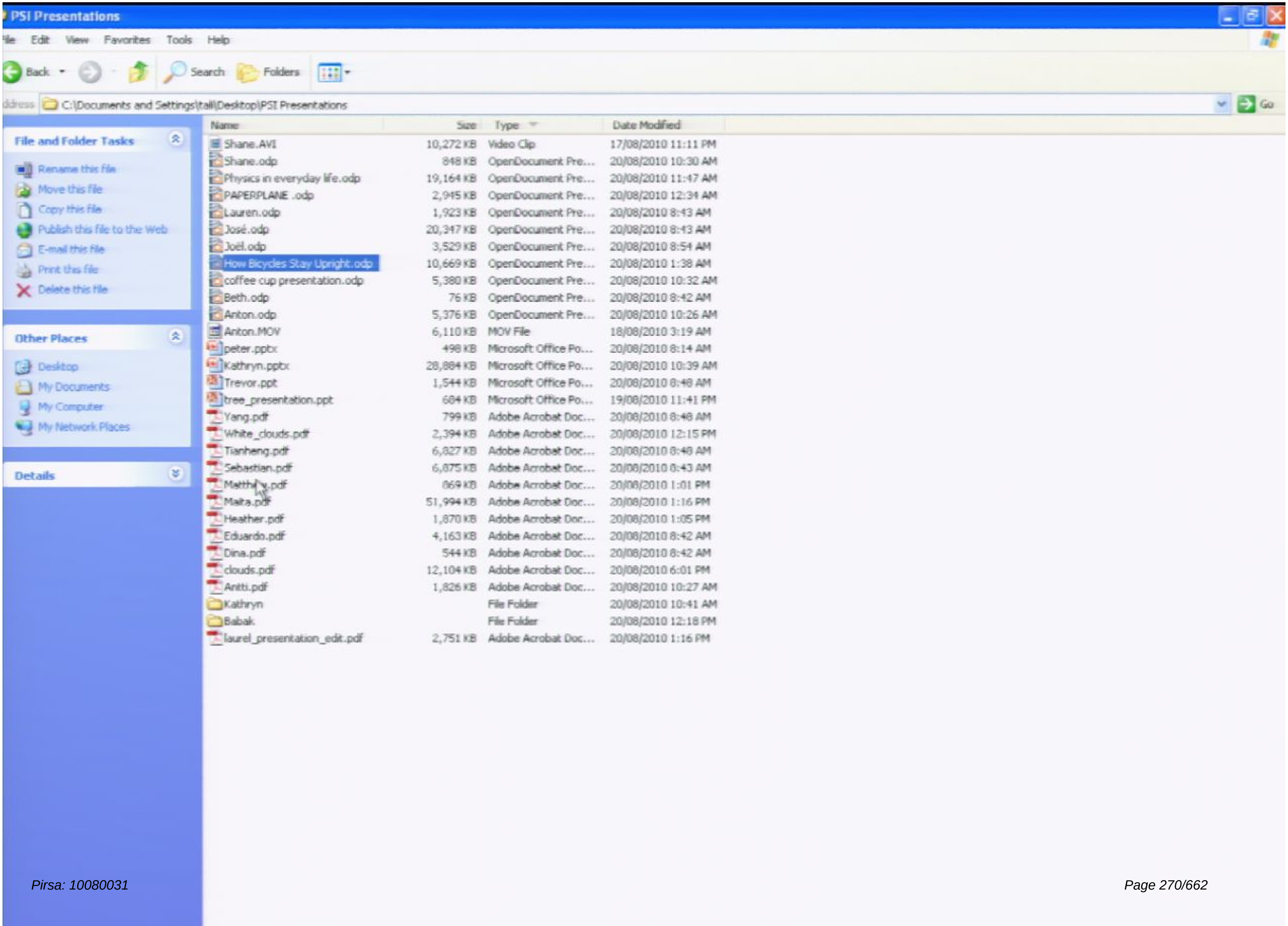
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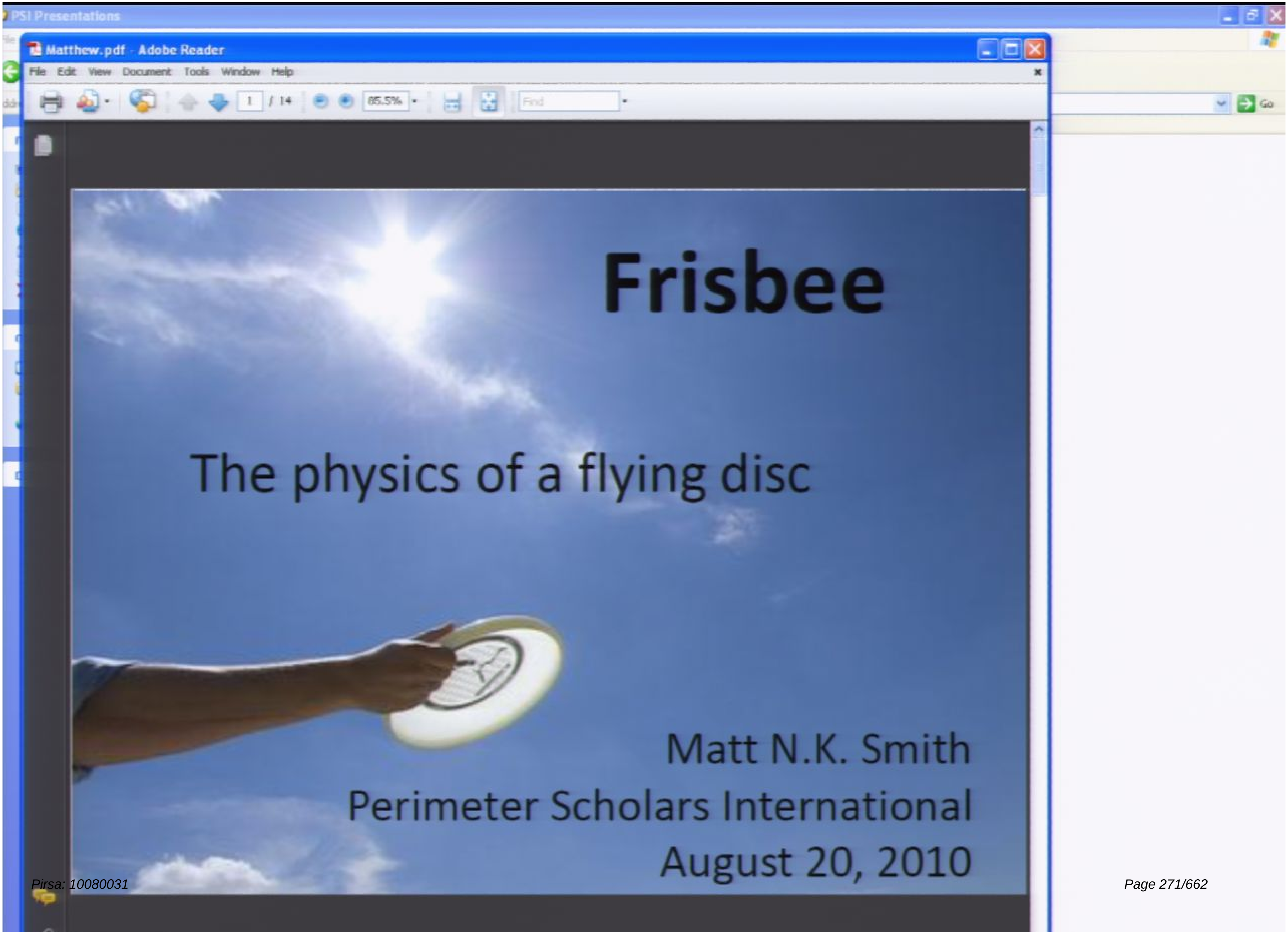
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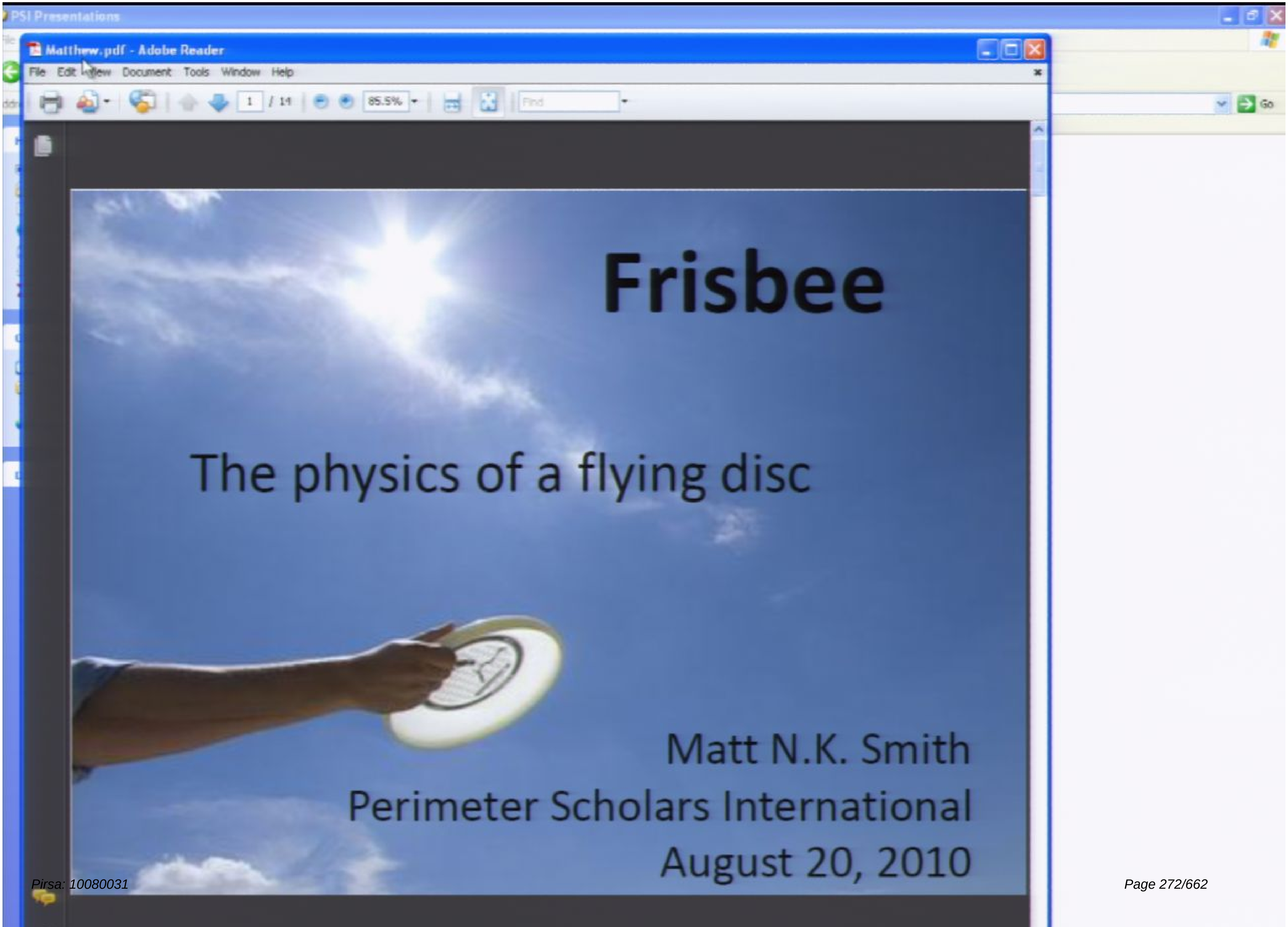
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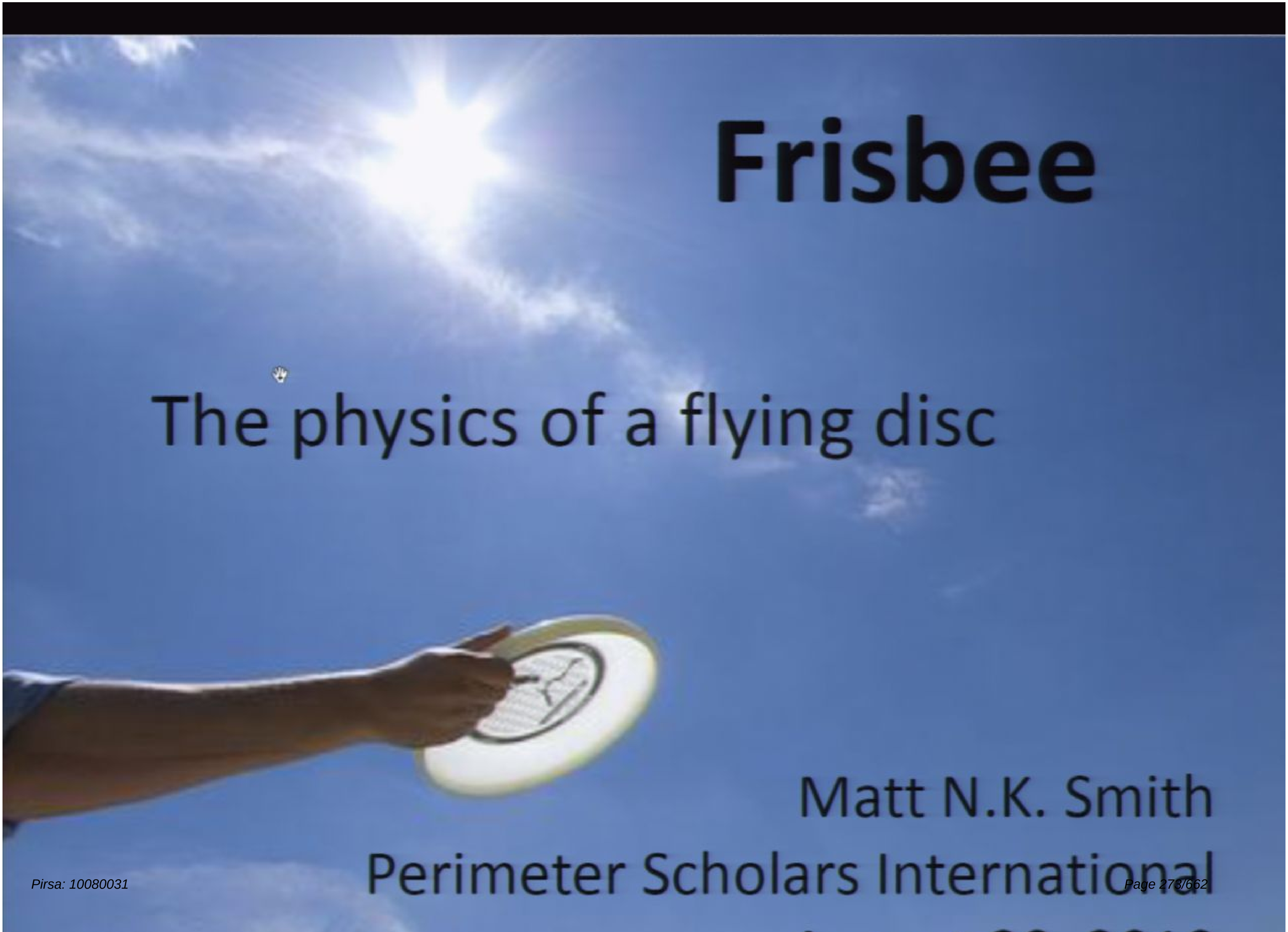
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Outline

I. Why frisbee?
II. Free body diagram
III. Physics of a flying object
   – Drag
   – Lift
IV. Physics of a rotating object
   – Angular momentum
   – Gyroscopic precession
V. Conclusions

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Some frisbee background

Frisbees began as flying pie-tins from a bakery in Connecticut in 1871

Ultimate frisbee and disc golf have gained tremendous popularity in the last 10 years

Today ultimate is played in at least 42 countries and the Ultimate Players Association of the US has nearly 30,000 members

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Ultimate frisbee and disc golf have gained tremendous popularity in the last 10 years

Today ultimate is played in at least 42 countries and the Ultimate Players Association of the US has nearly 30,000 members

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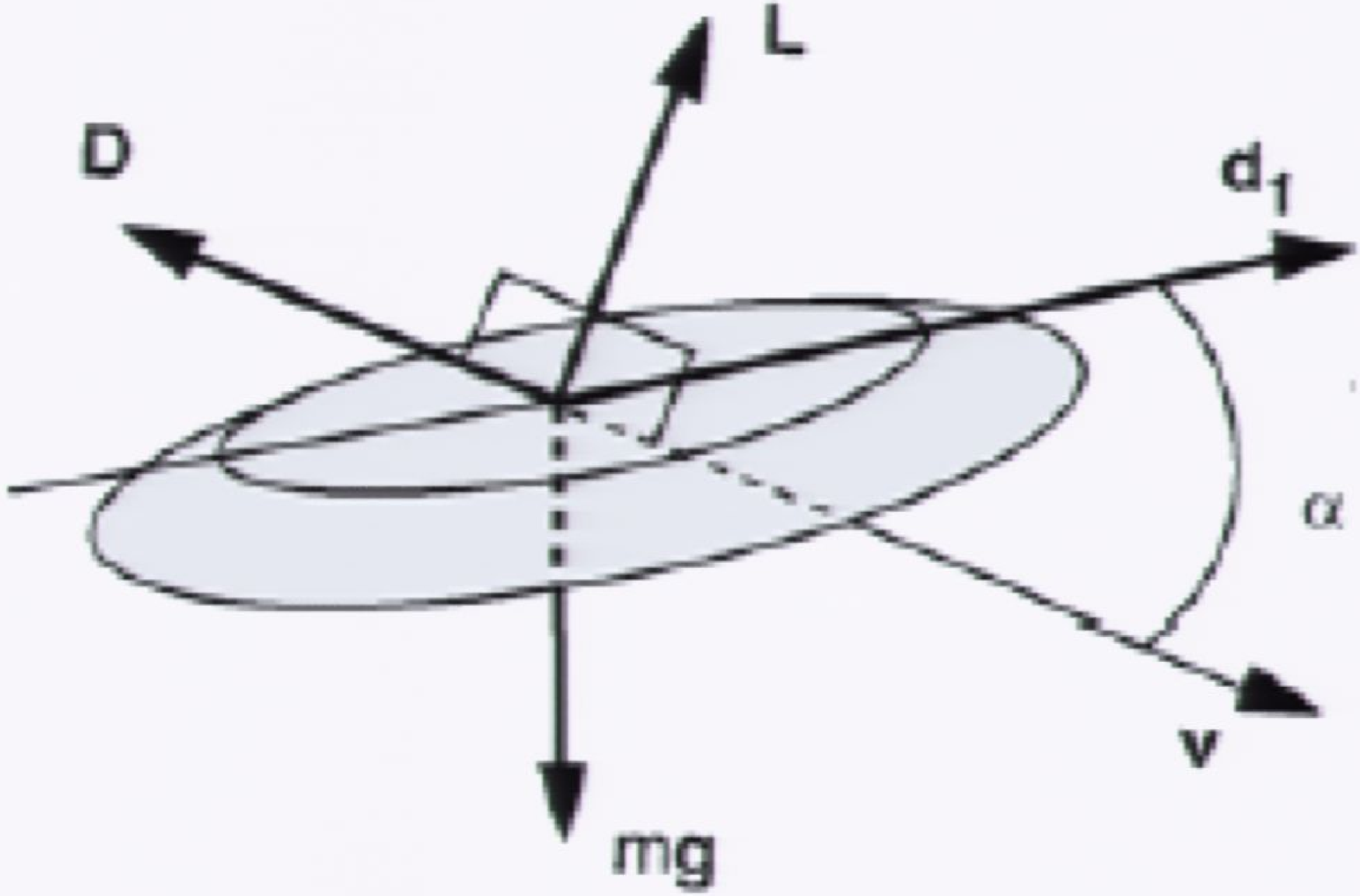

Morrison, *The Physics of Frisbee*, <http://web.mit.edu/womens-ult/www/smite/frisbee_physics.pdf>

Air resistance

- A thrown disc travels farther than a thrown ball
- The frisbee has high resistance to vertical velocity

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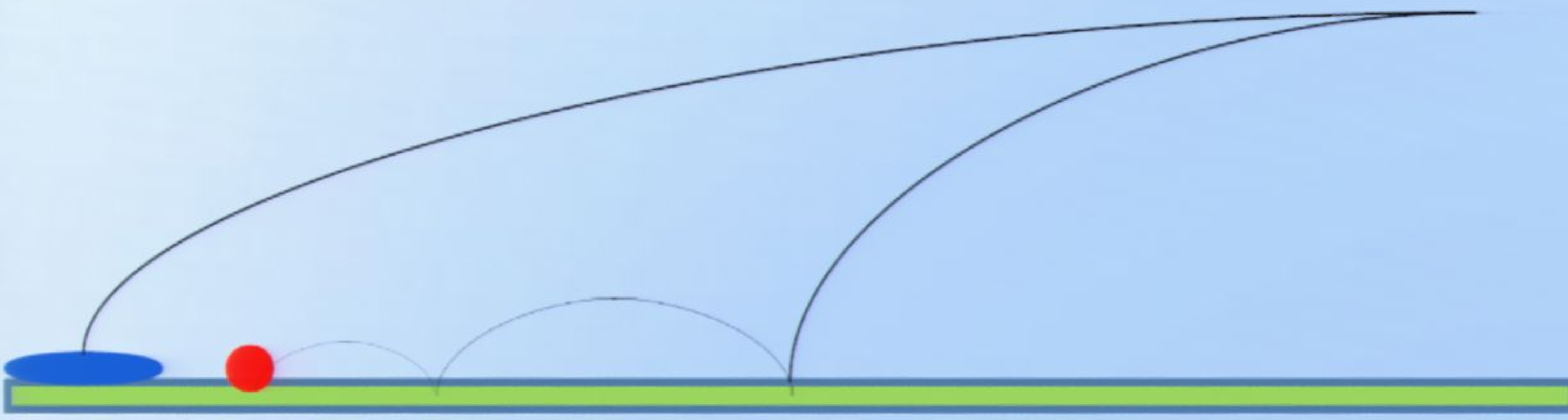

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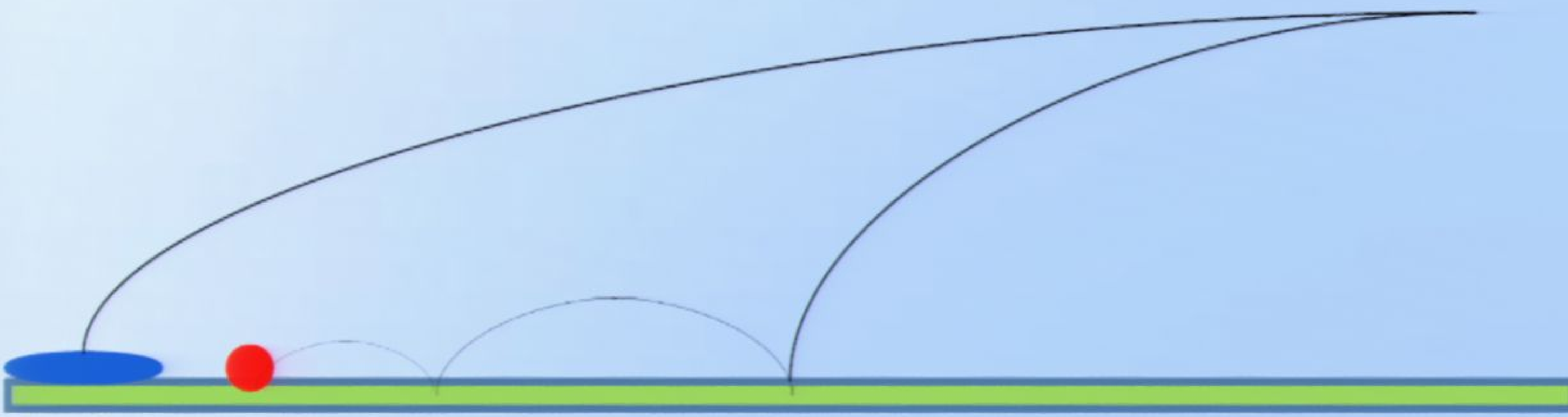

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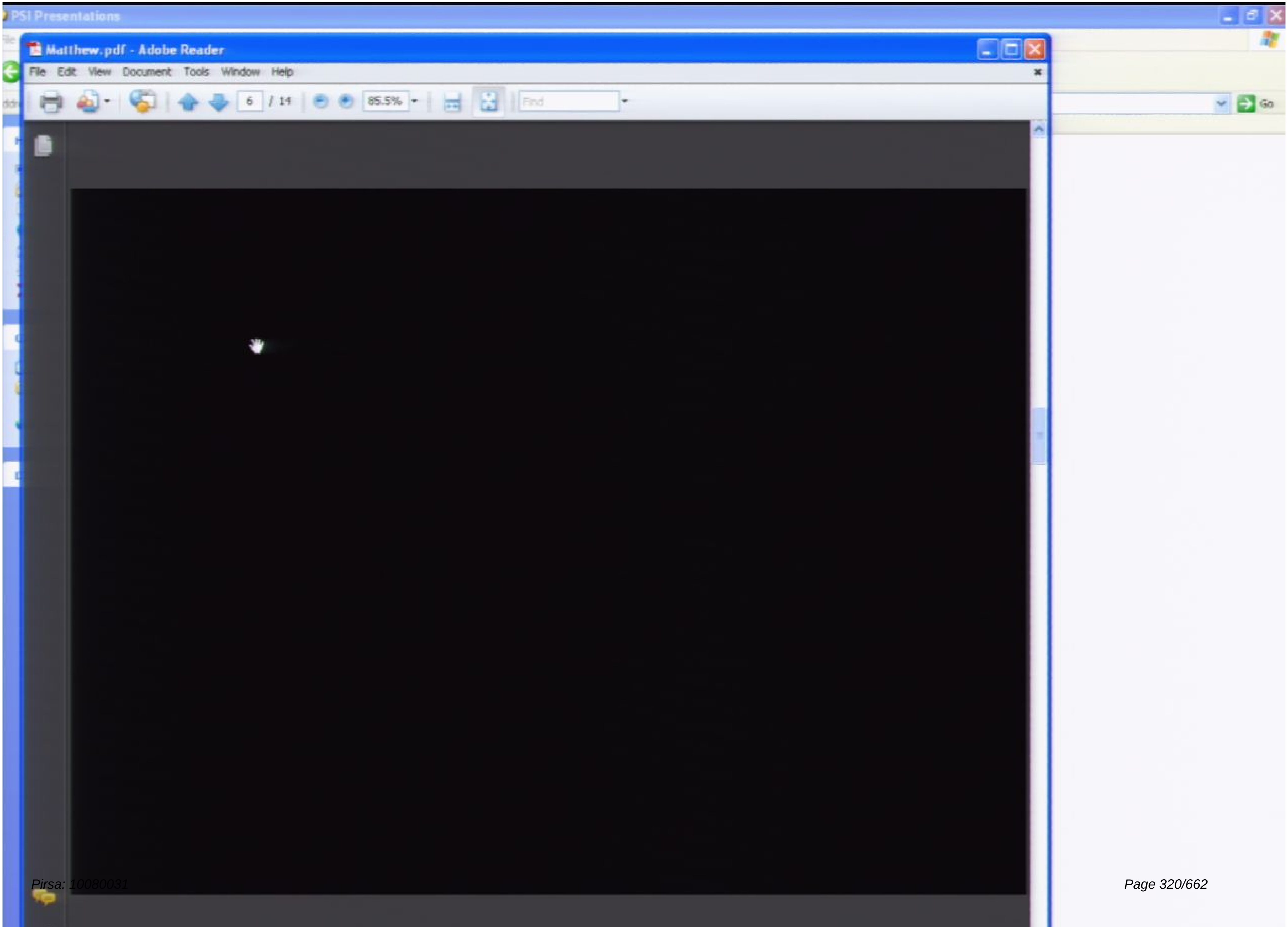
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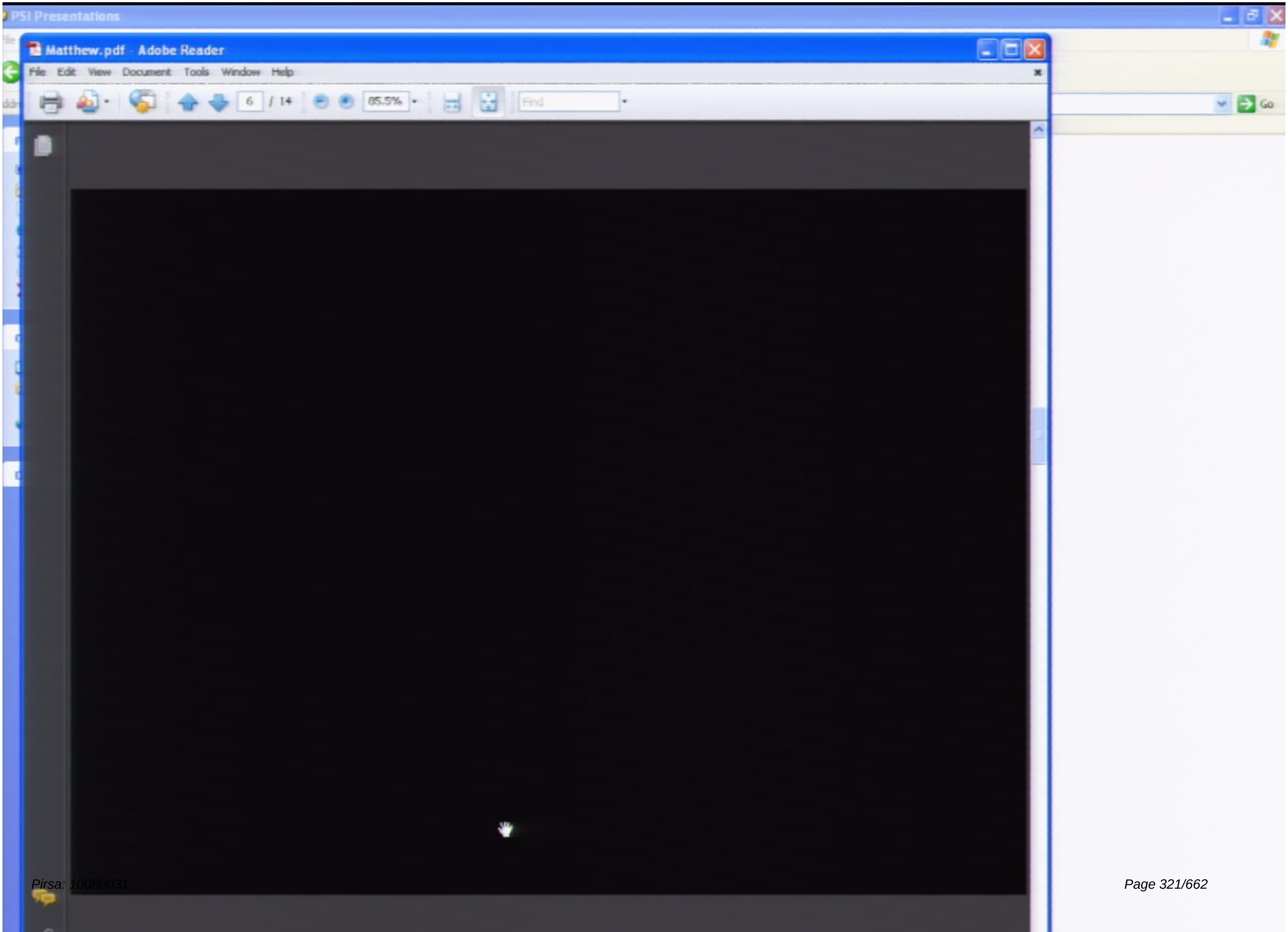
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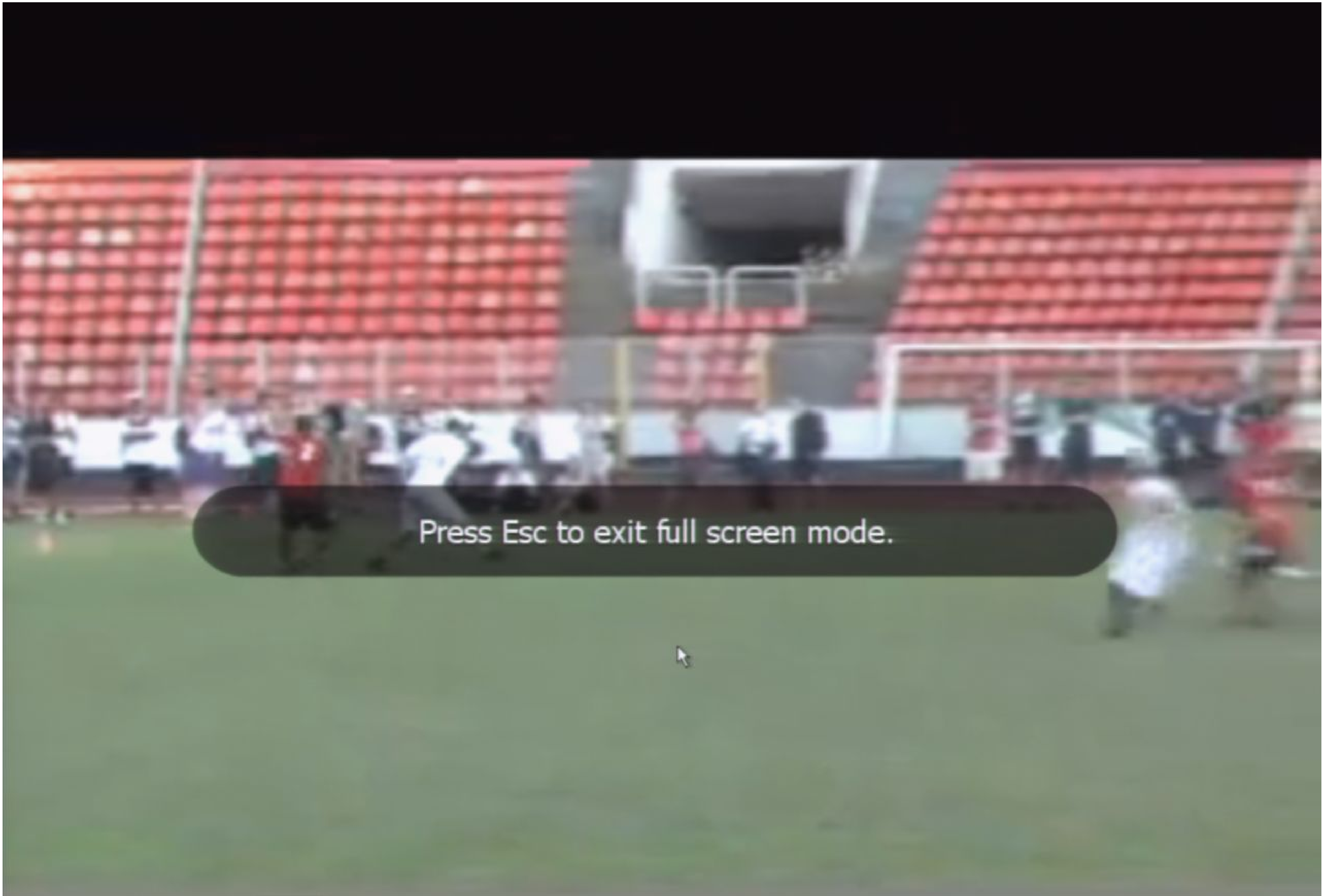
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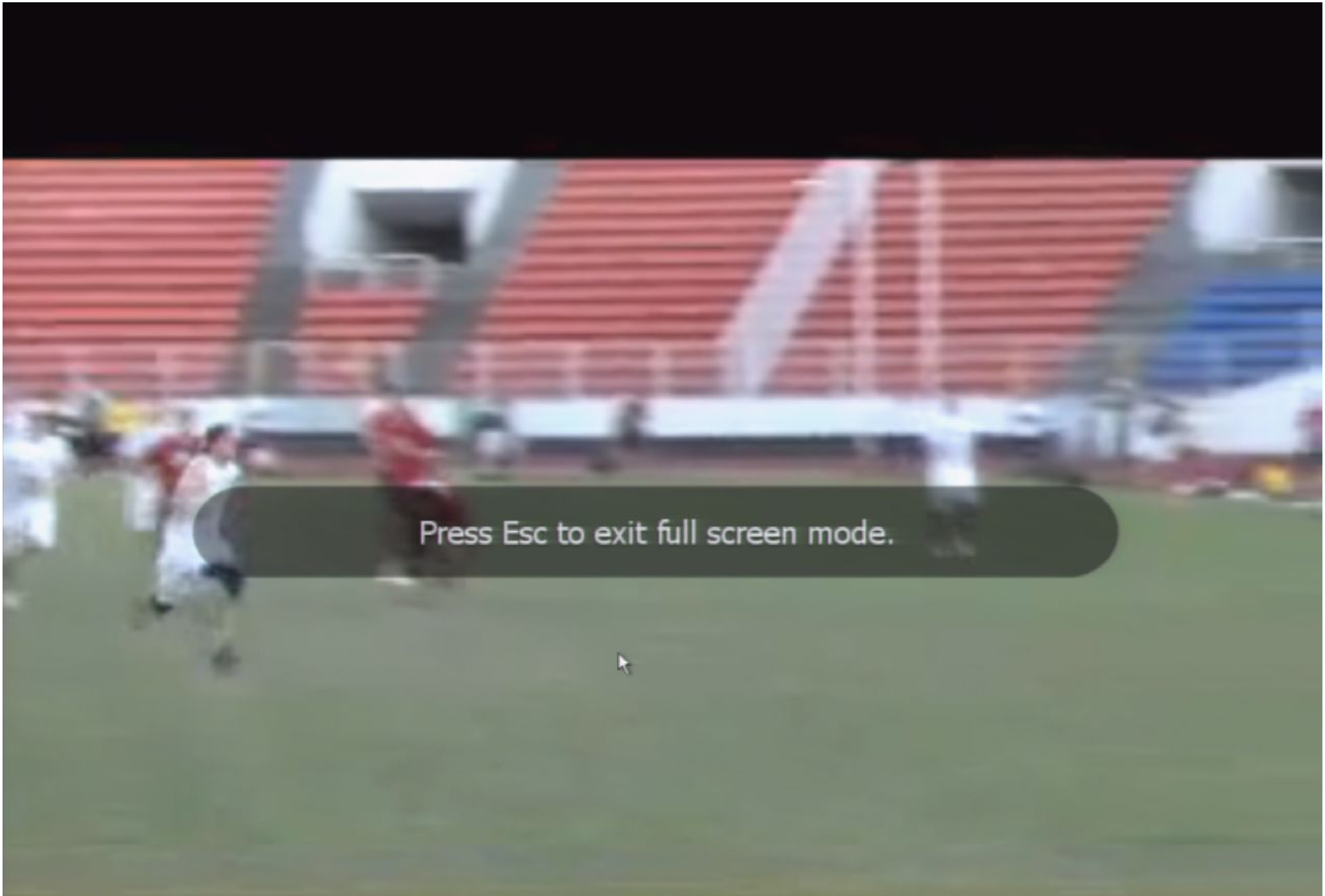
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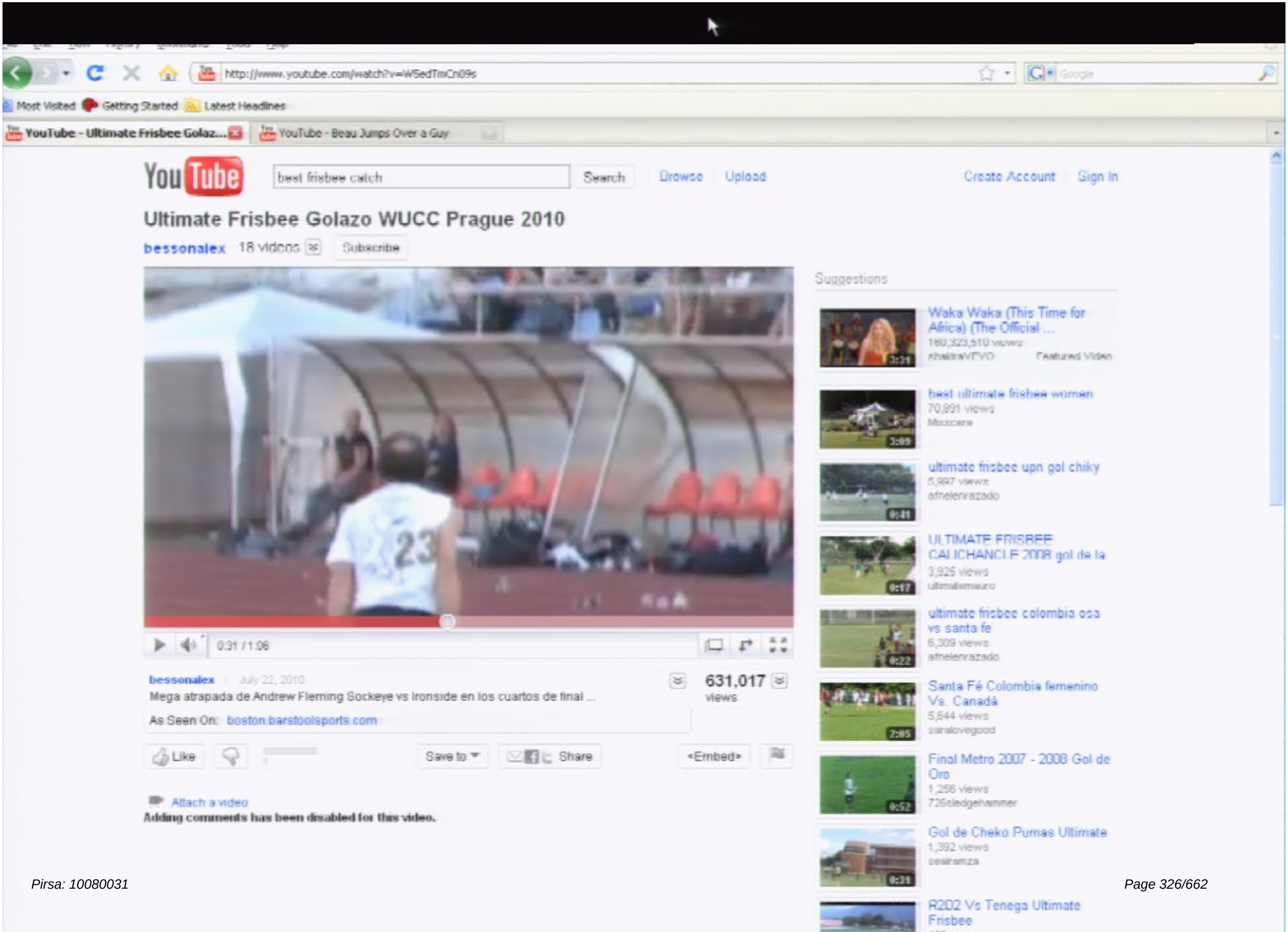
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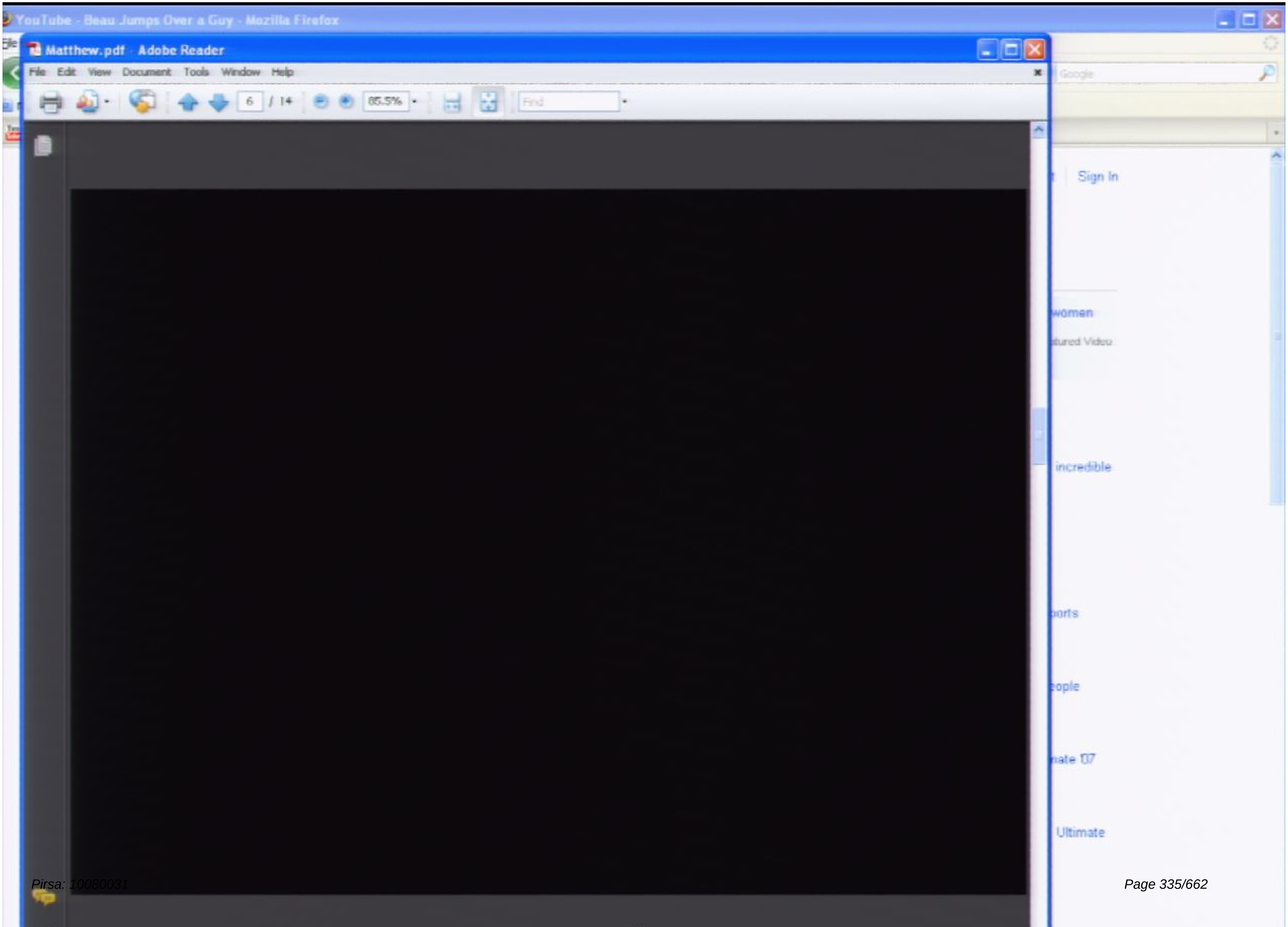
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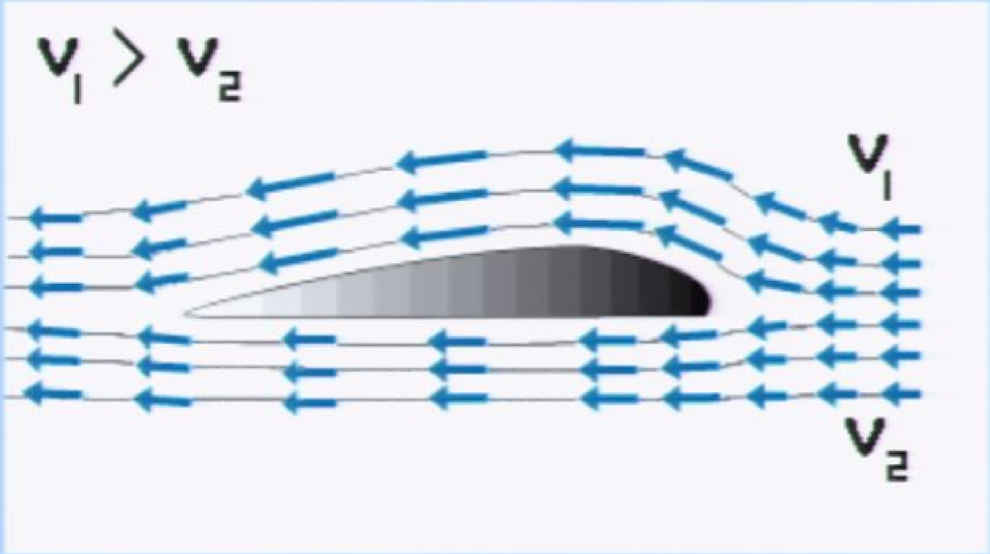
Lift: Bernoulli's explanation

- Air going over the frisbee moves faster than air traveling under
- So the pressure above the disc is lower than the pressure below it
- The result is a lift force upward



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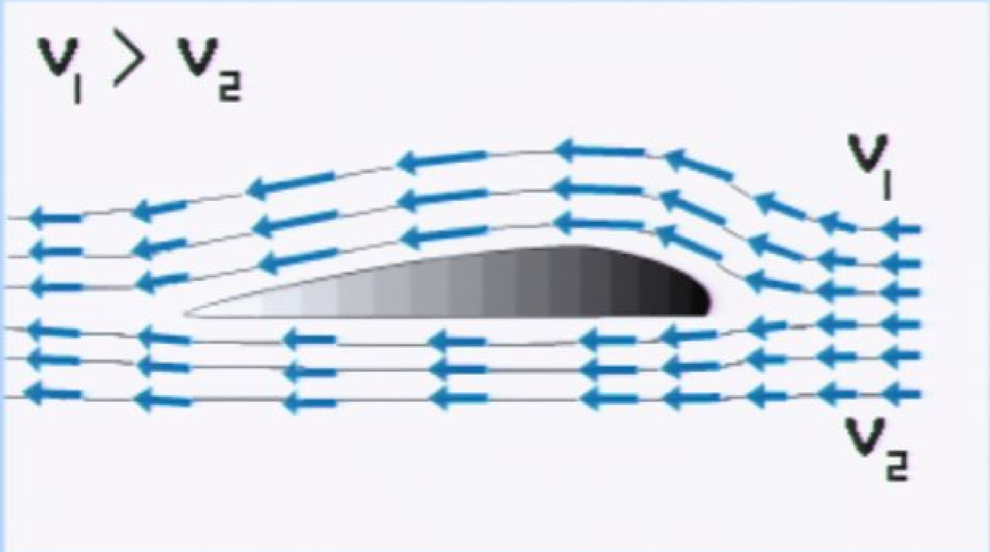

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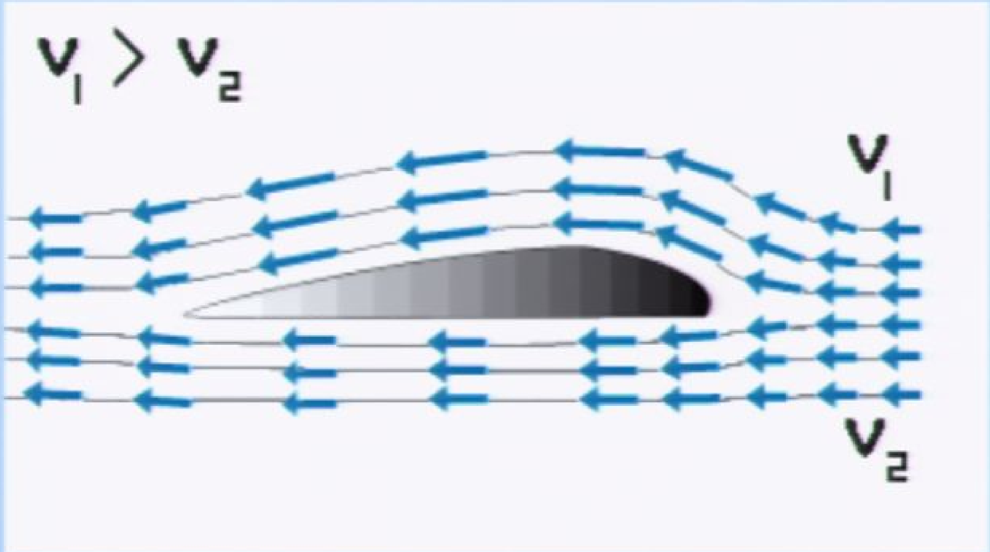

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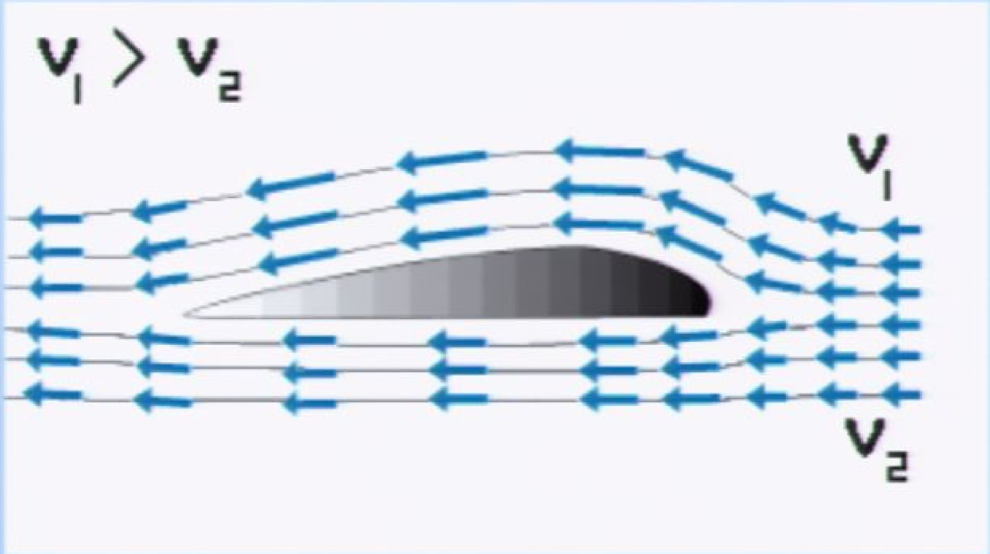

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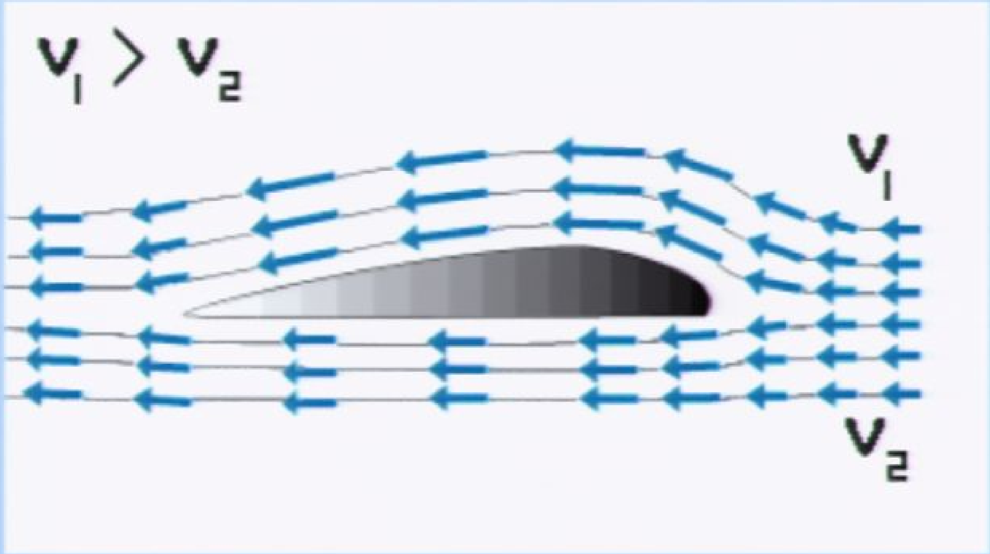

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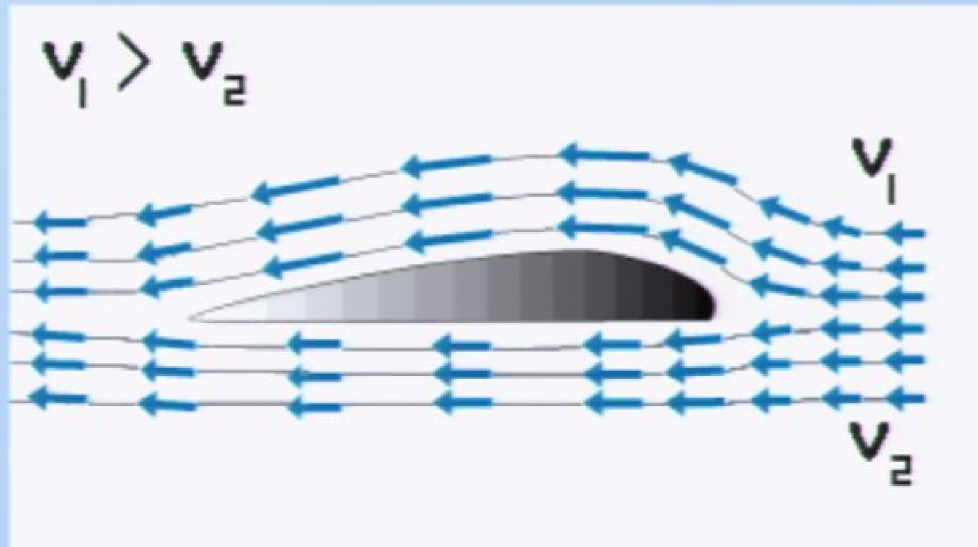

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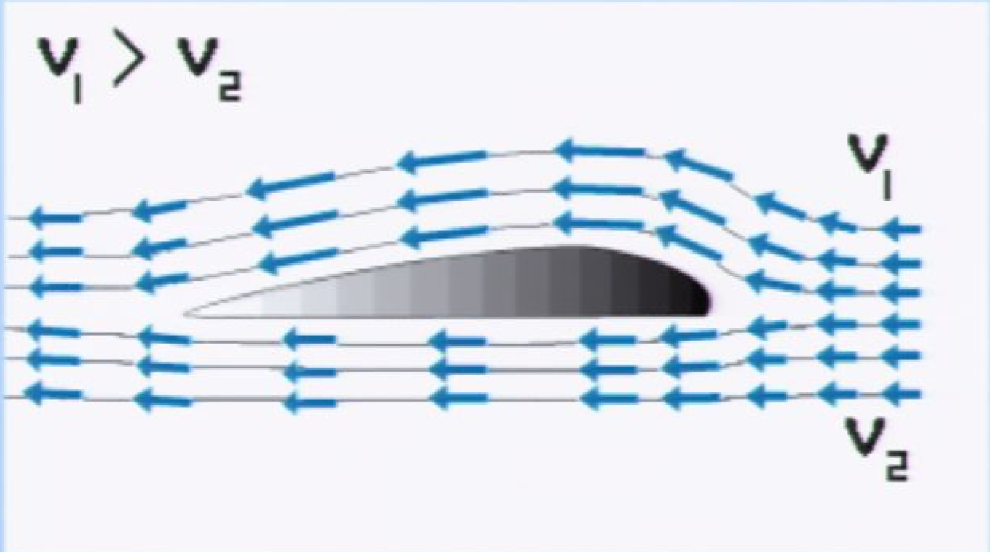

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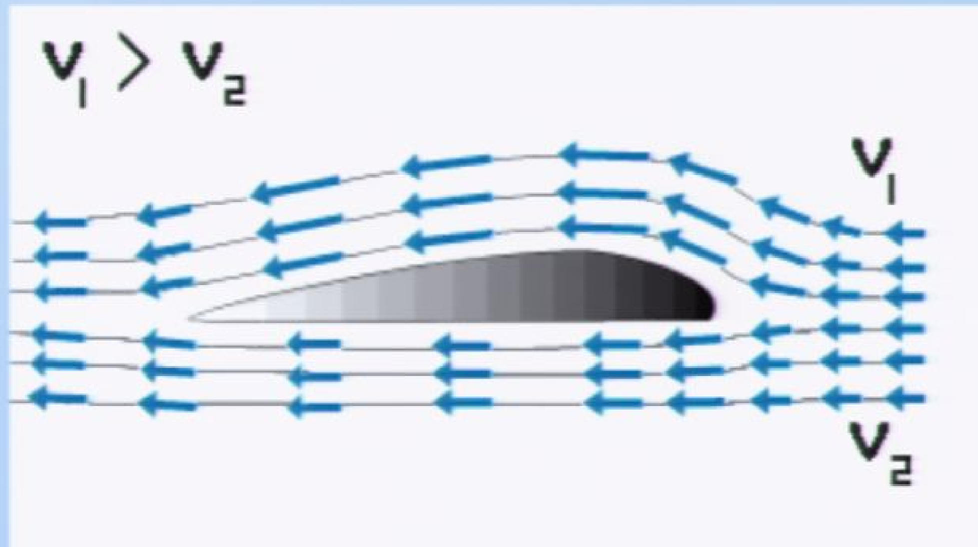

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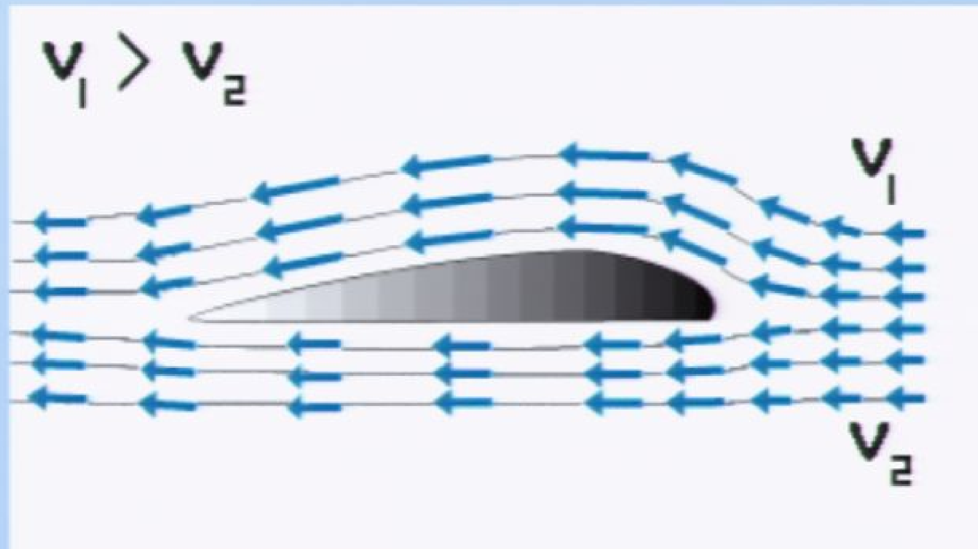

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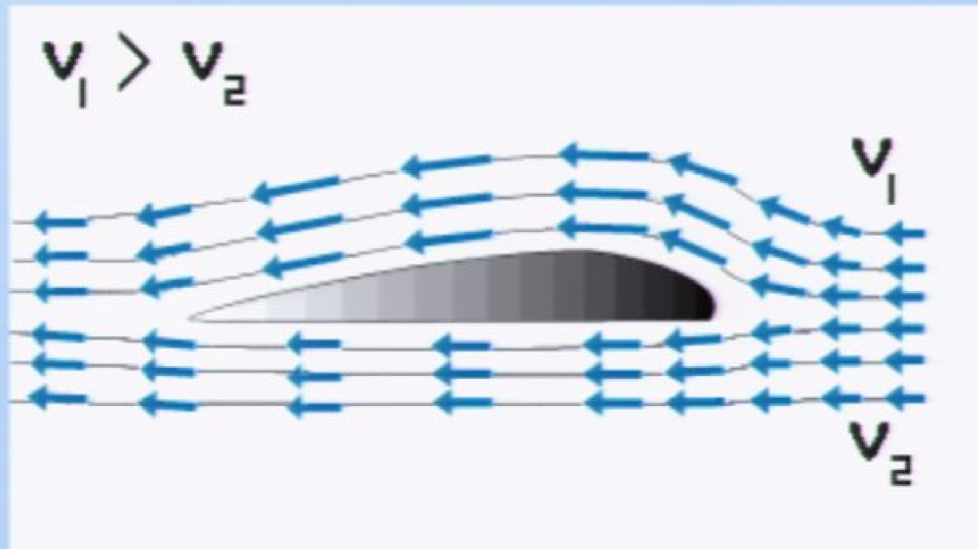

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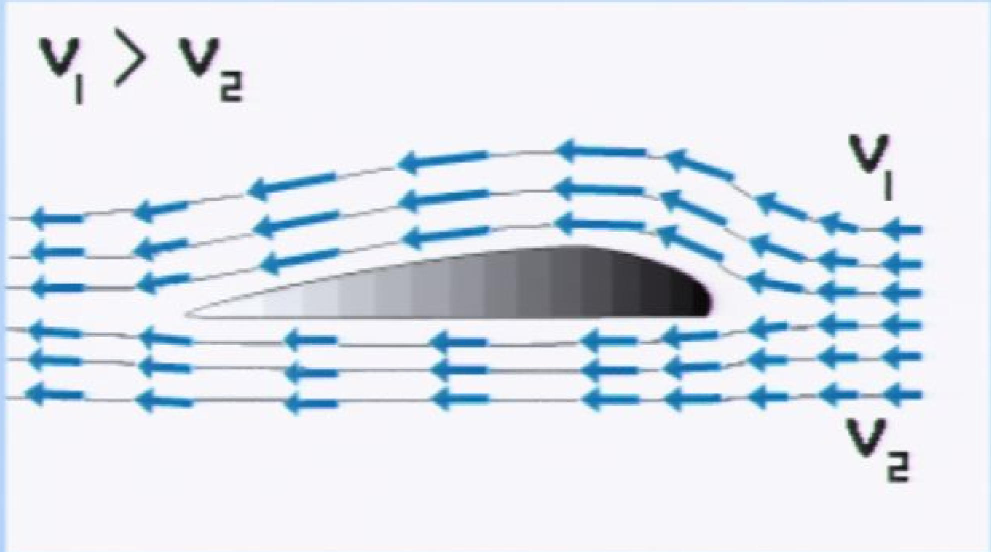

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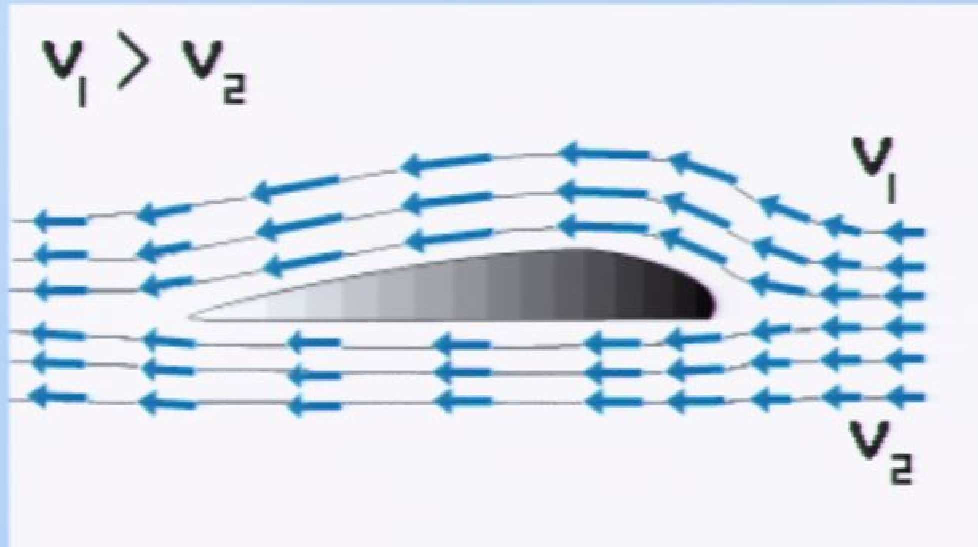

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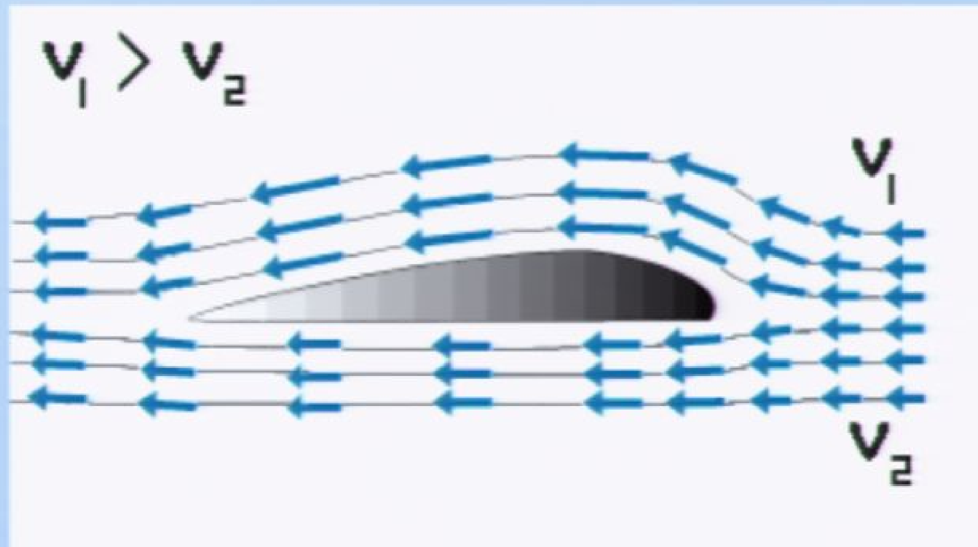

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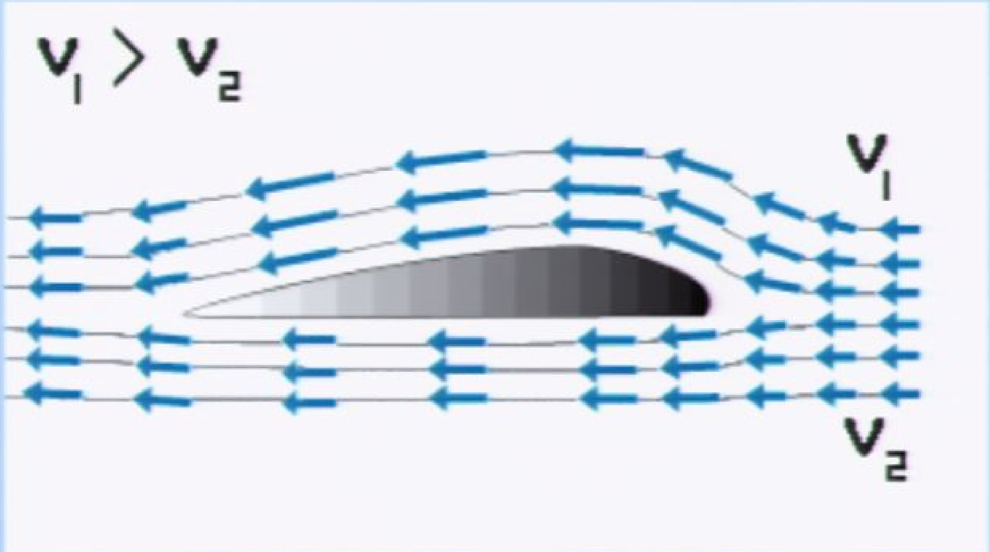

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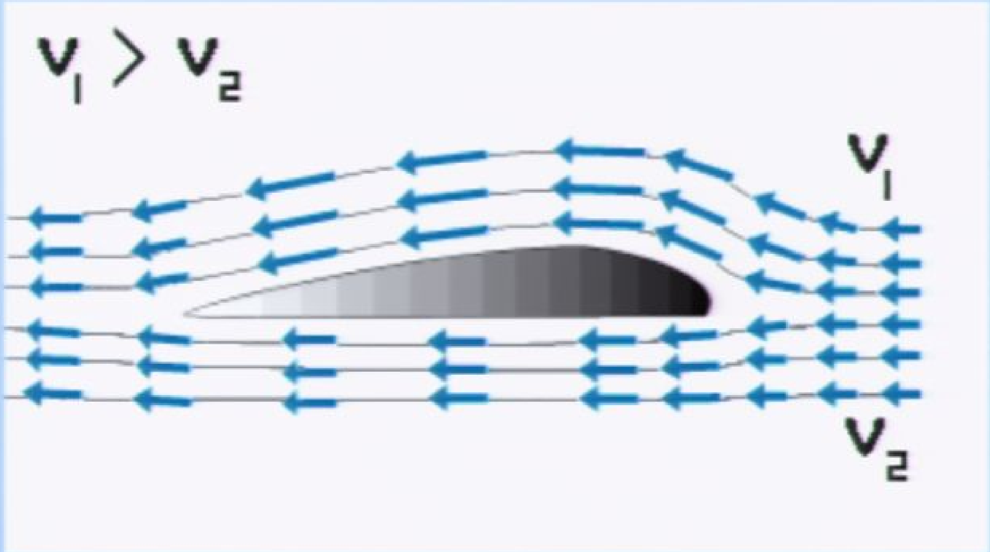

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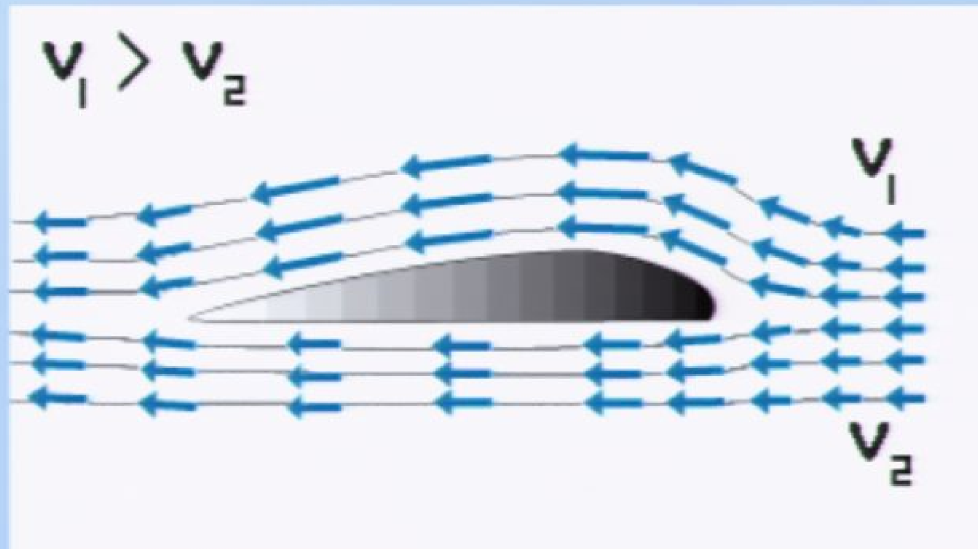

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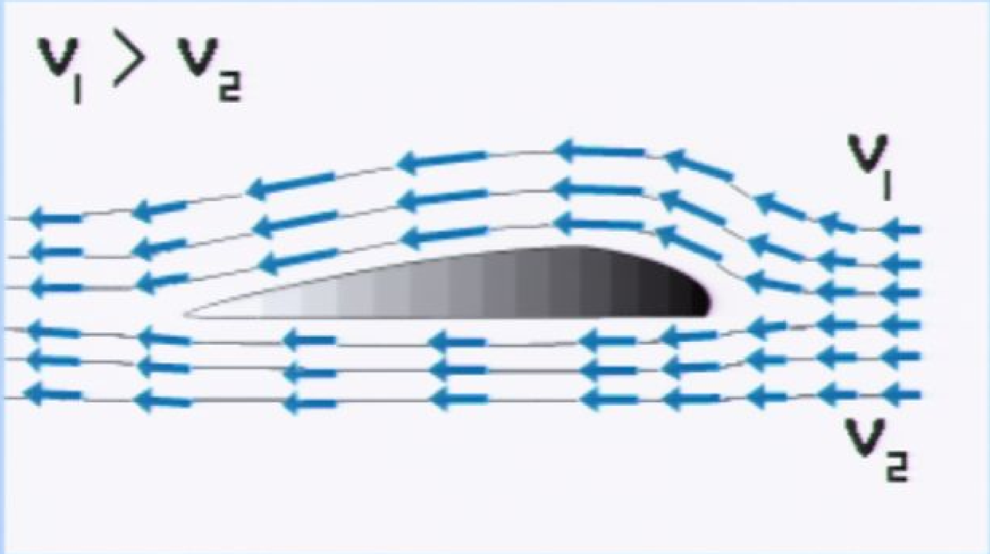

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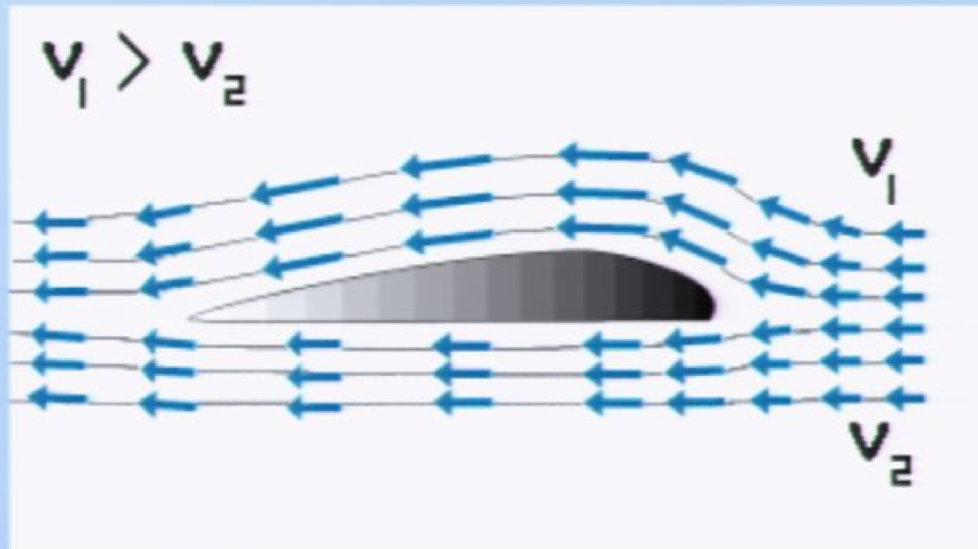

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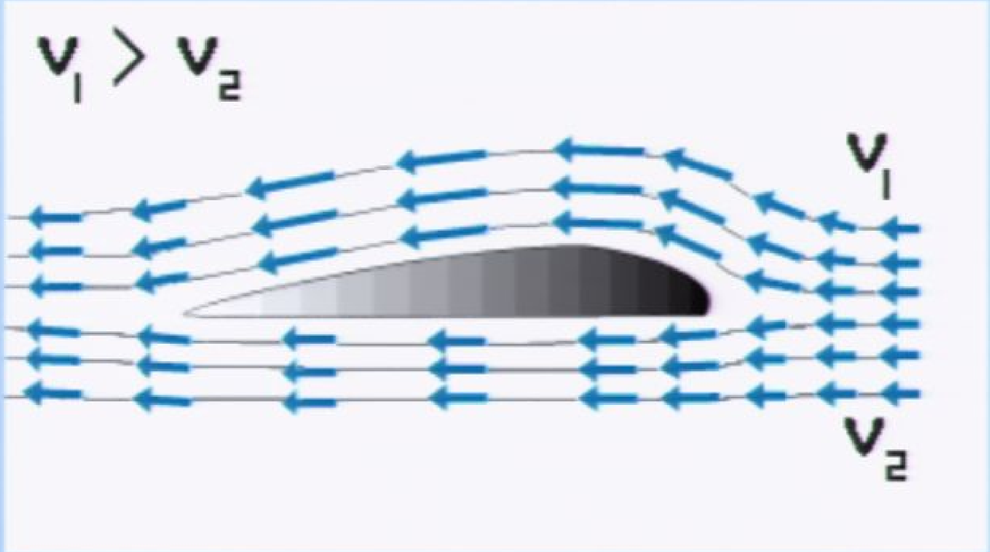

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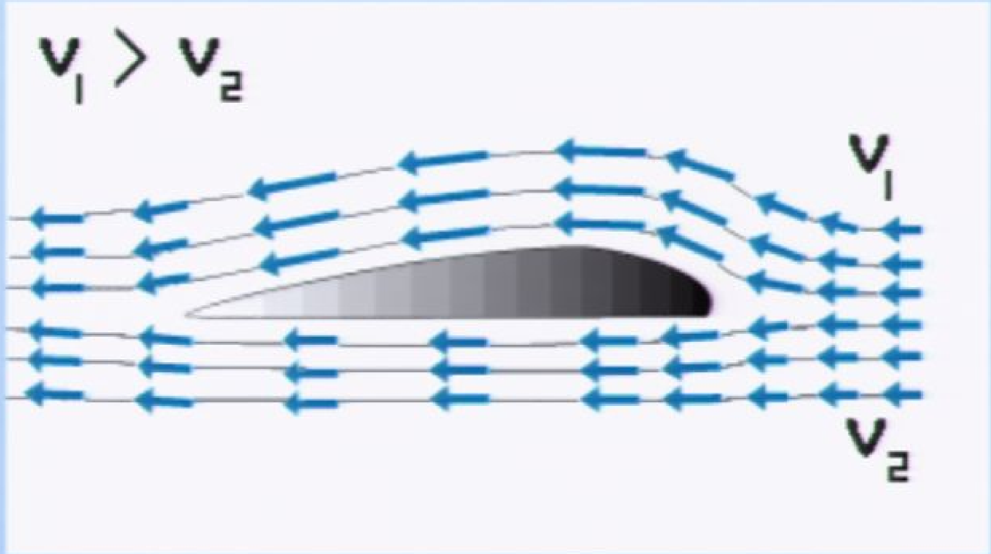

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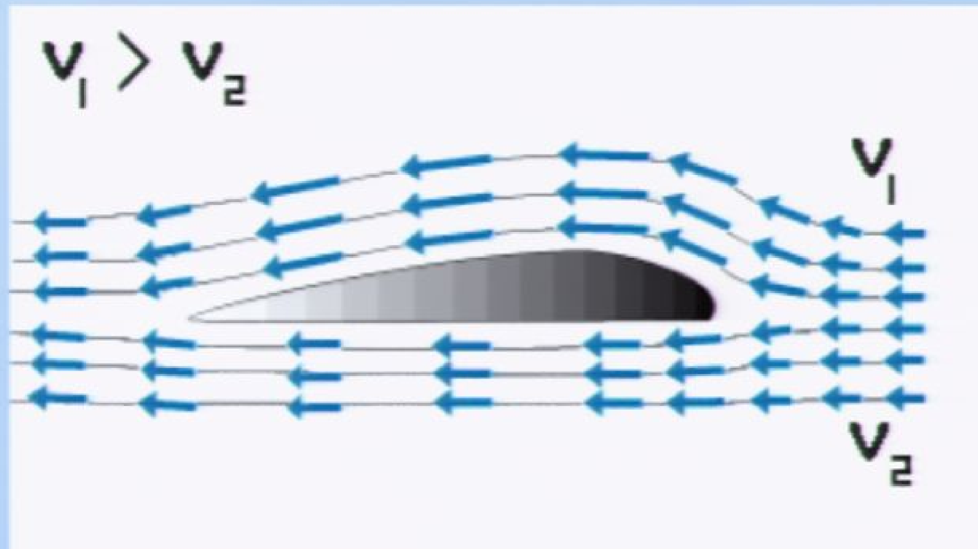

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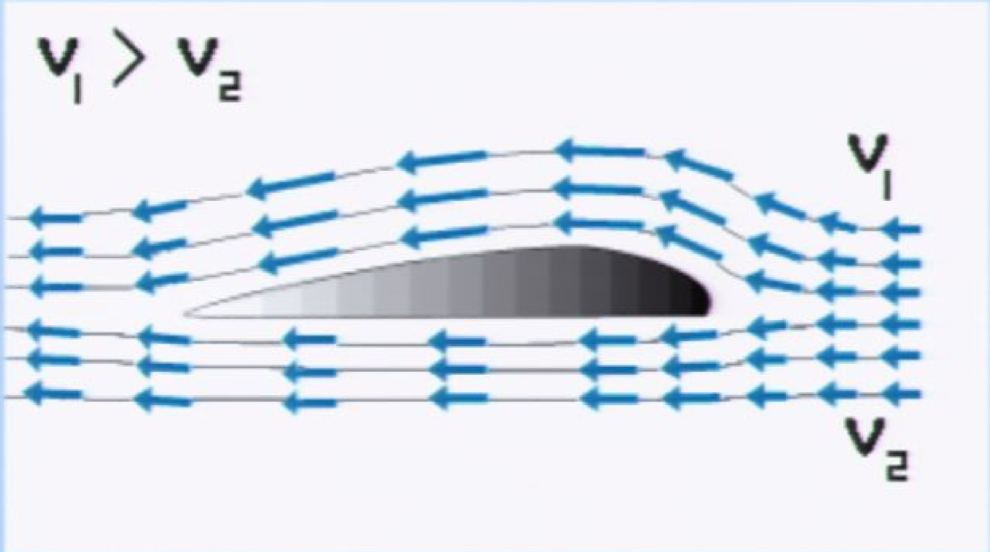

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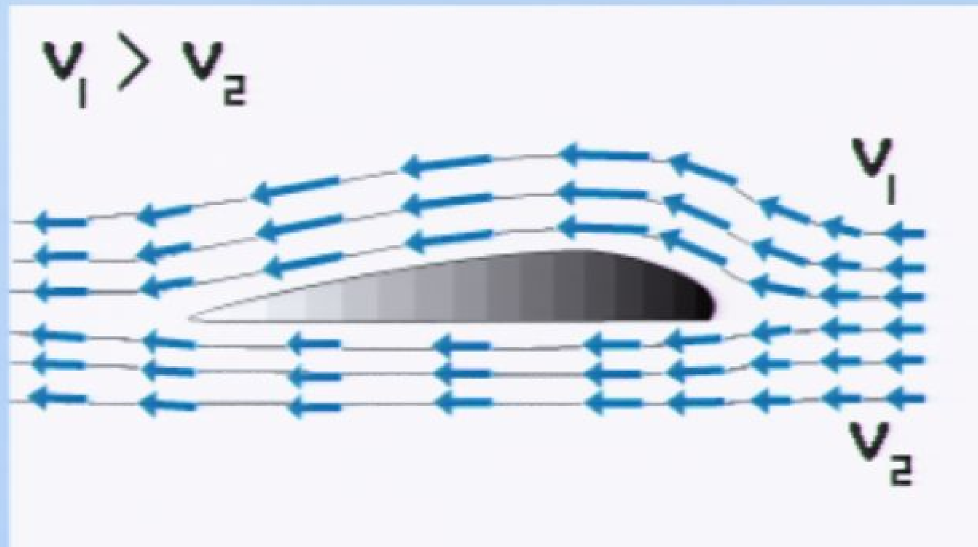

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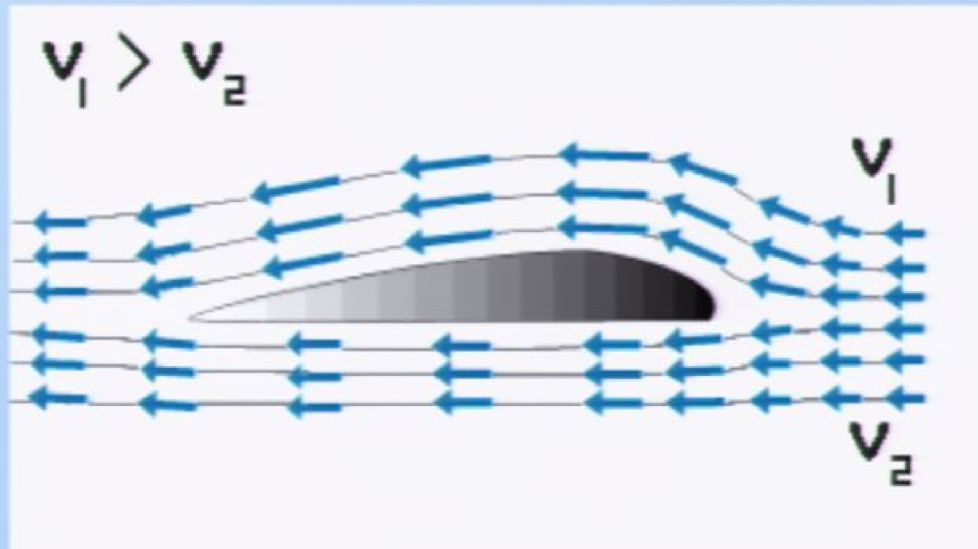

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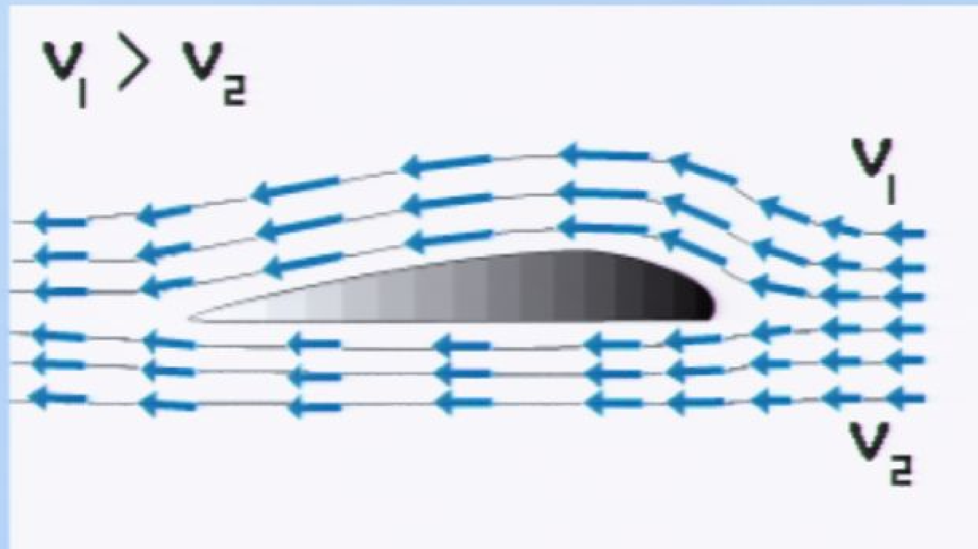

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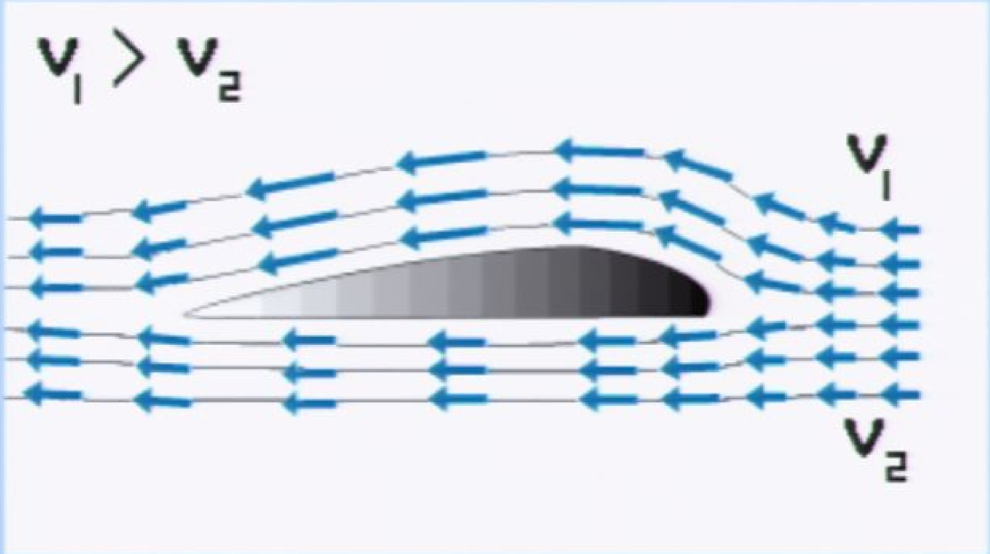

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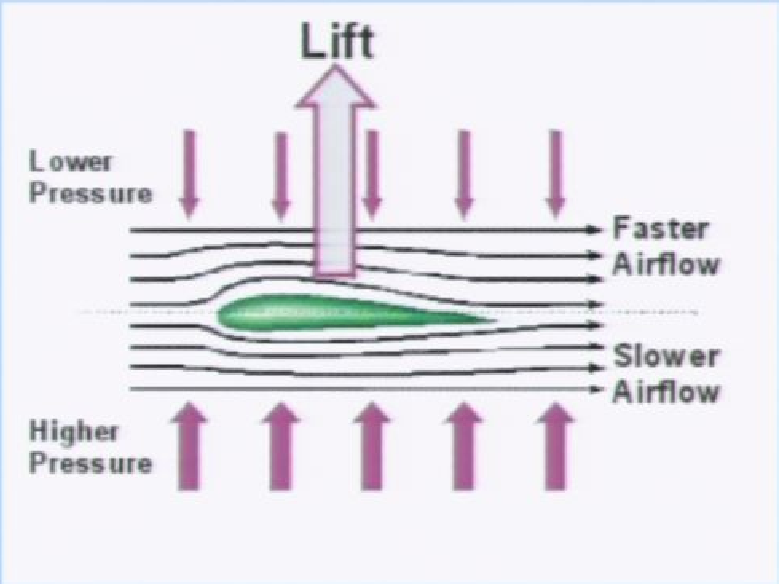

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- Where Γ, the circulation, is the line integral of the fluid velocity around the path of the airflow

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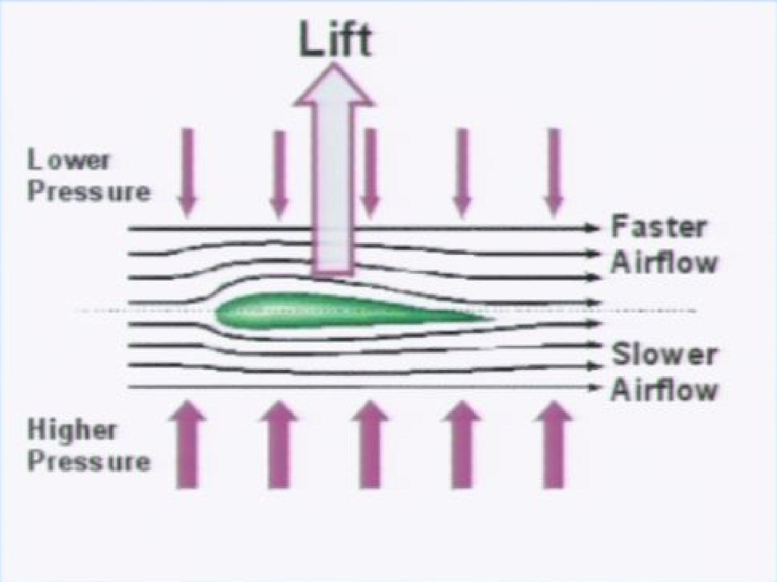

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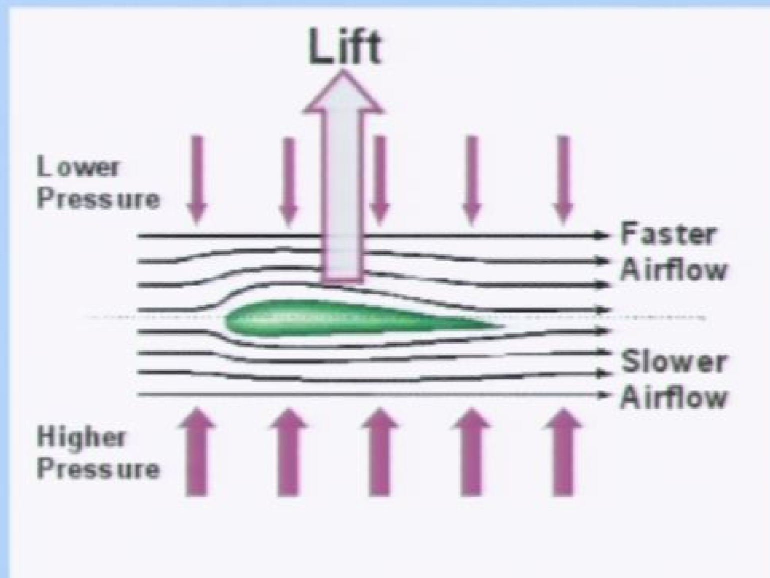

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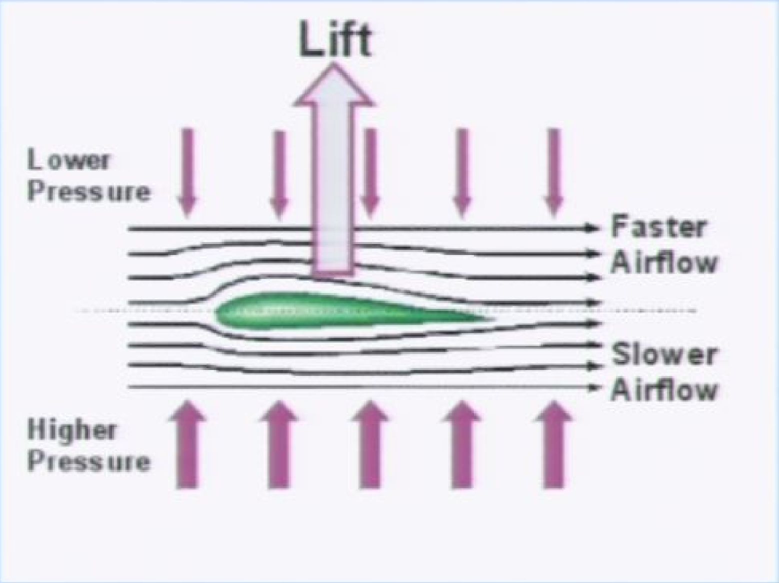

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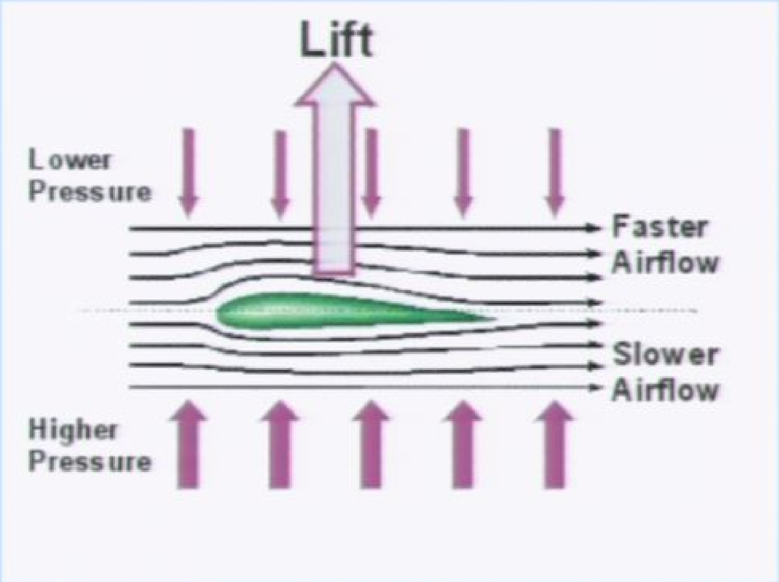

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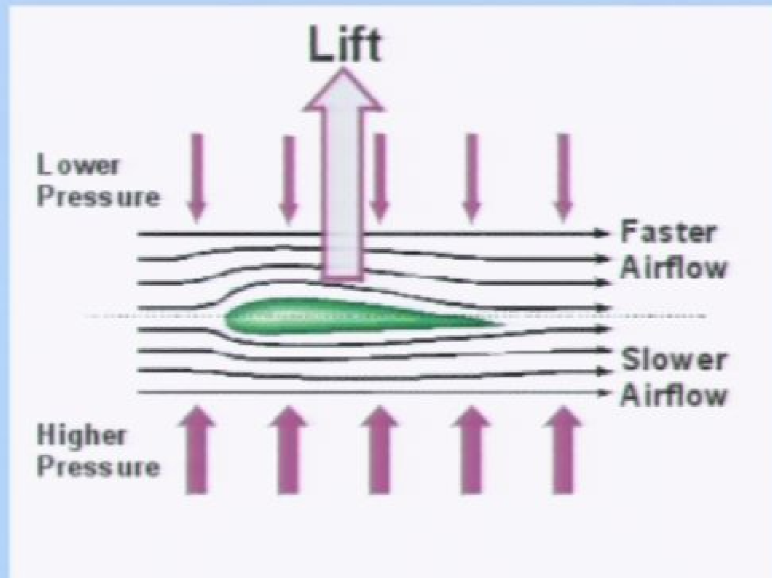

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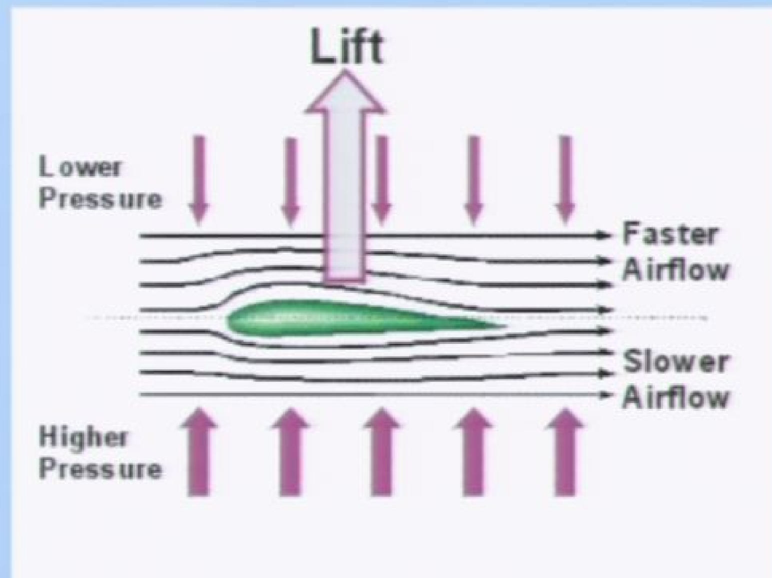

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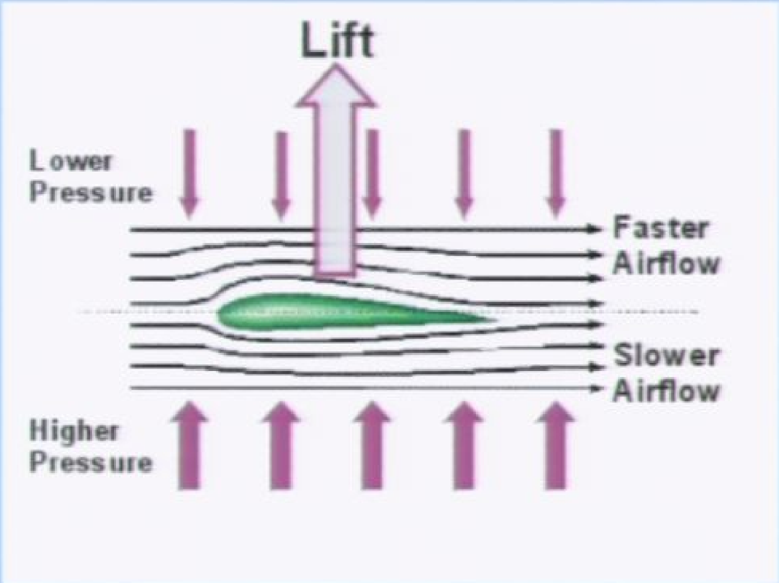

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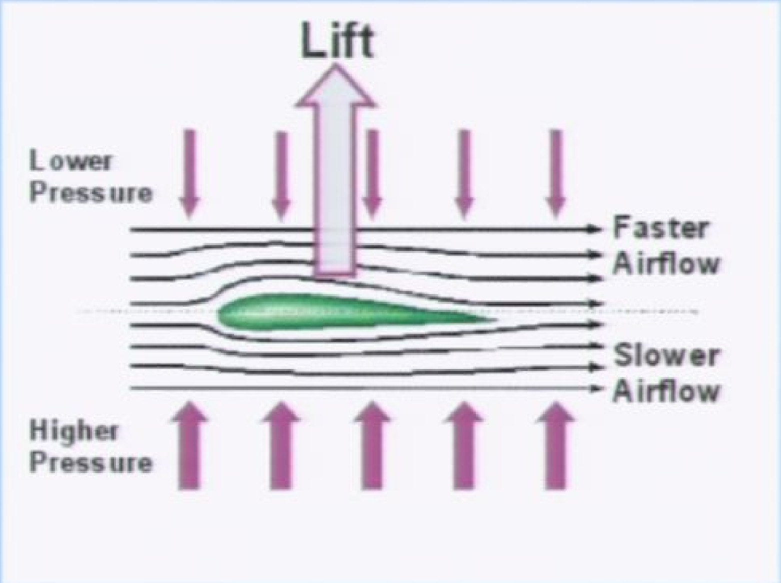

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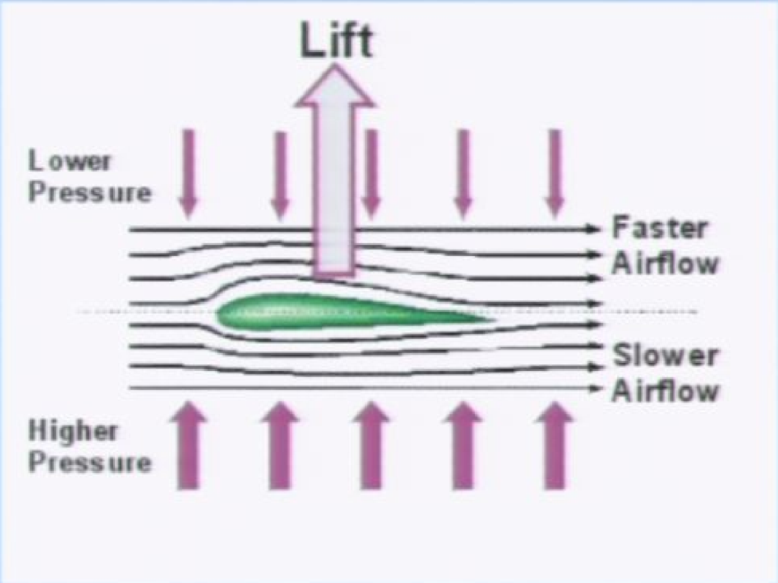

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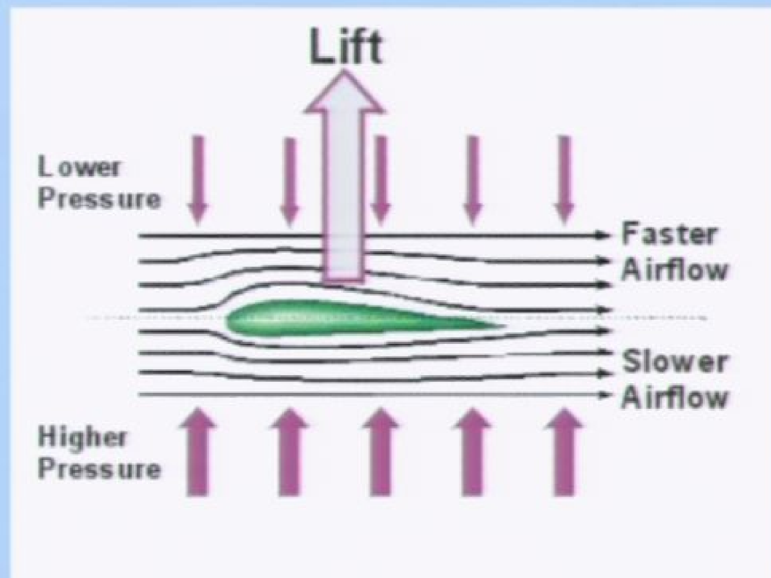

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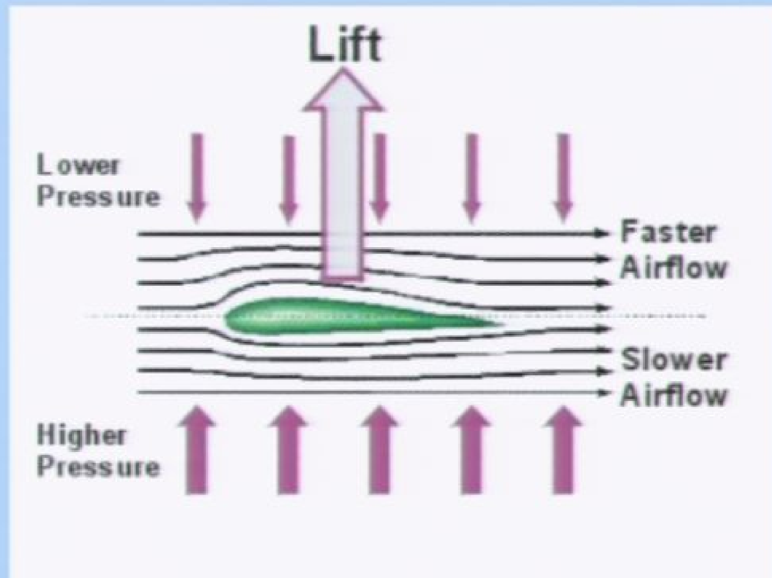

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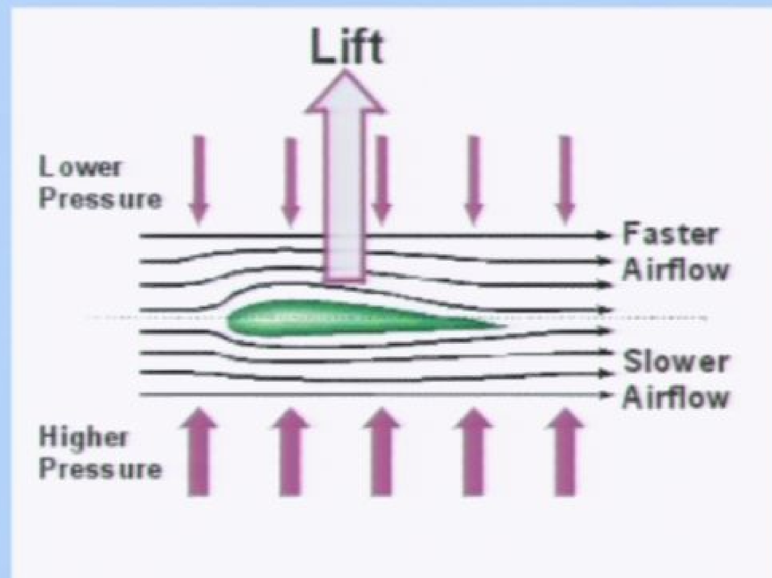

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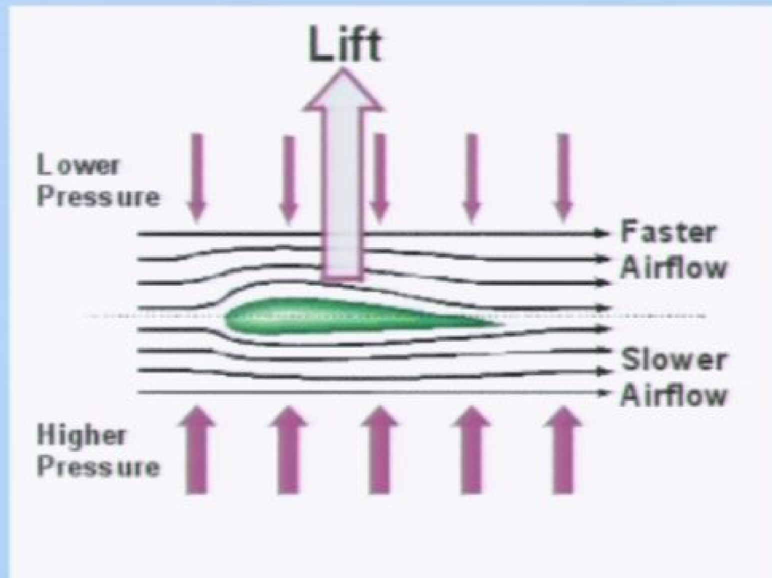

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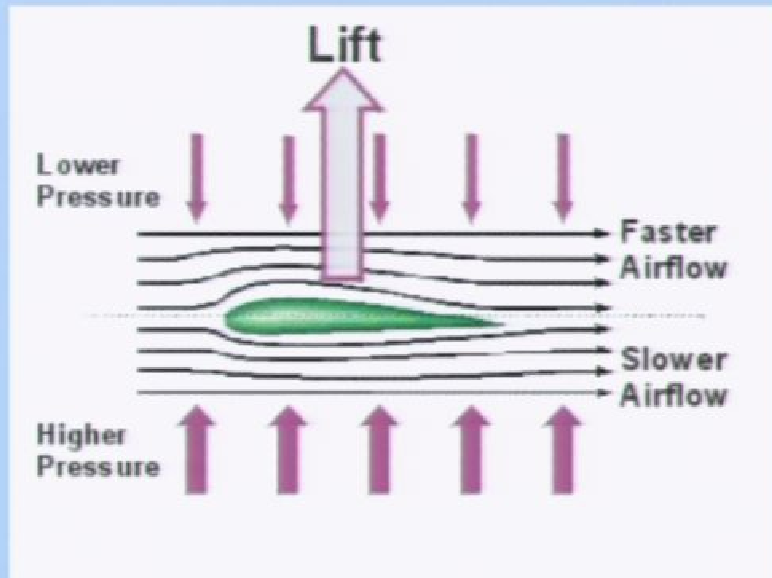

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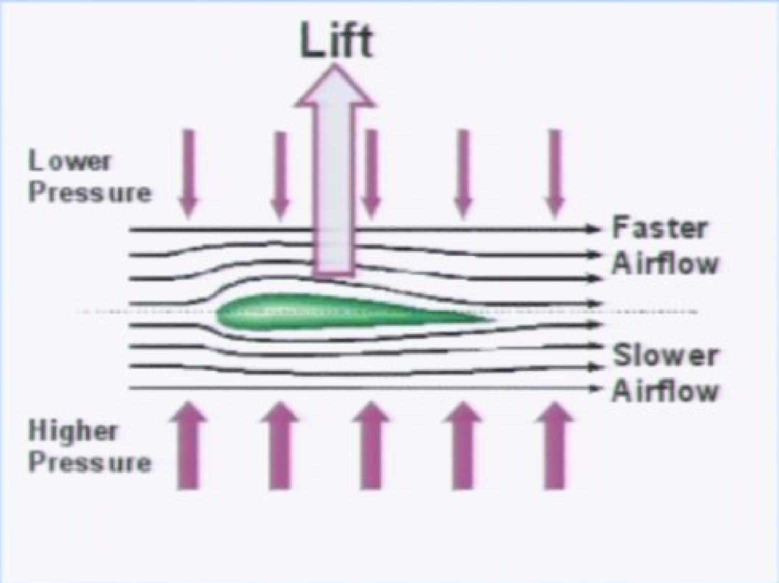

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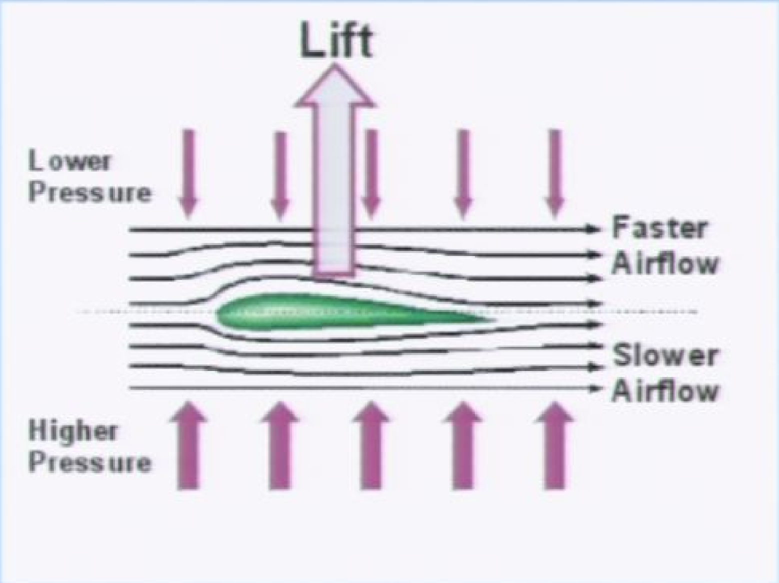

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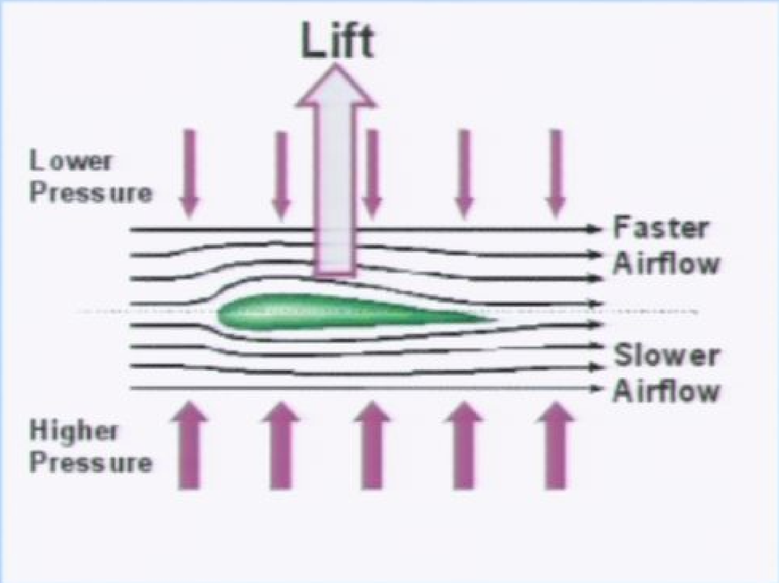

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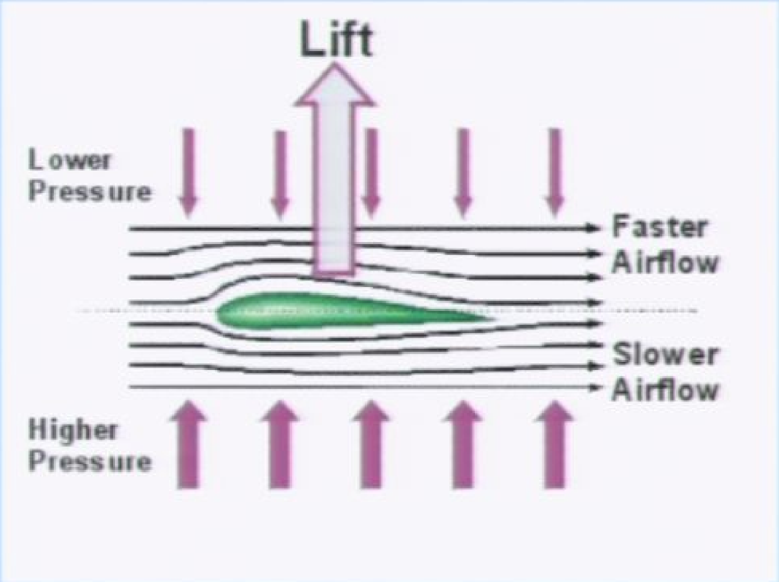

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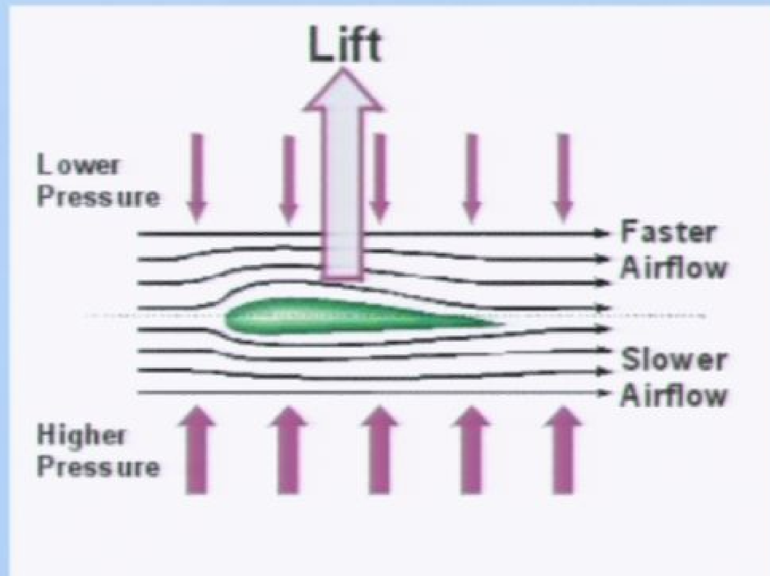

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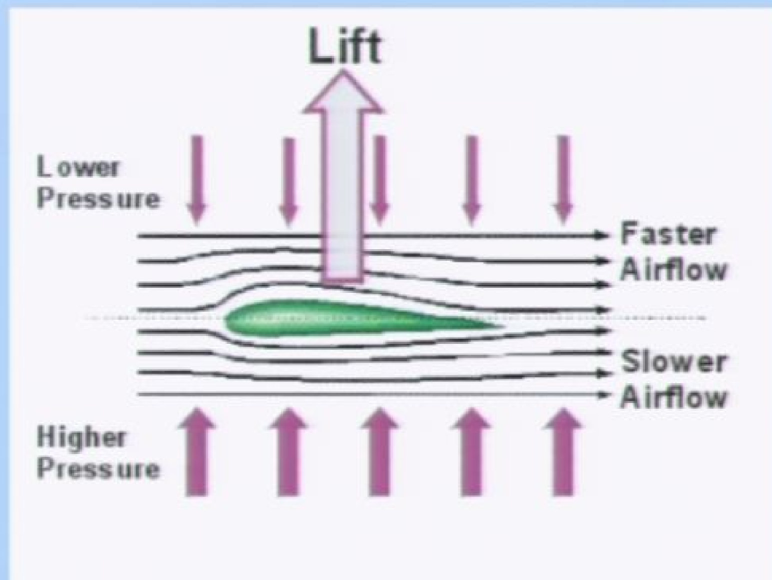

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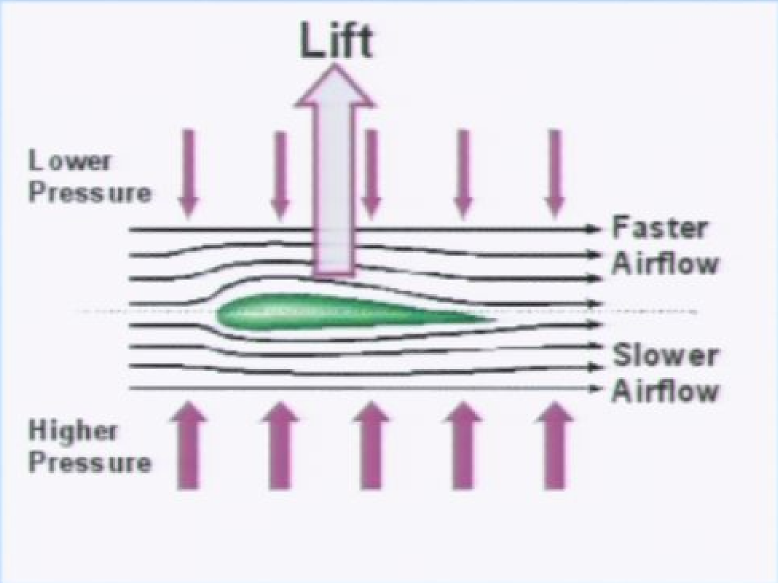

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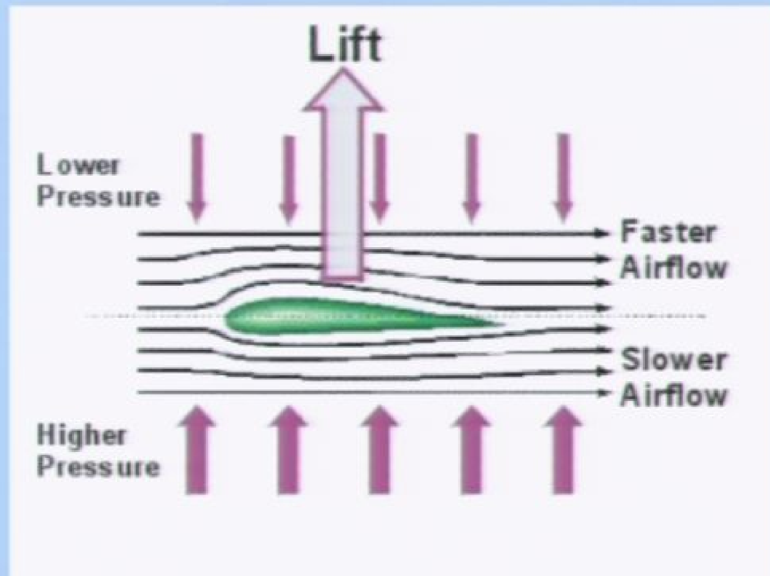

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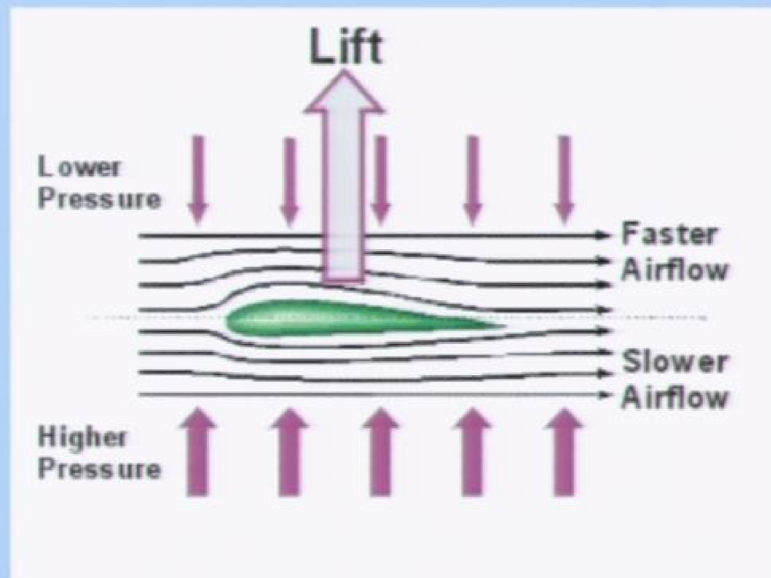

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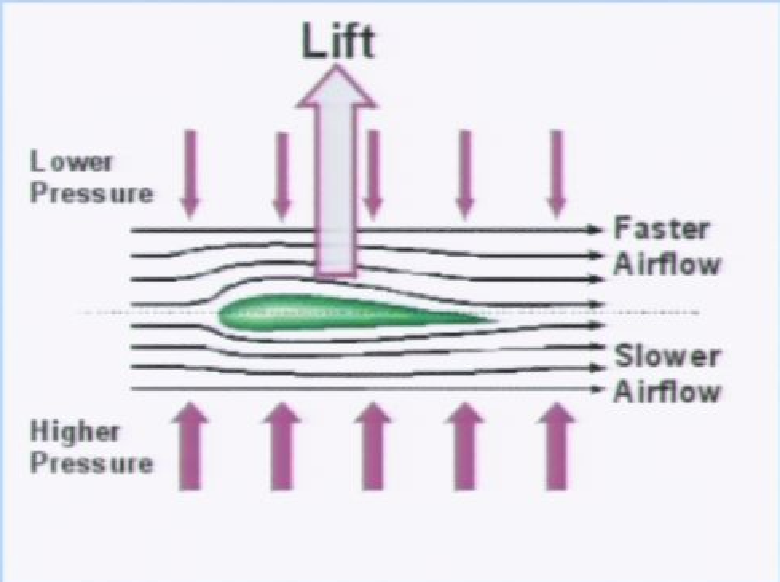

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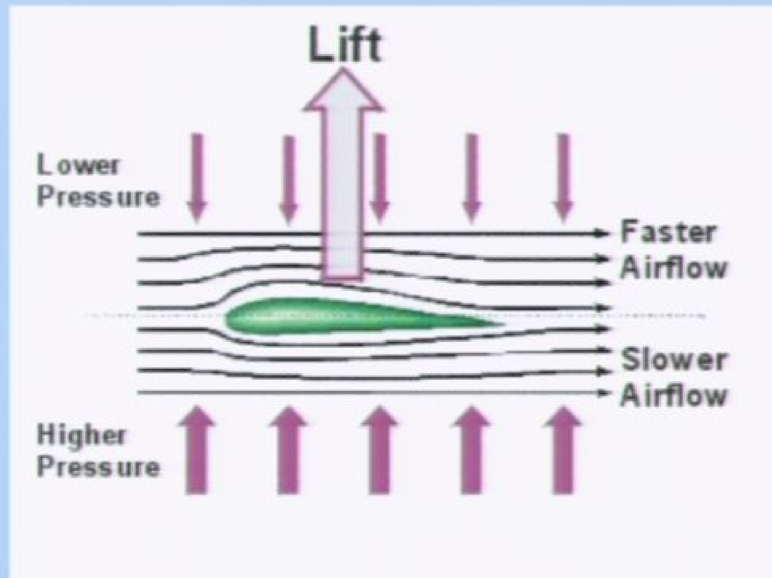

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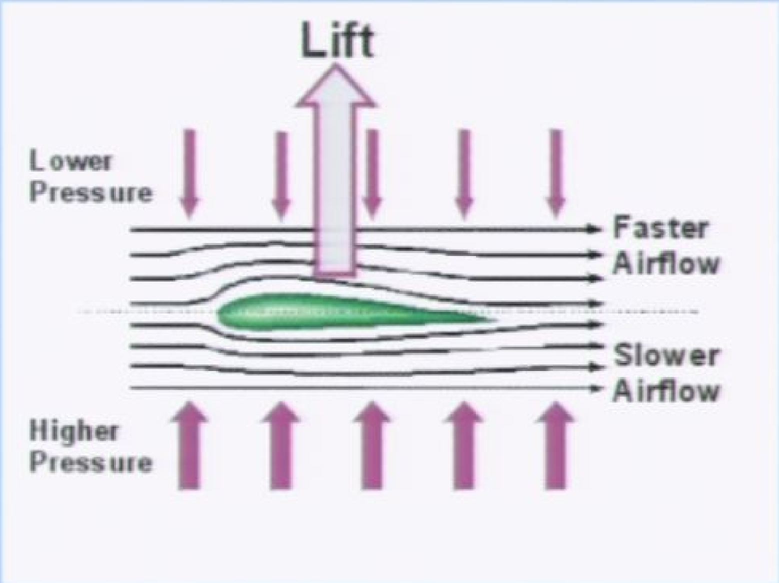

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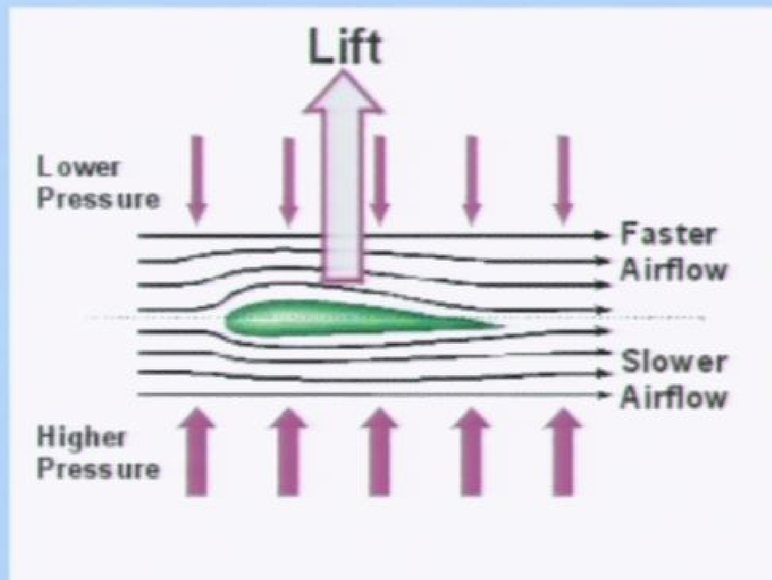

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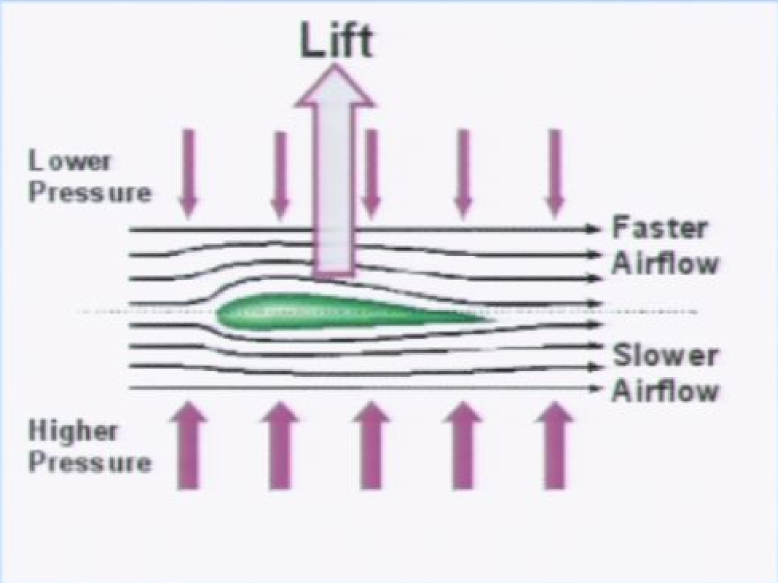

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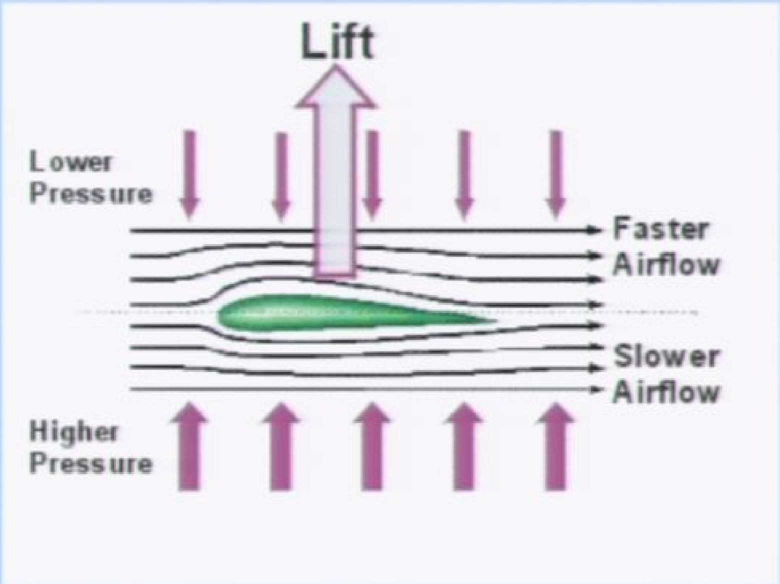

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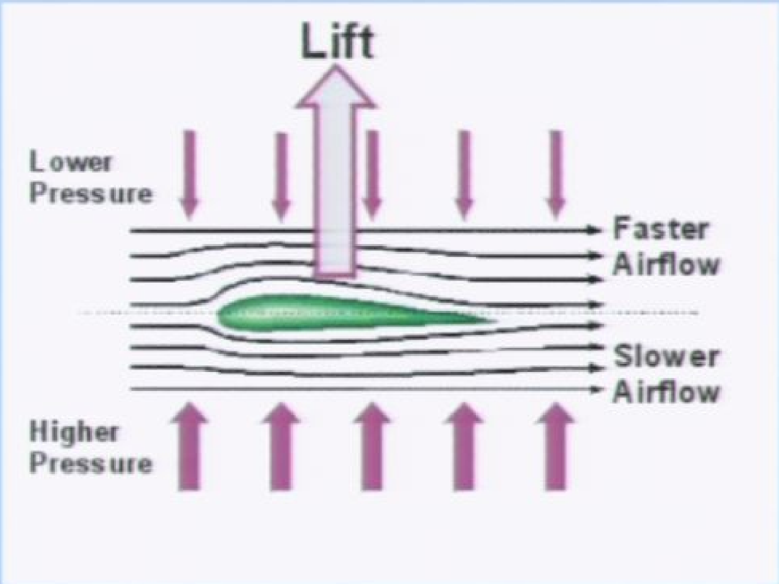

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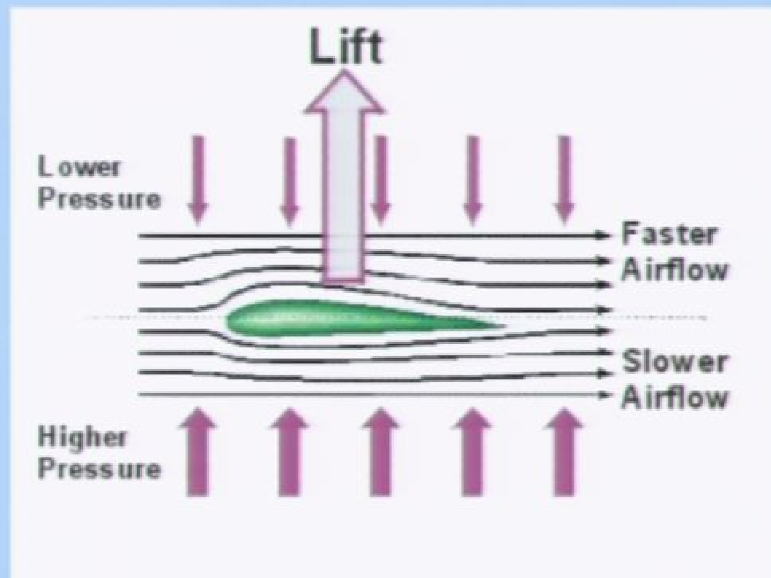

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Lift: Alternative view

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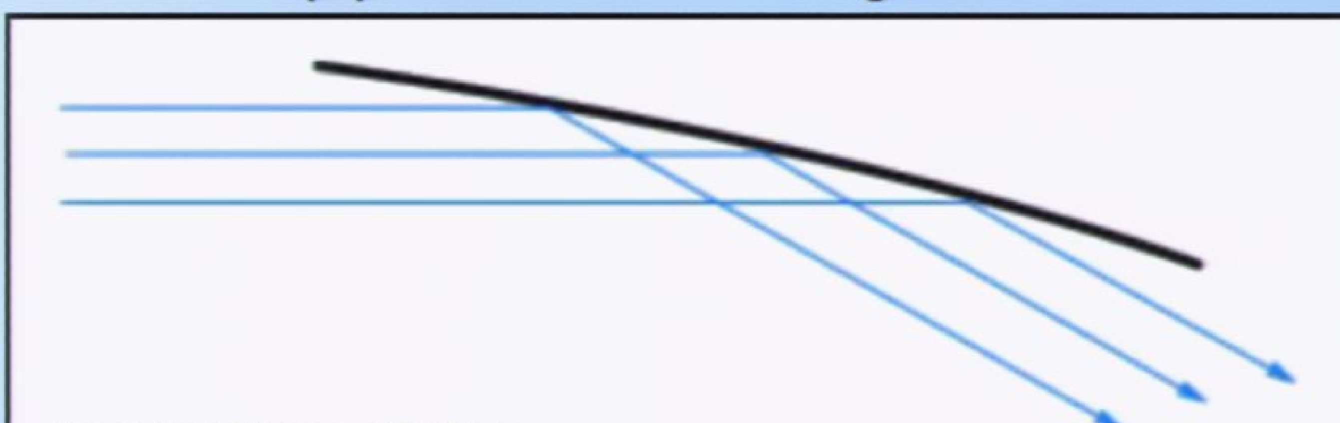

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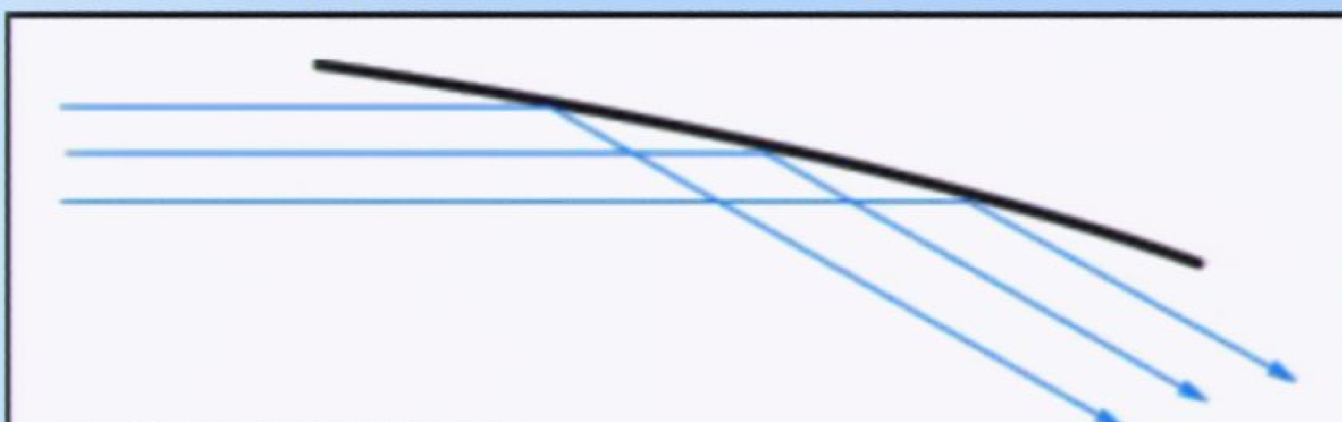

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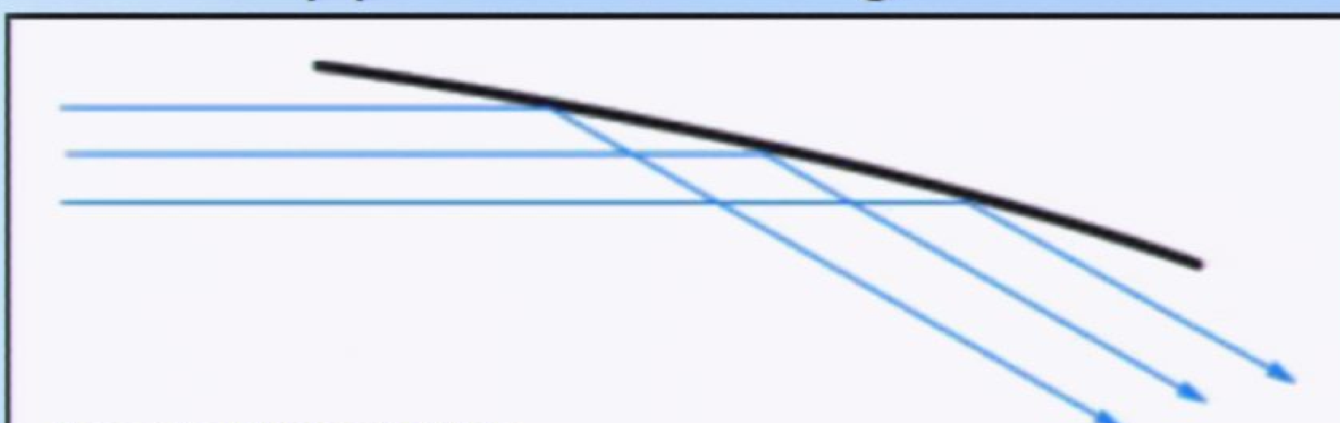

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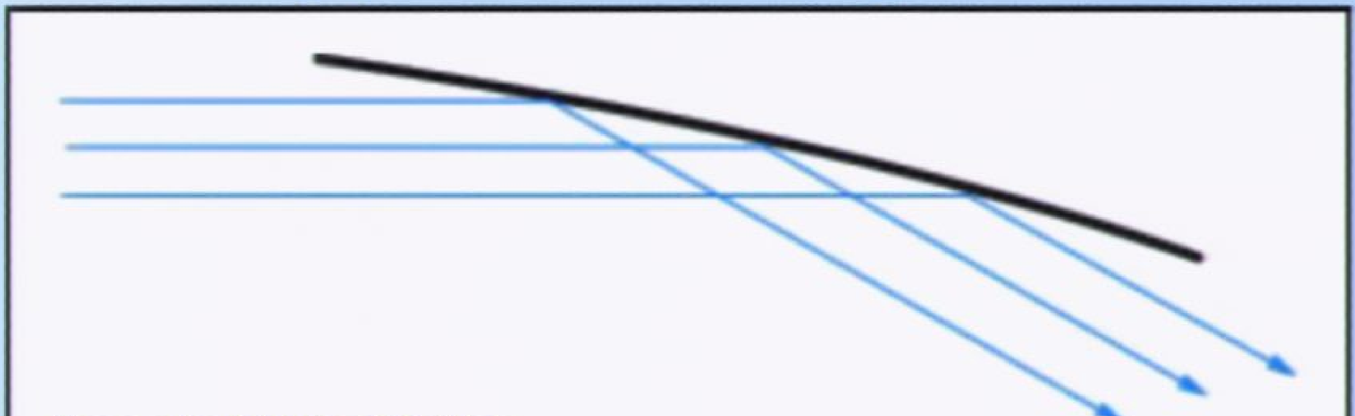

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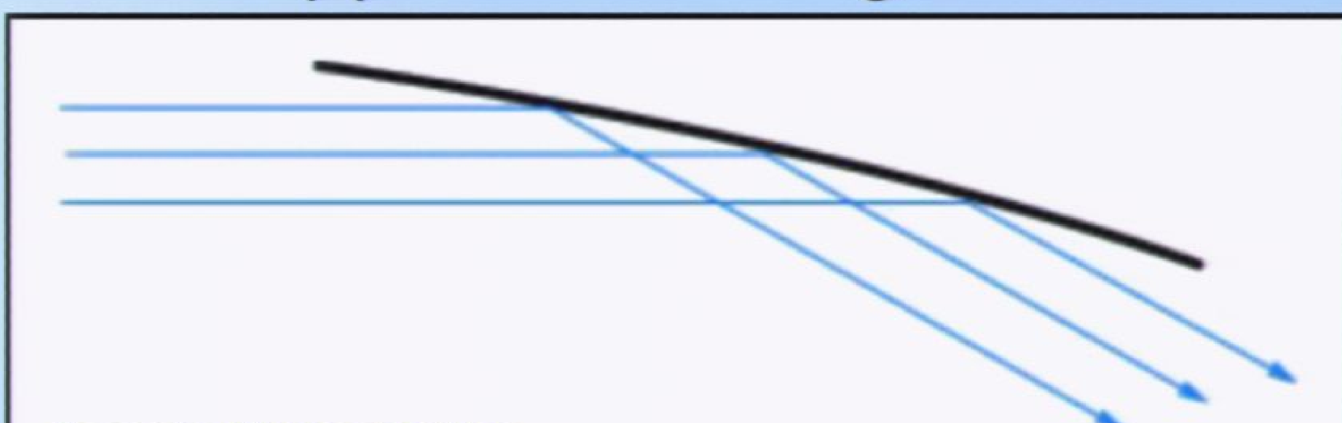

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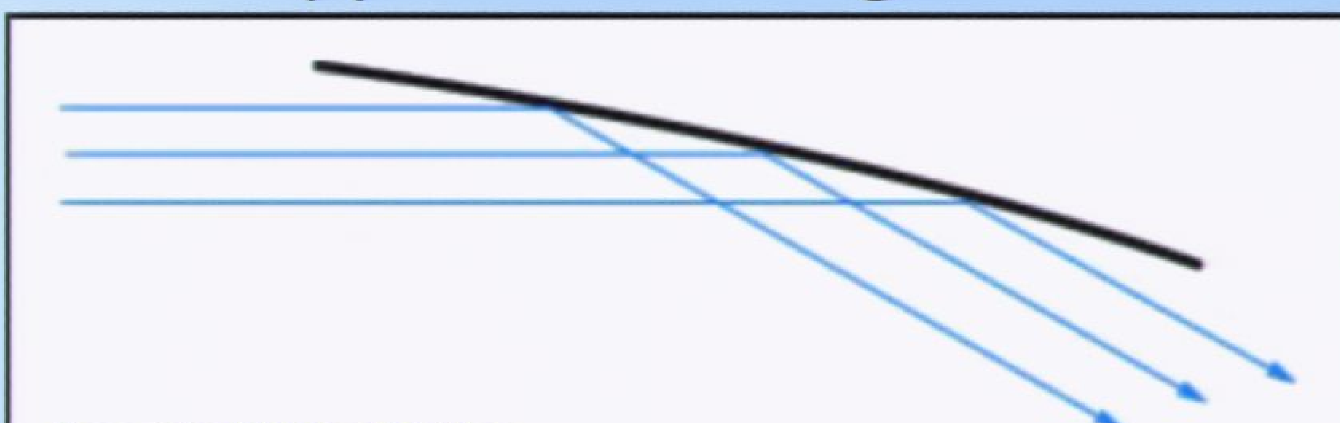

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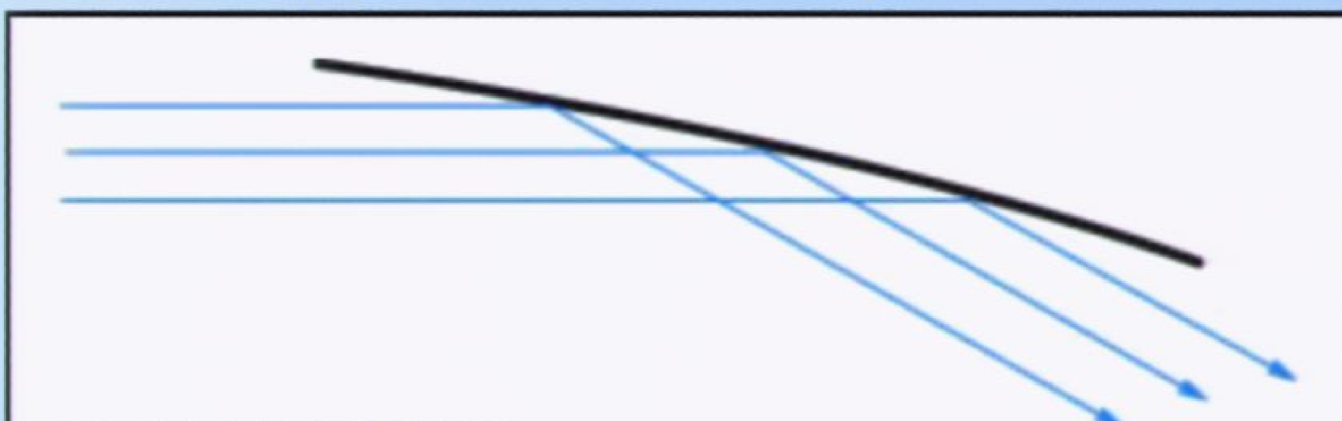

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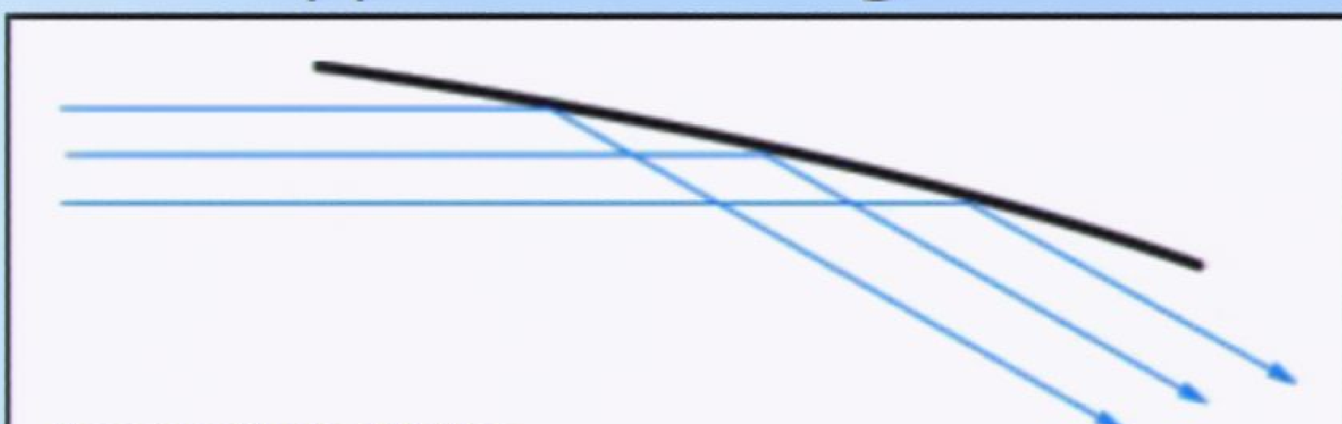

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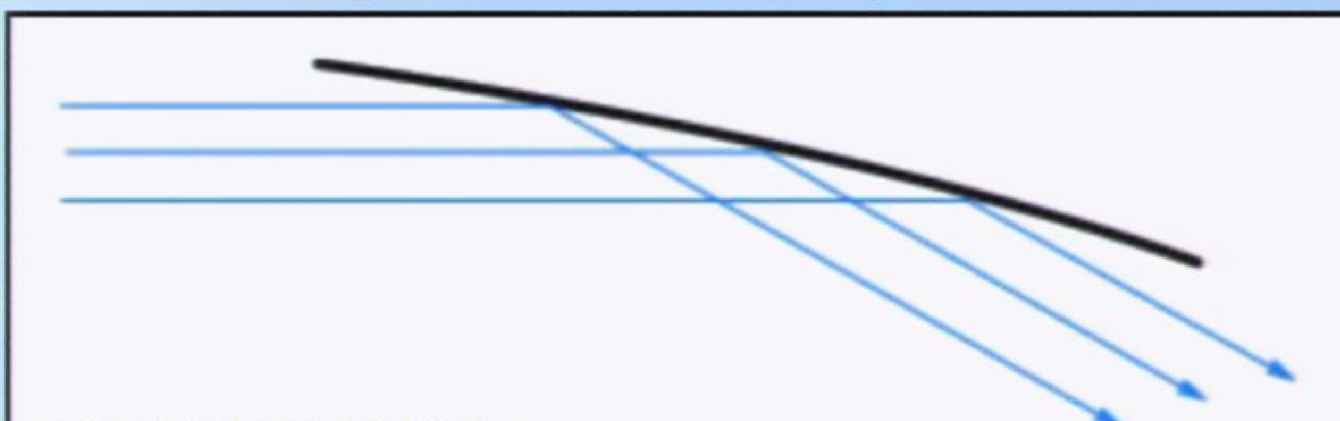

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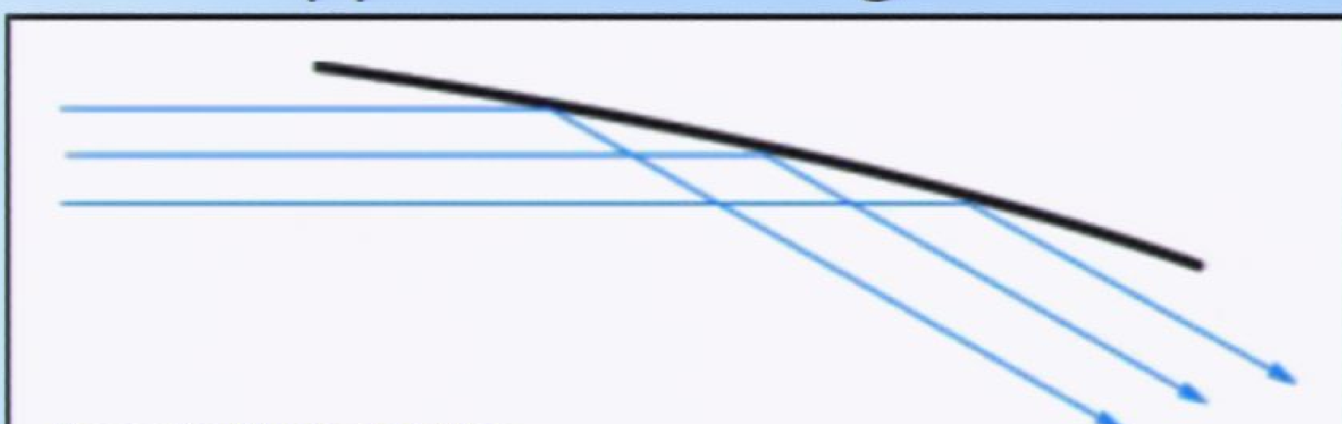

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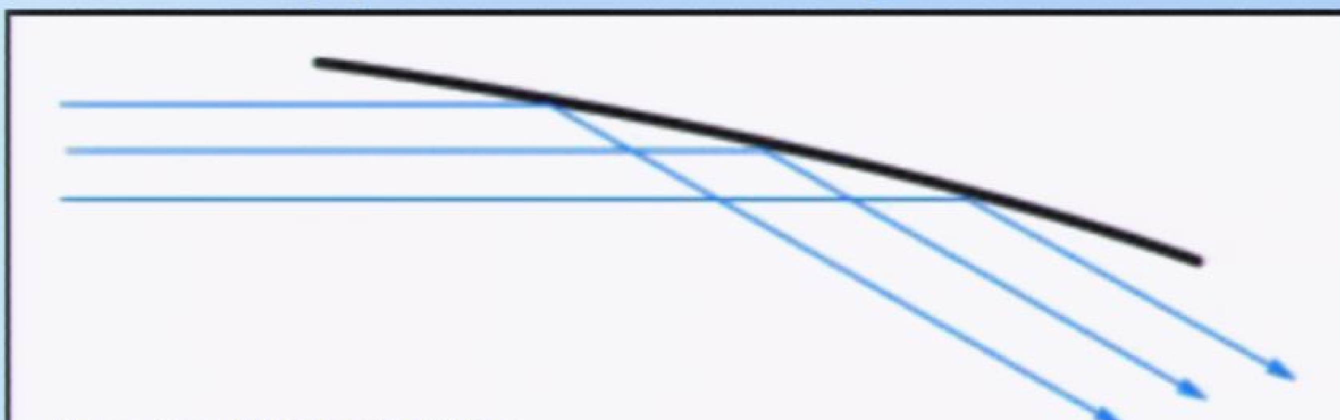

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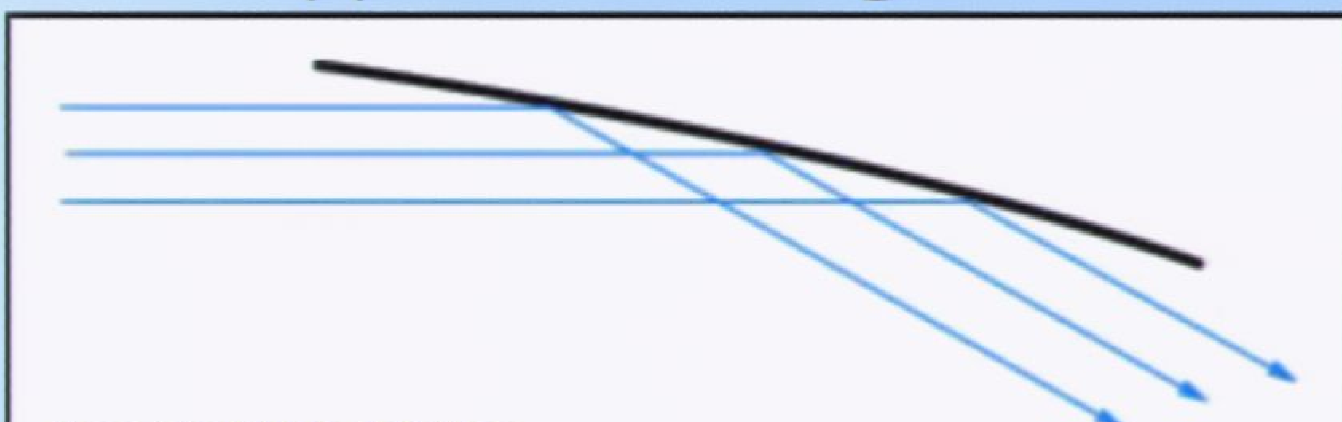

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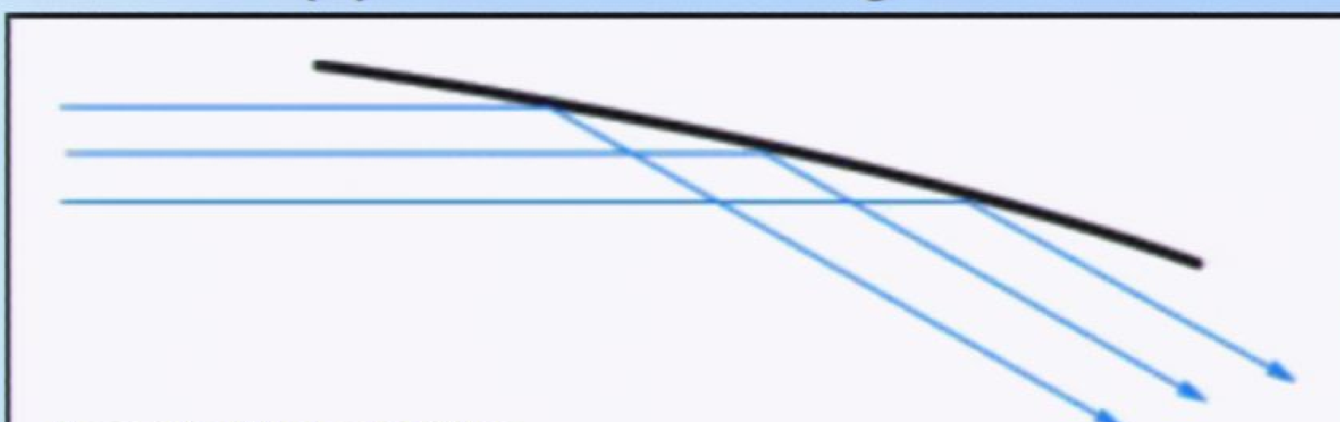

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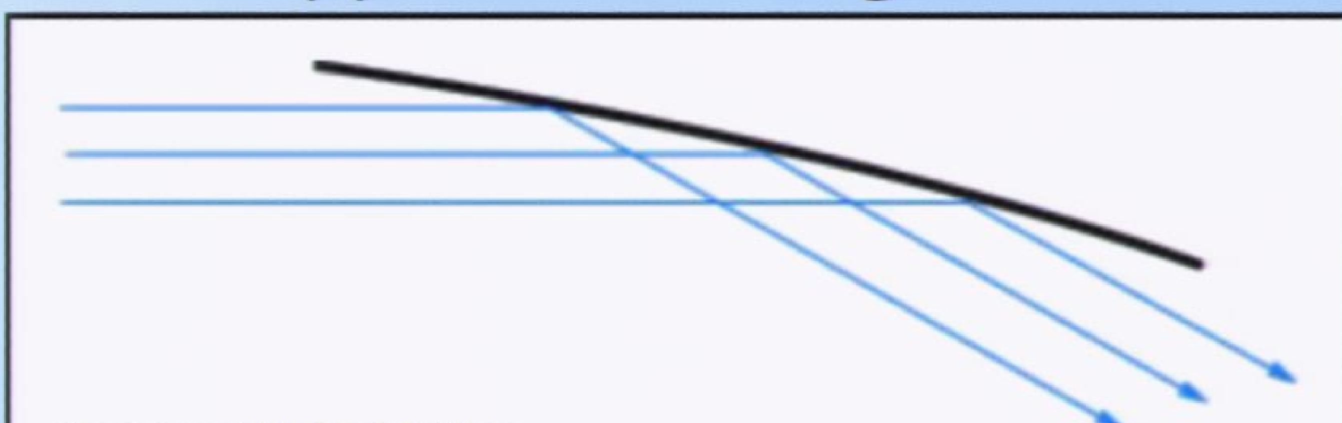

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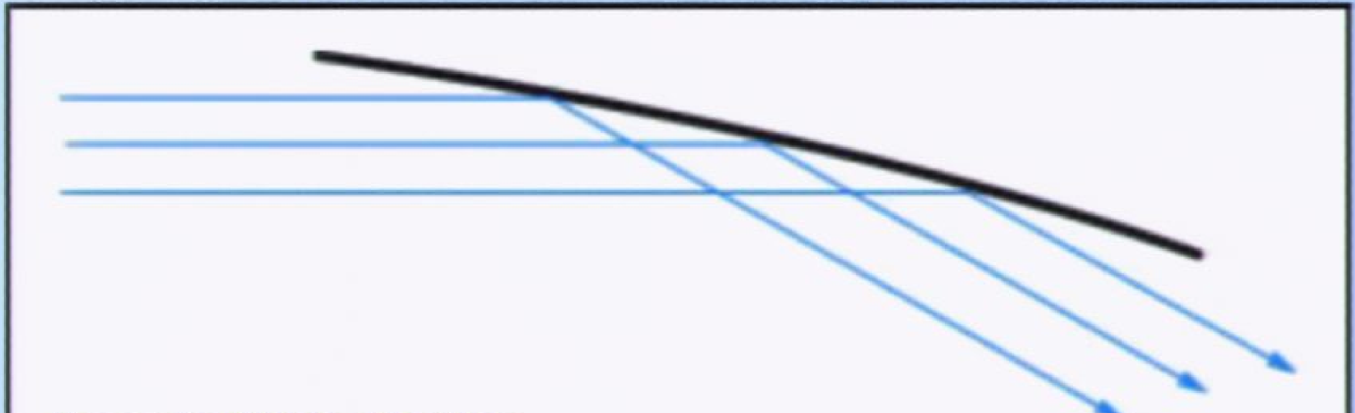

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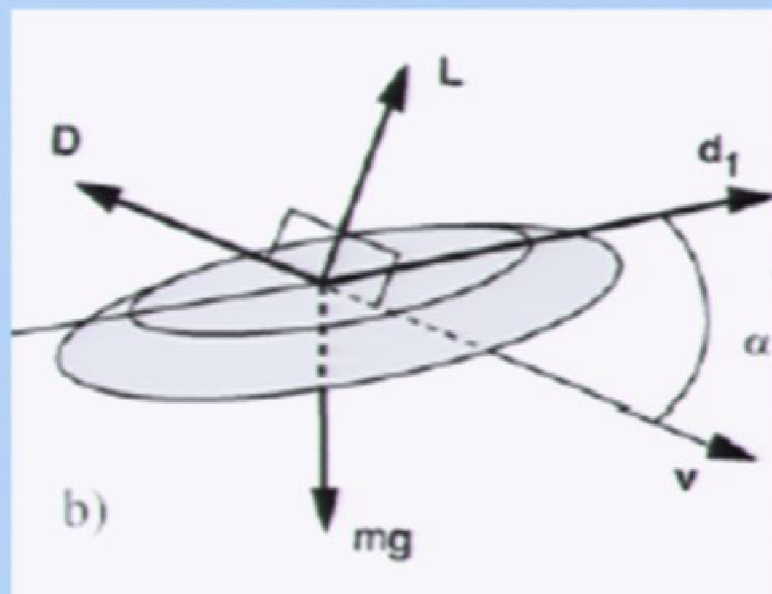

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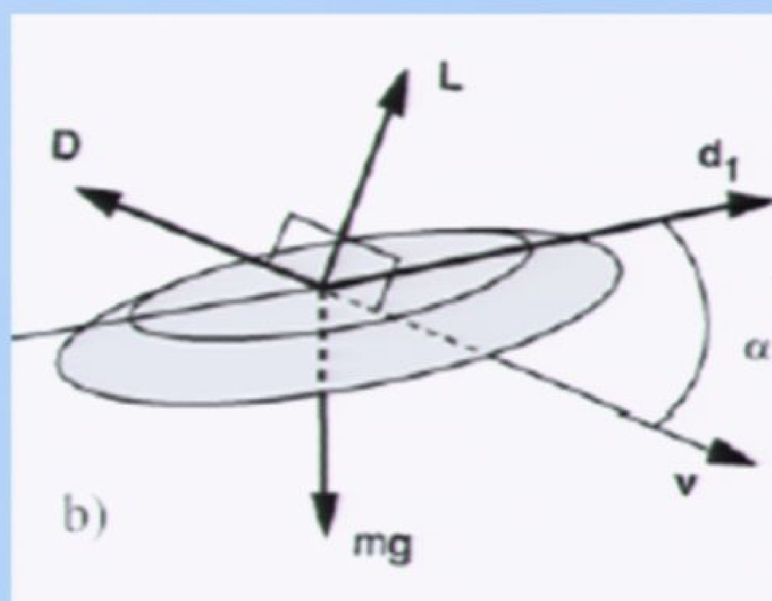

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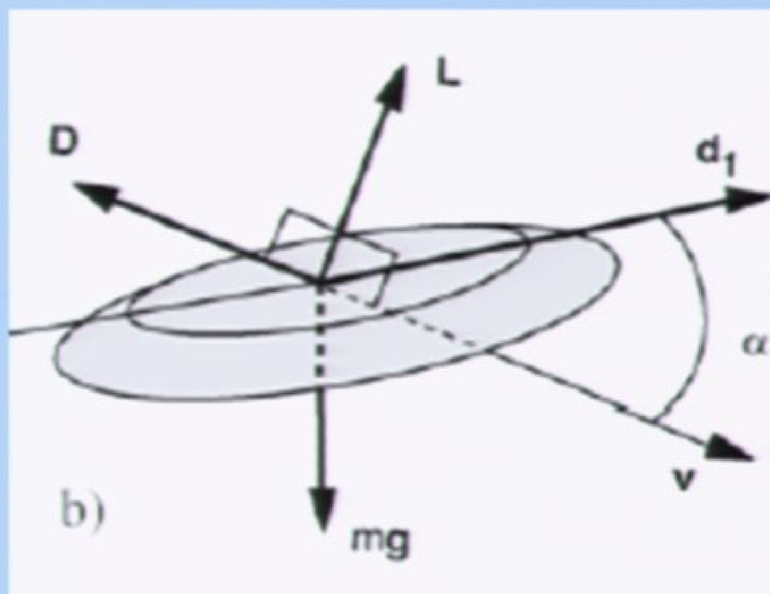

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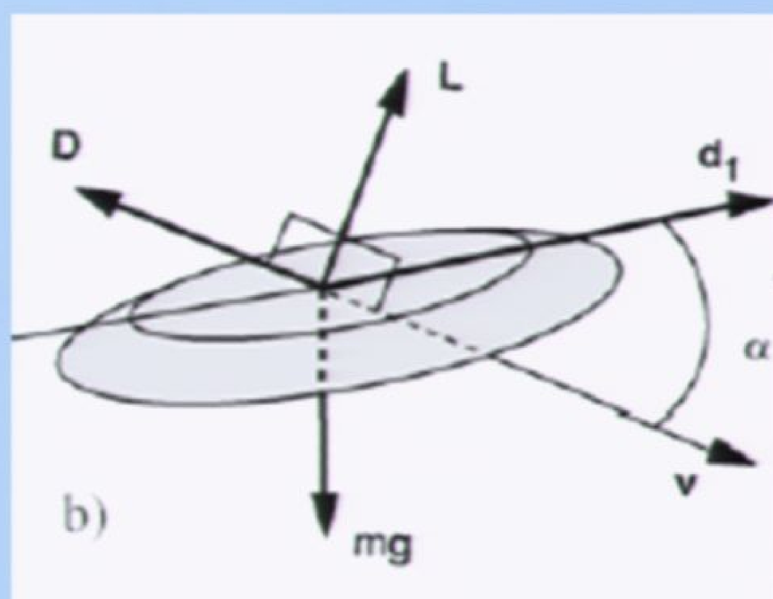

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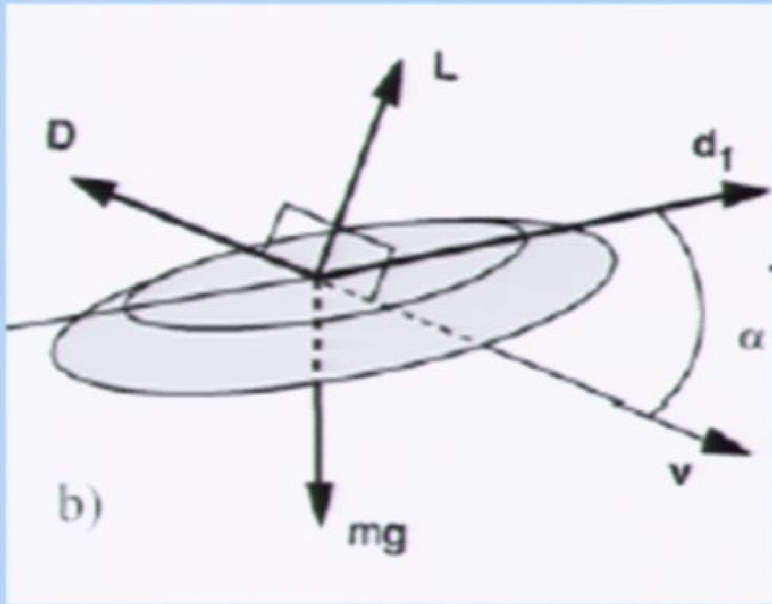

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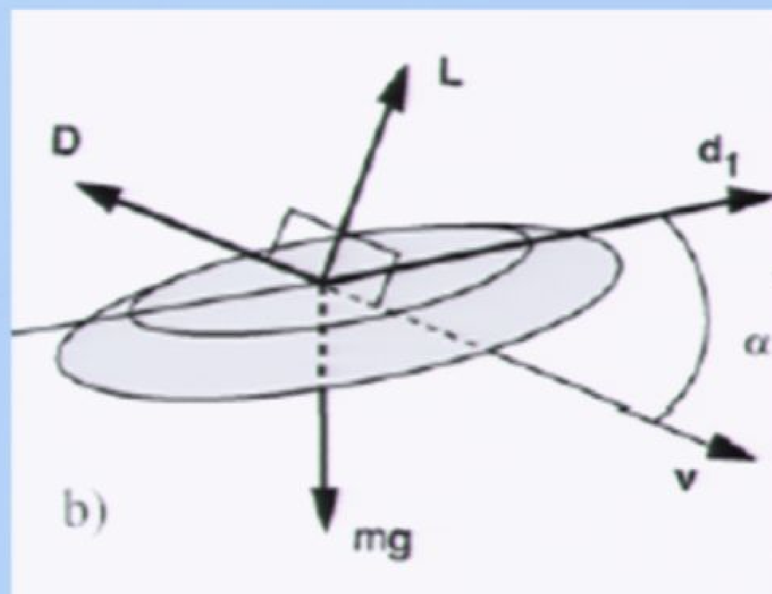

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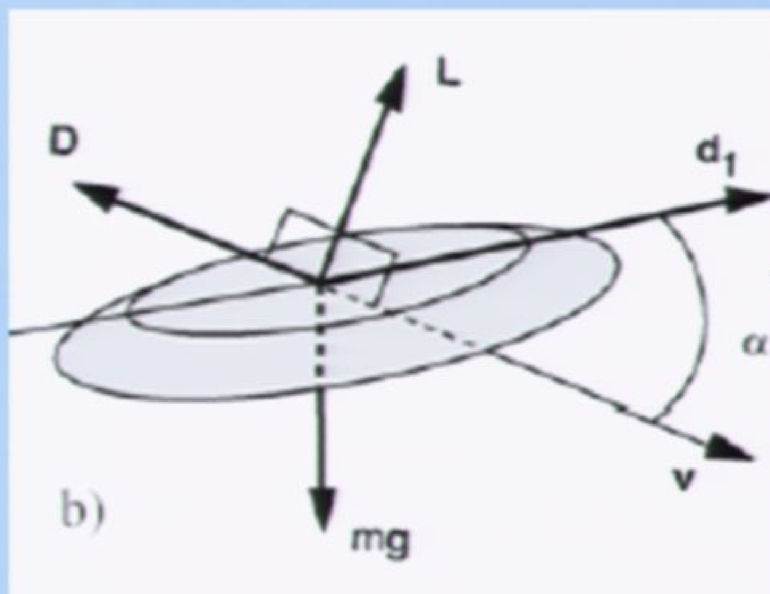

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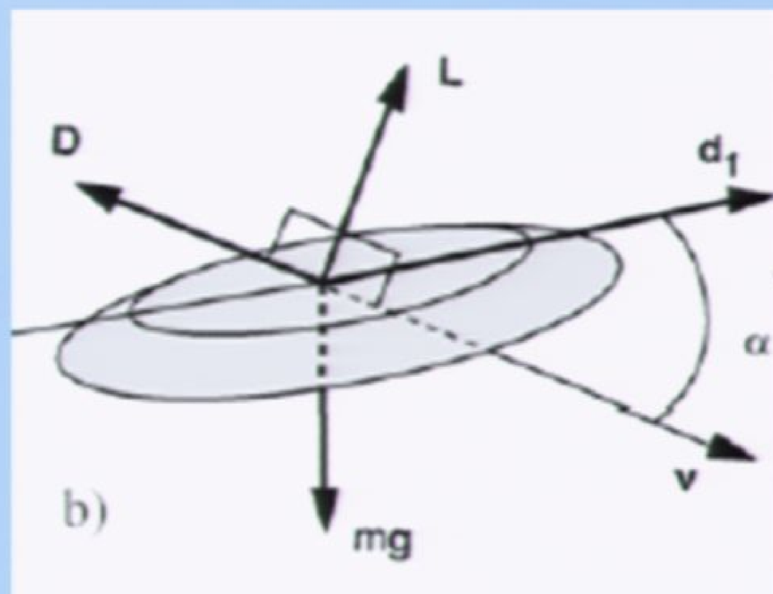

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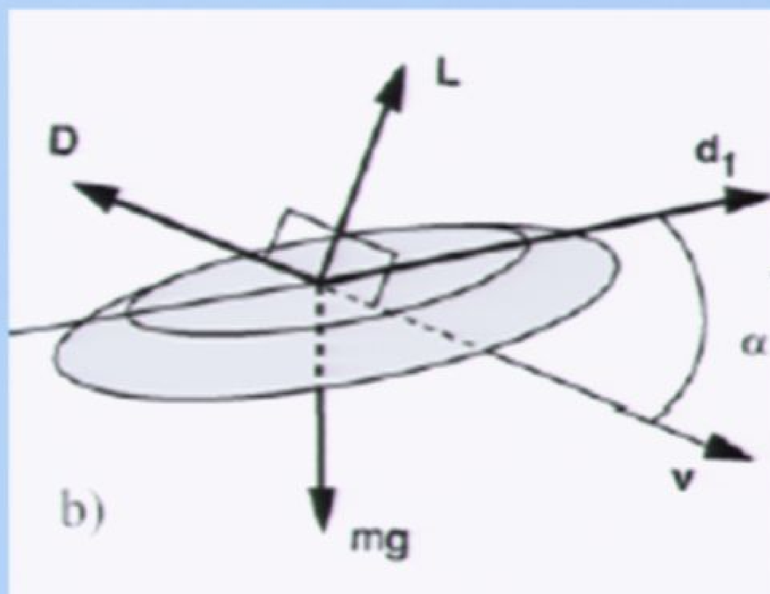

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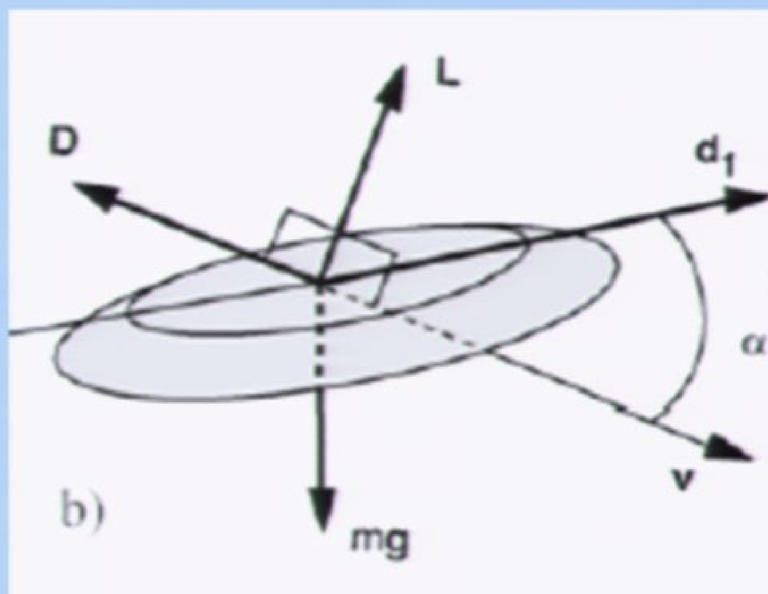

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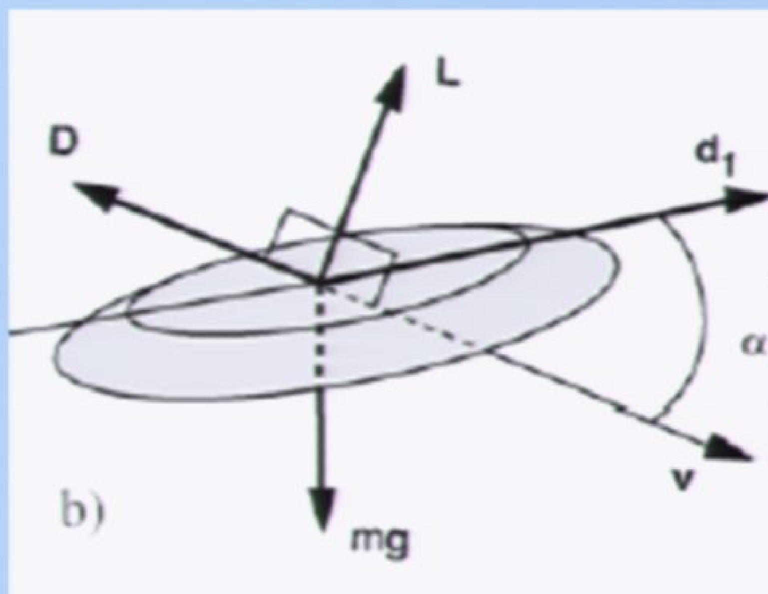

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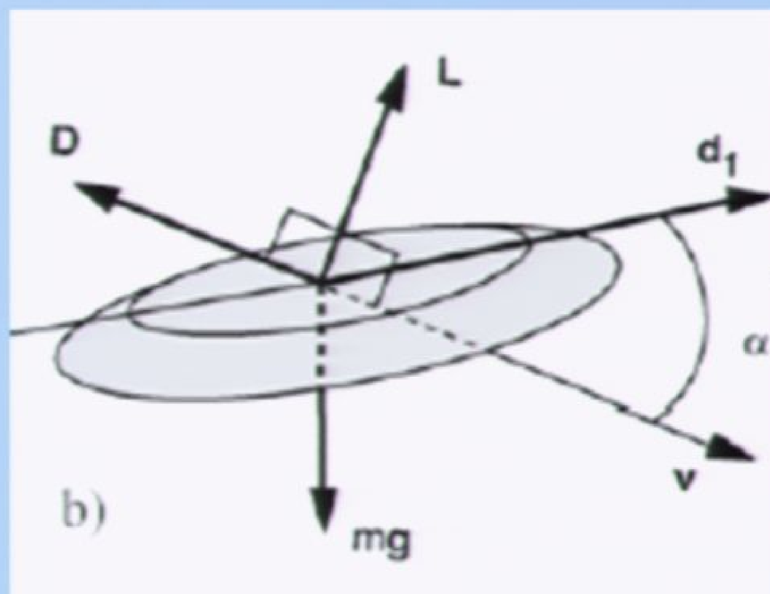

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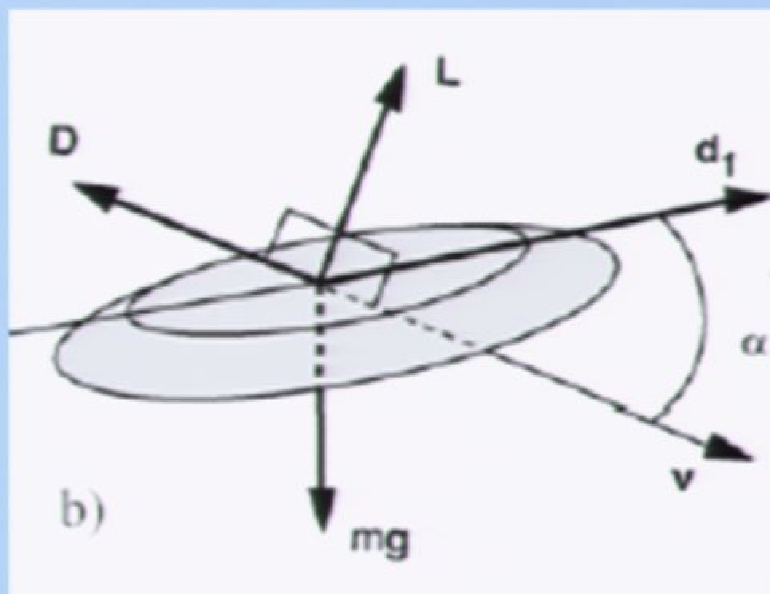

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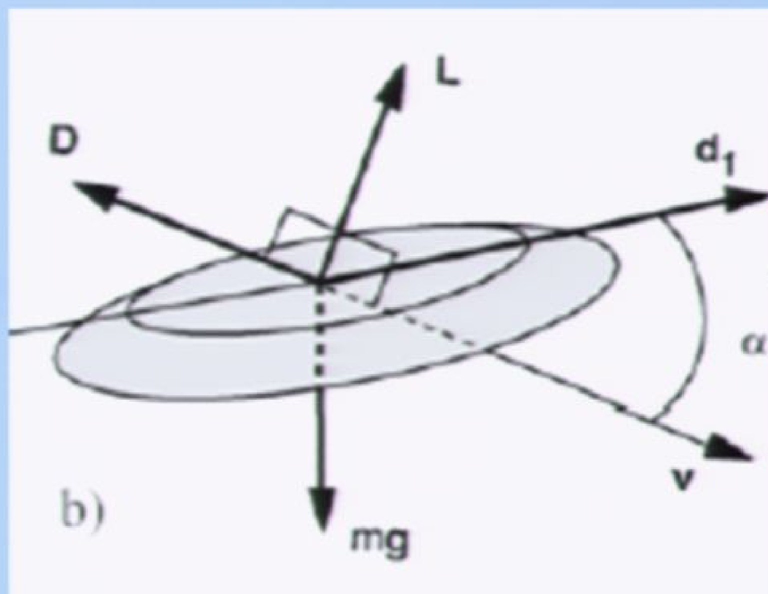

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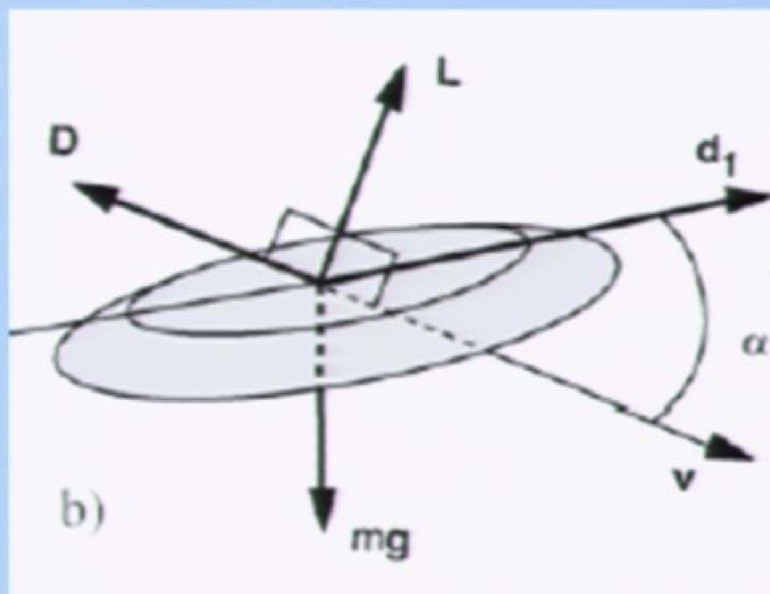

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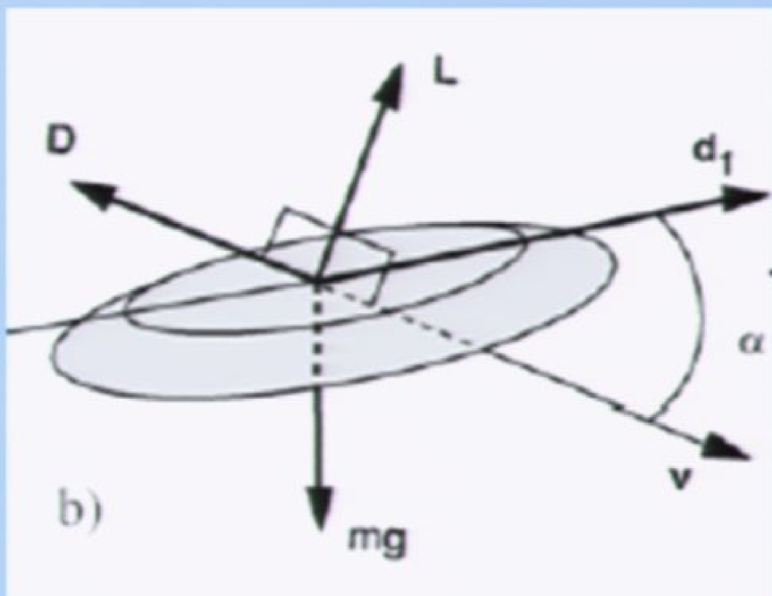

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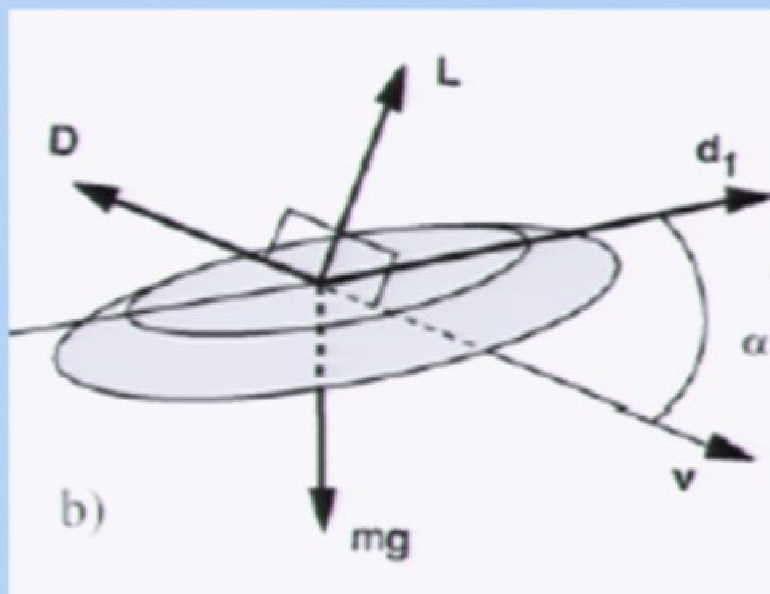

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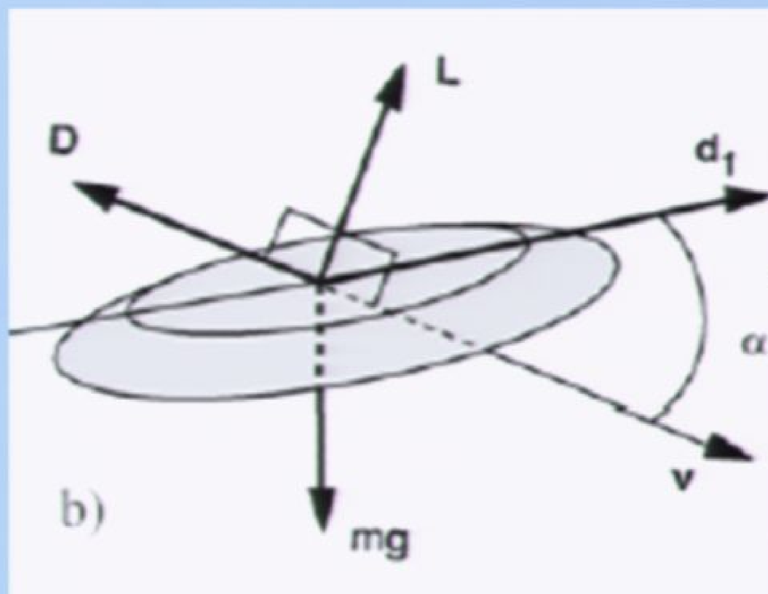

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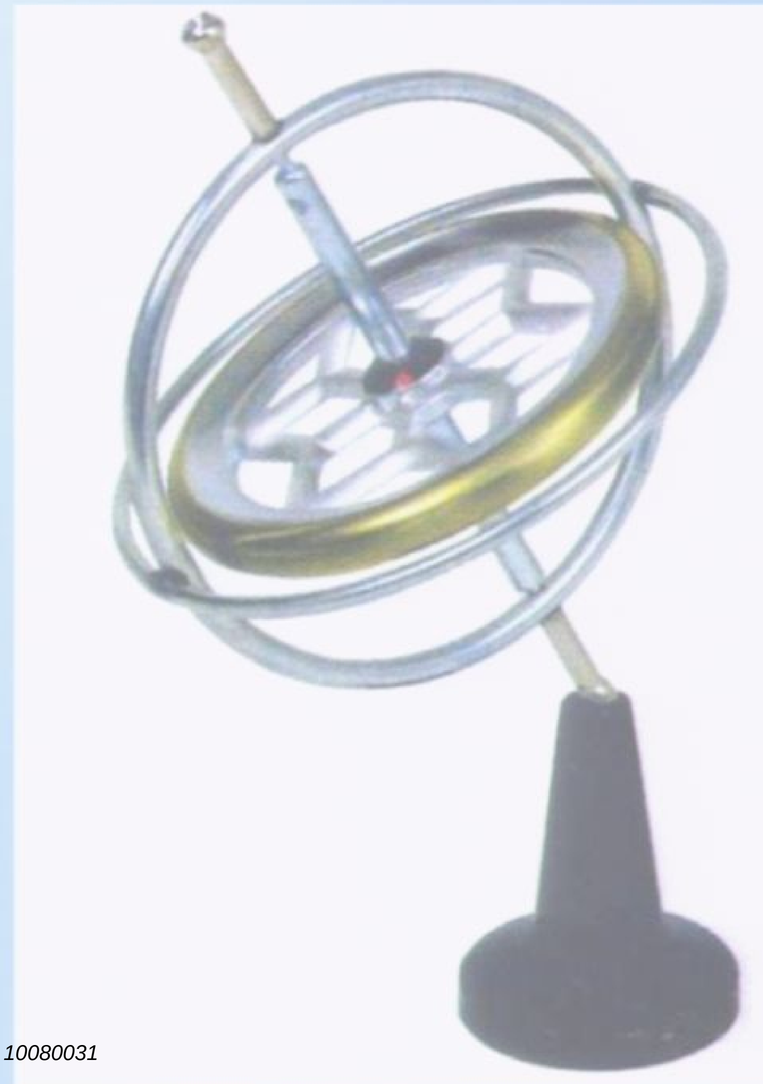

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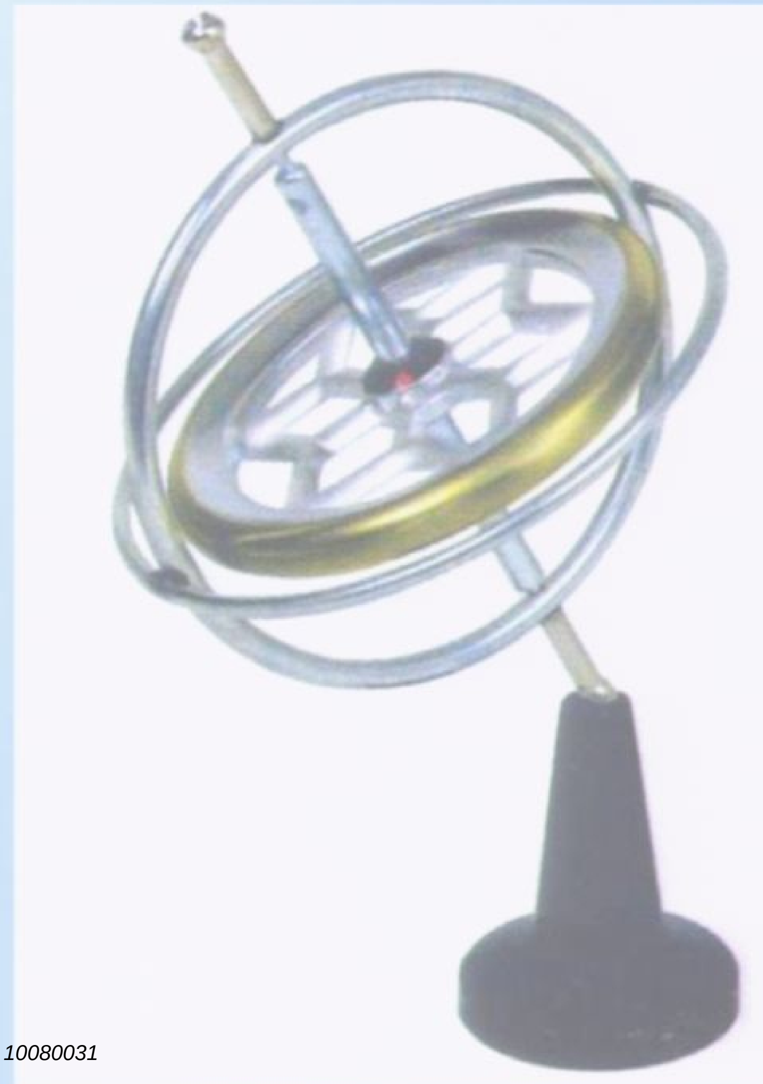

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- But frisbees rely on gyroscopic precession for stable flight
- Distance flown depends most on initial velocity, angle of attack, and angular momentum.

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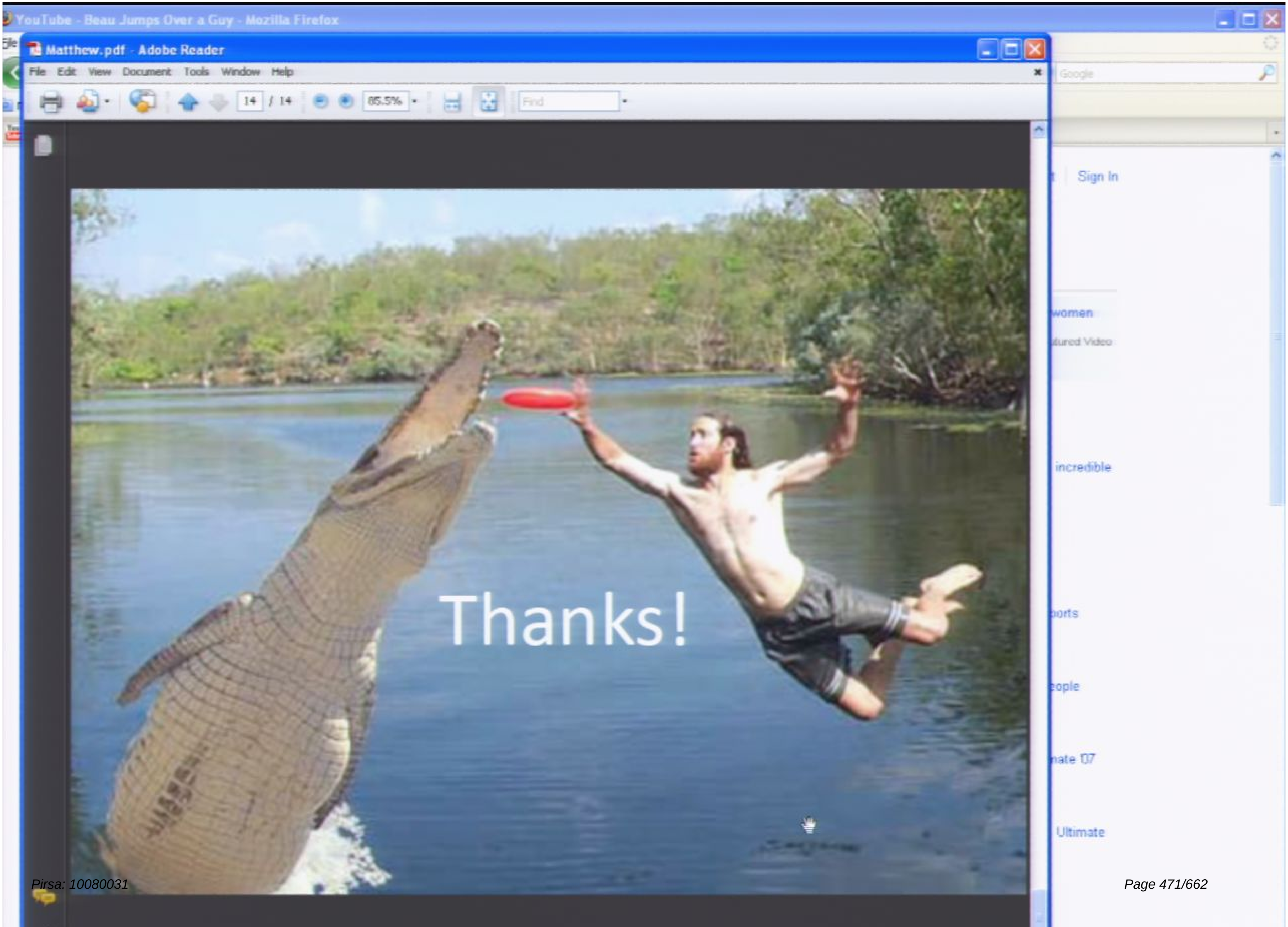
- But frisbees rely on gyroscopic precession for stable flight
- Distance flown depends most on initial velocity, angle of attack, and angular momentum.


Thanks!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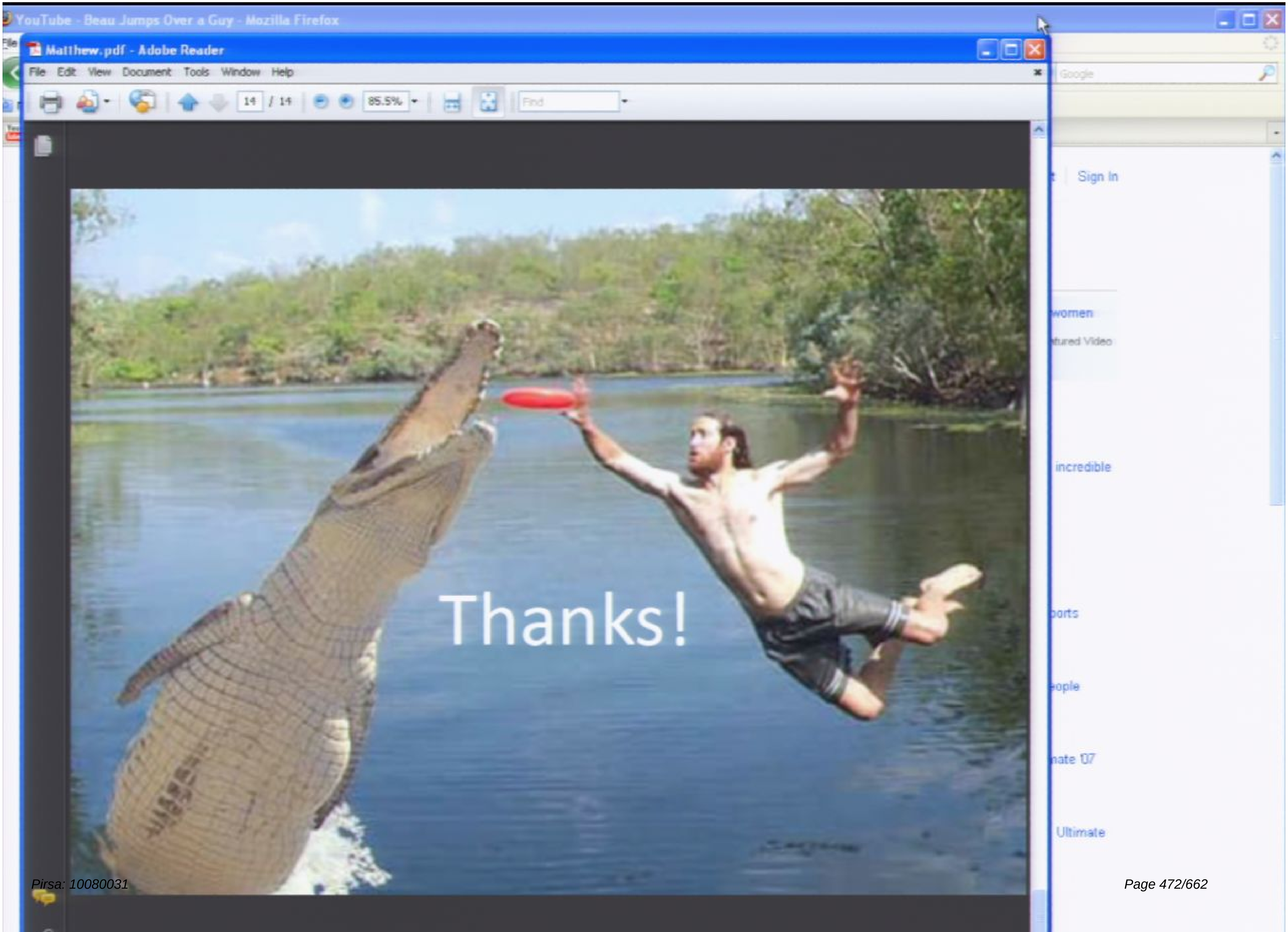
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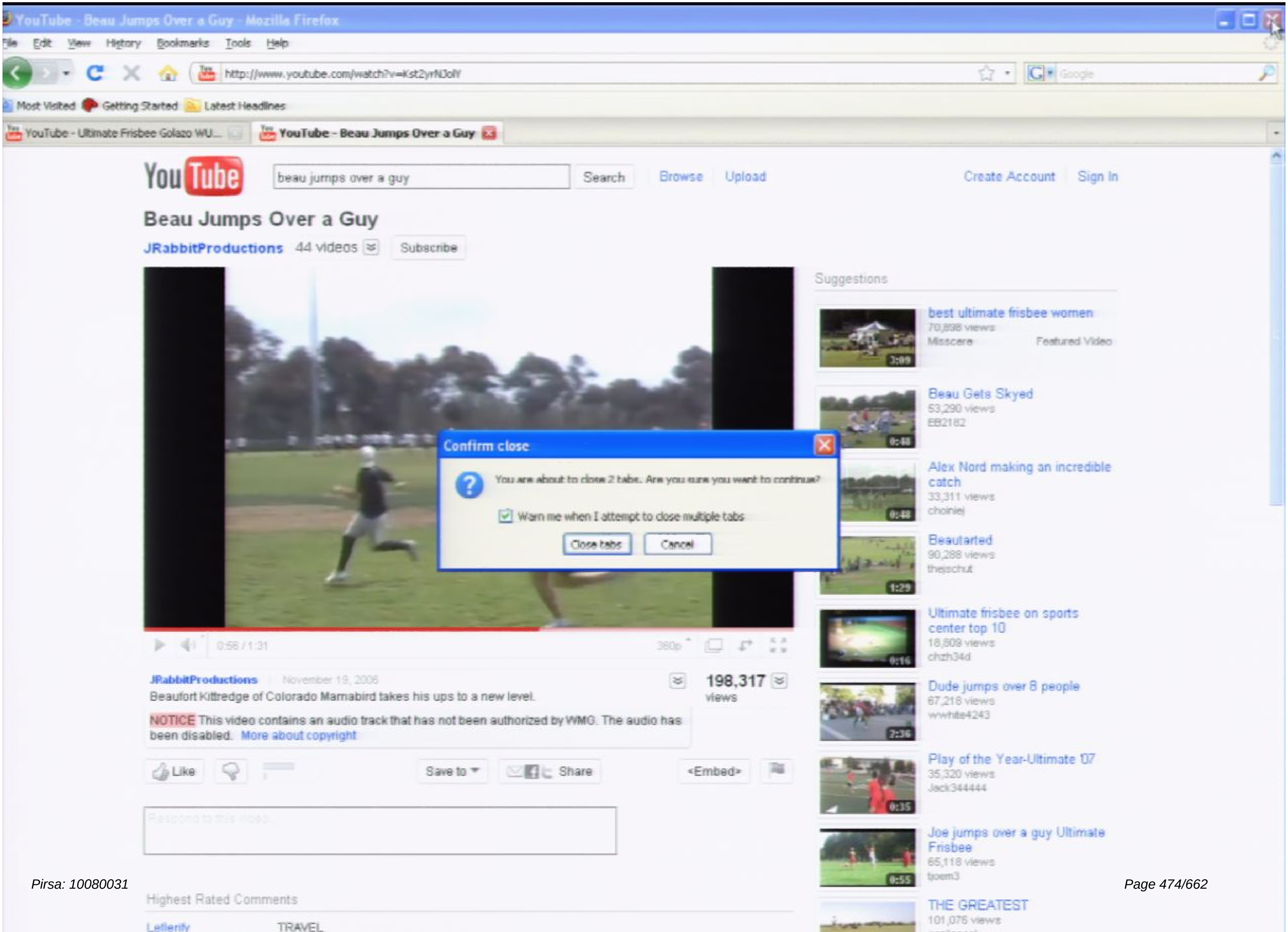
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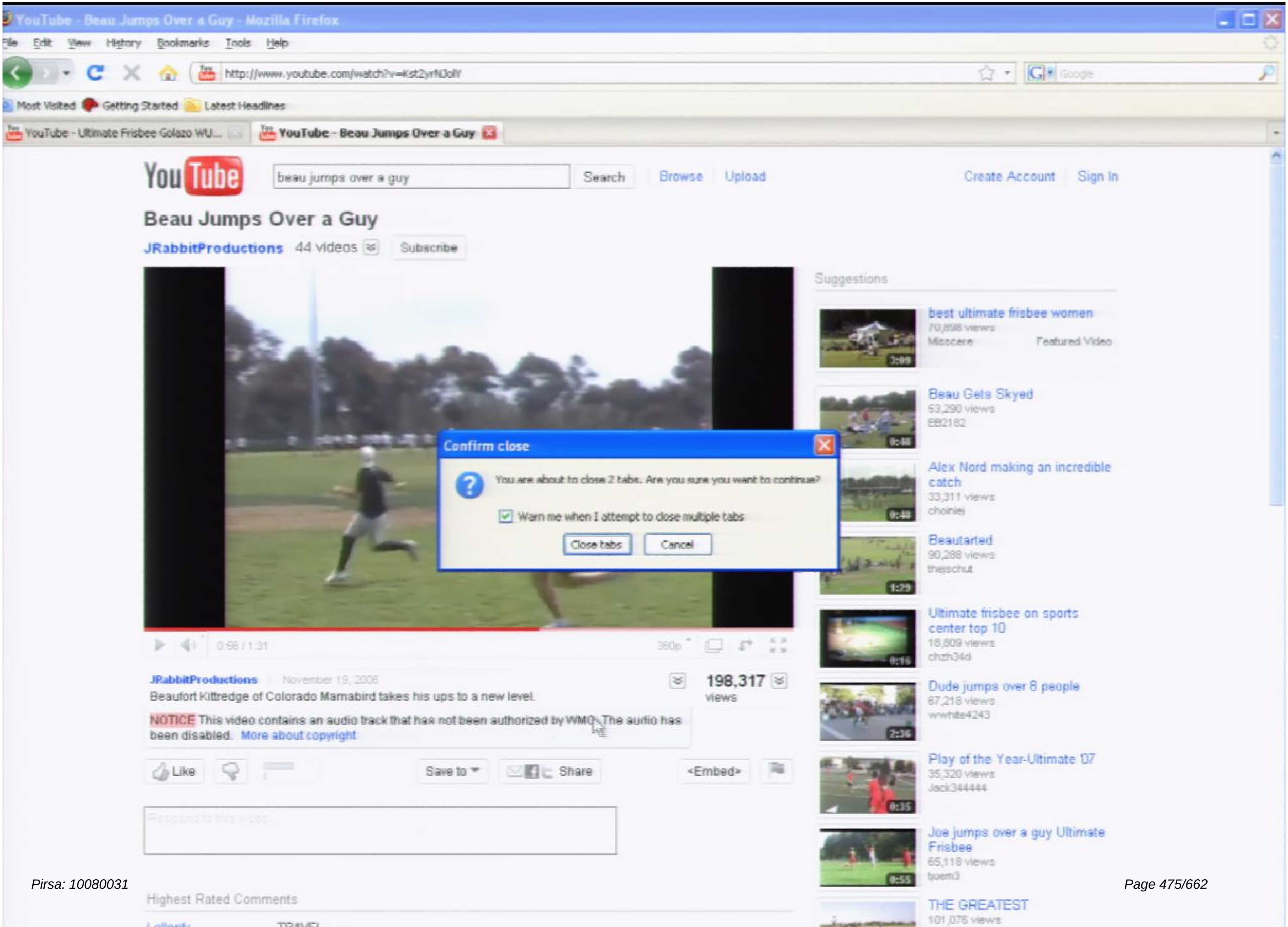
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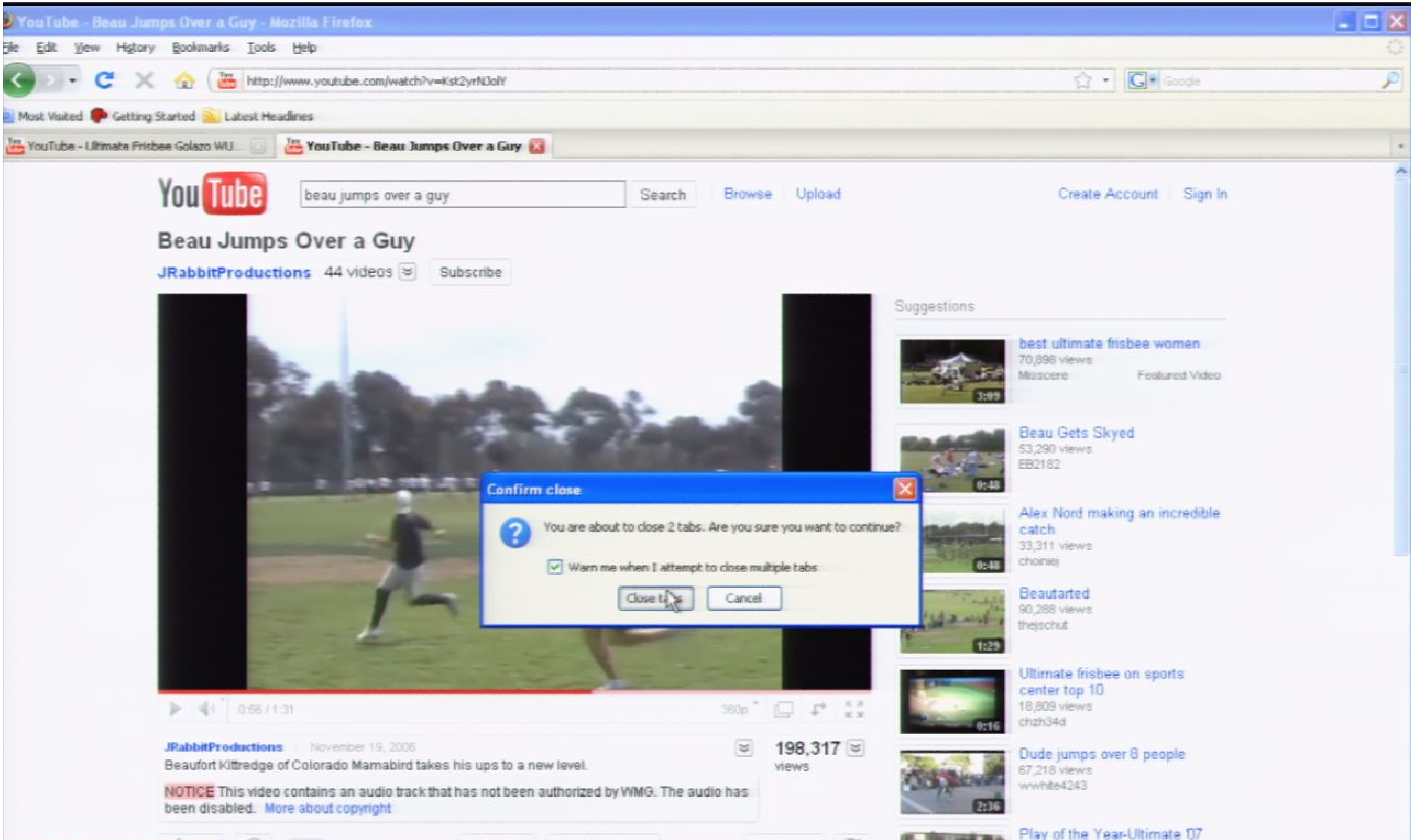
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Clouds?

Laura Piispanen

Theoretical physics
University of Turku

August 20, 2010

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Contents

A cloud is made of billows upon billows upon billows that look like clouds. As you come closer to a cloud you don't get something smooth, but irregularities at a smaller scale.

Benoit Mandelbrot

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Benoit Mandelbrot

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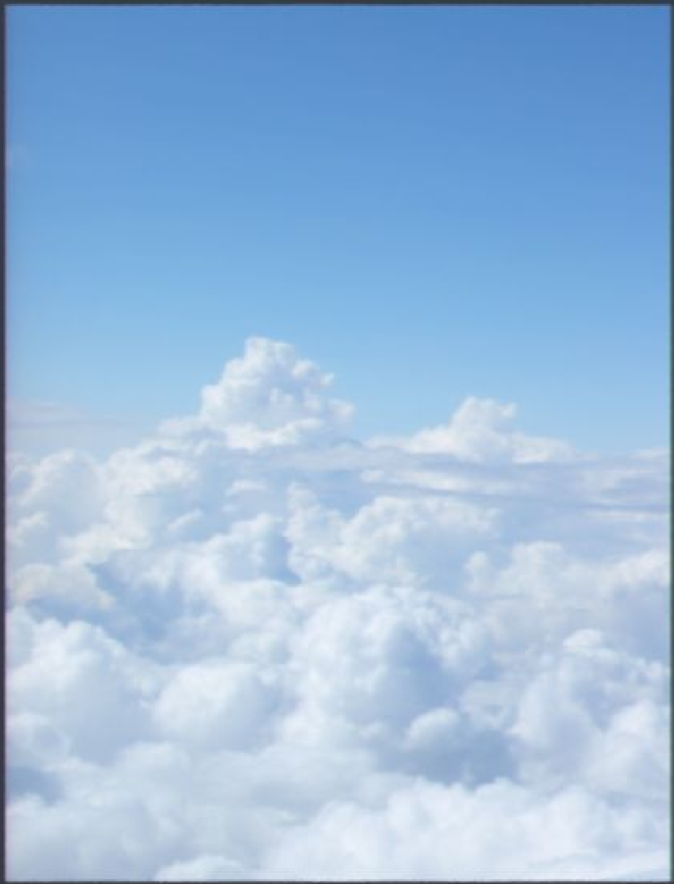

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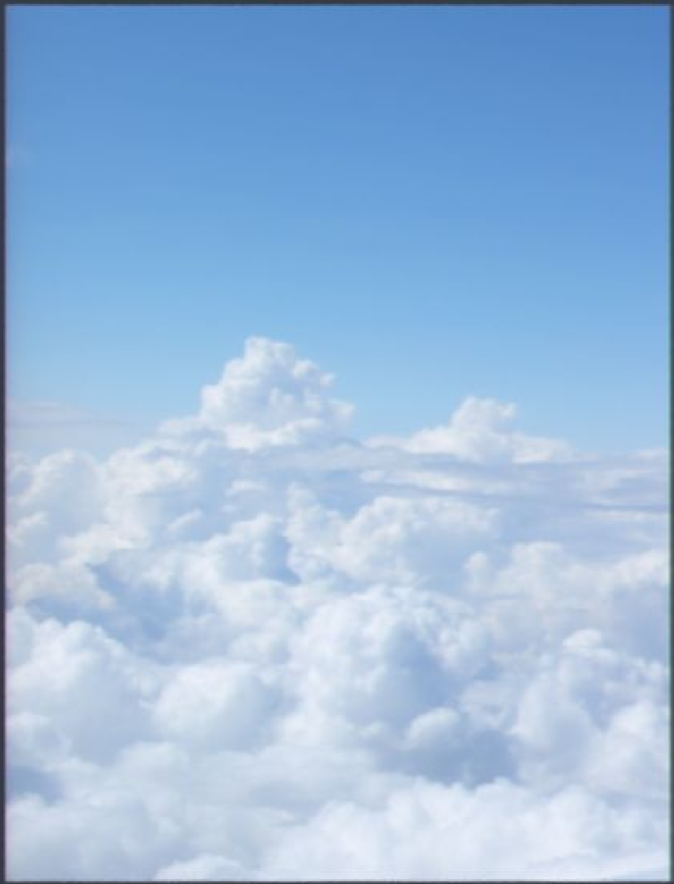

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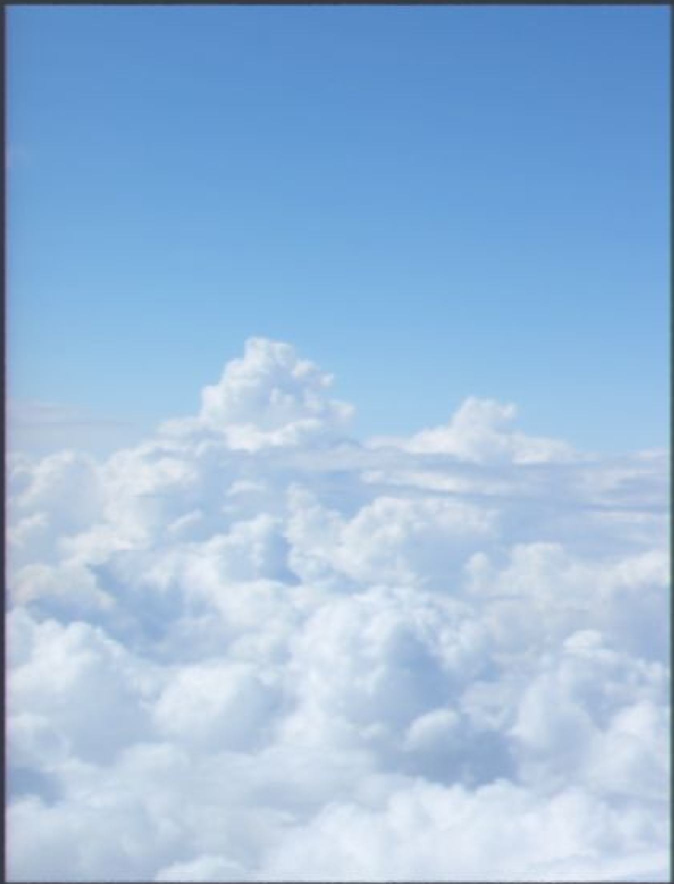

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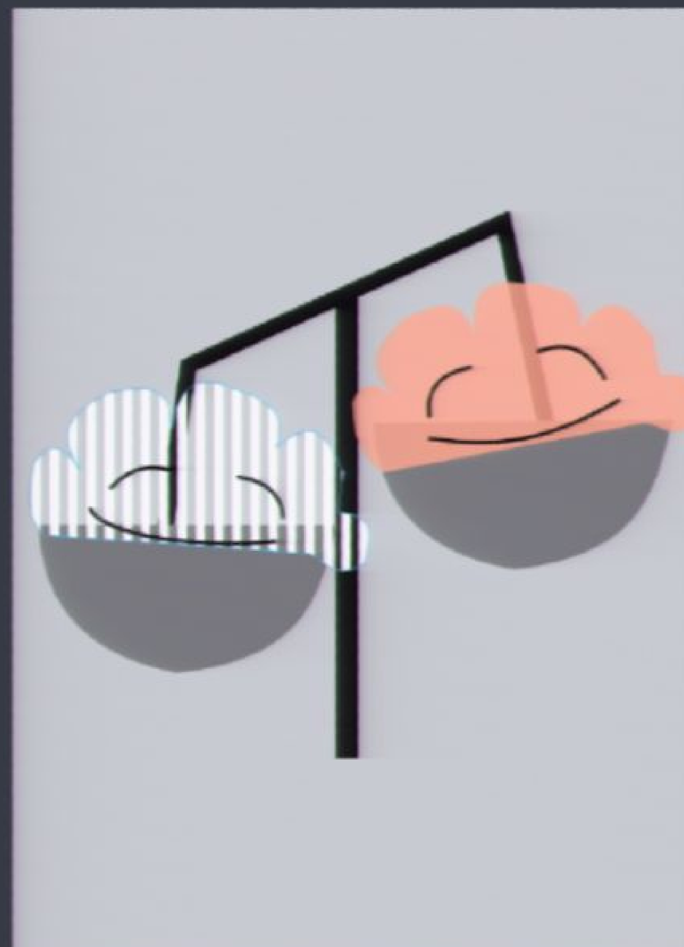

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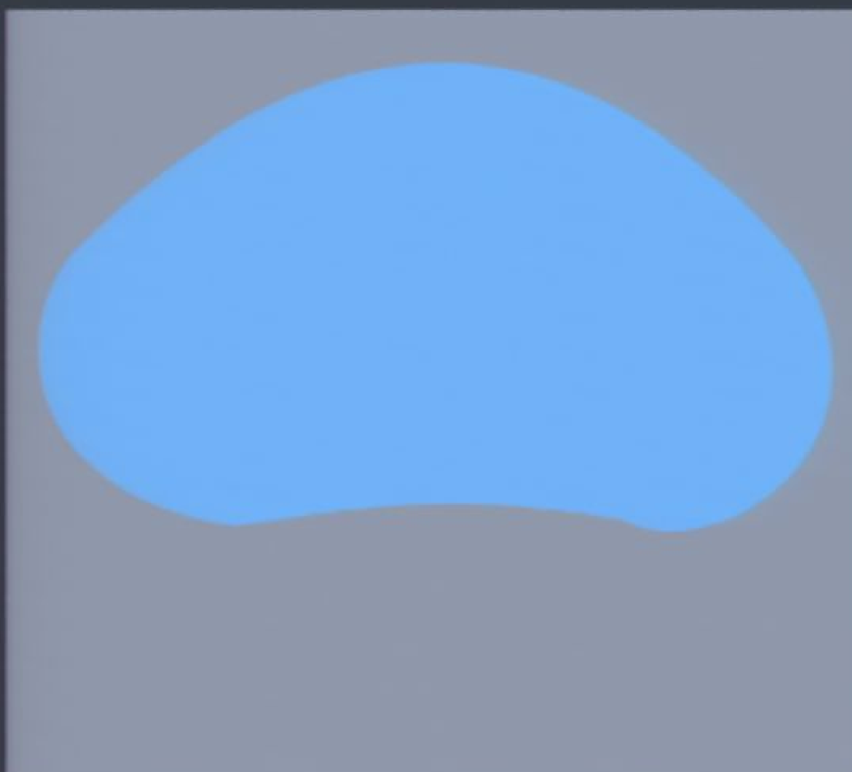

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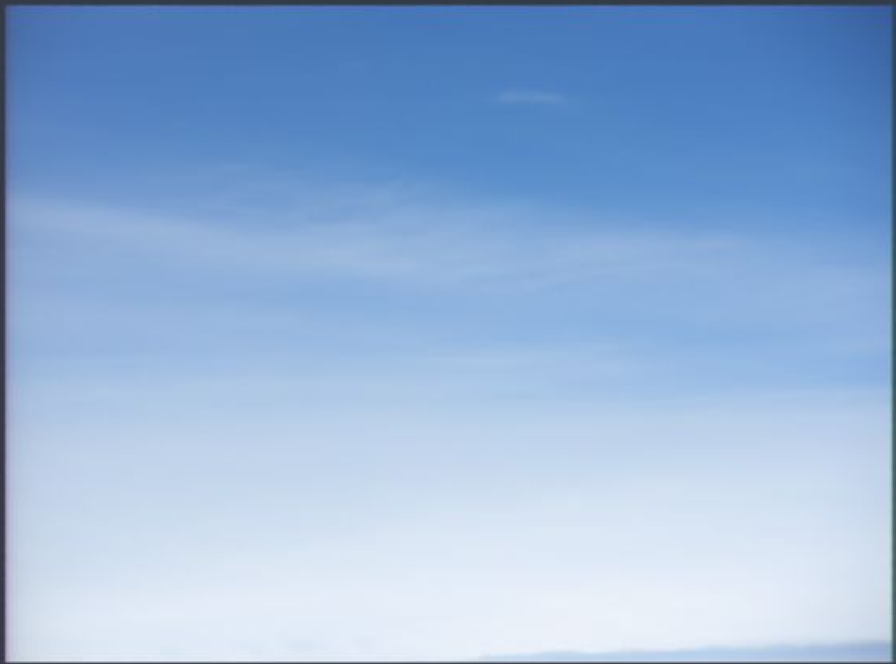

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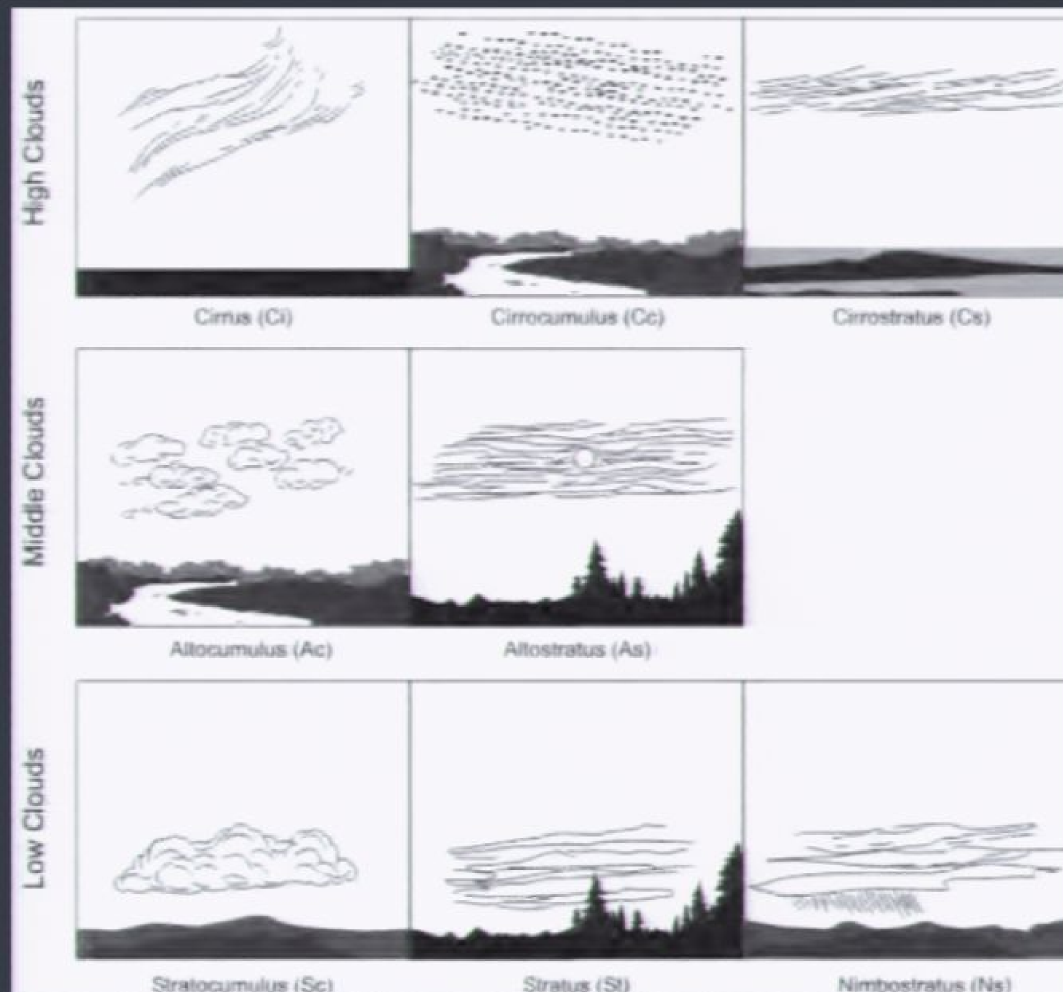

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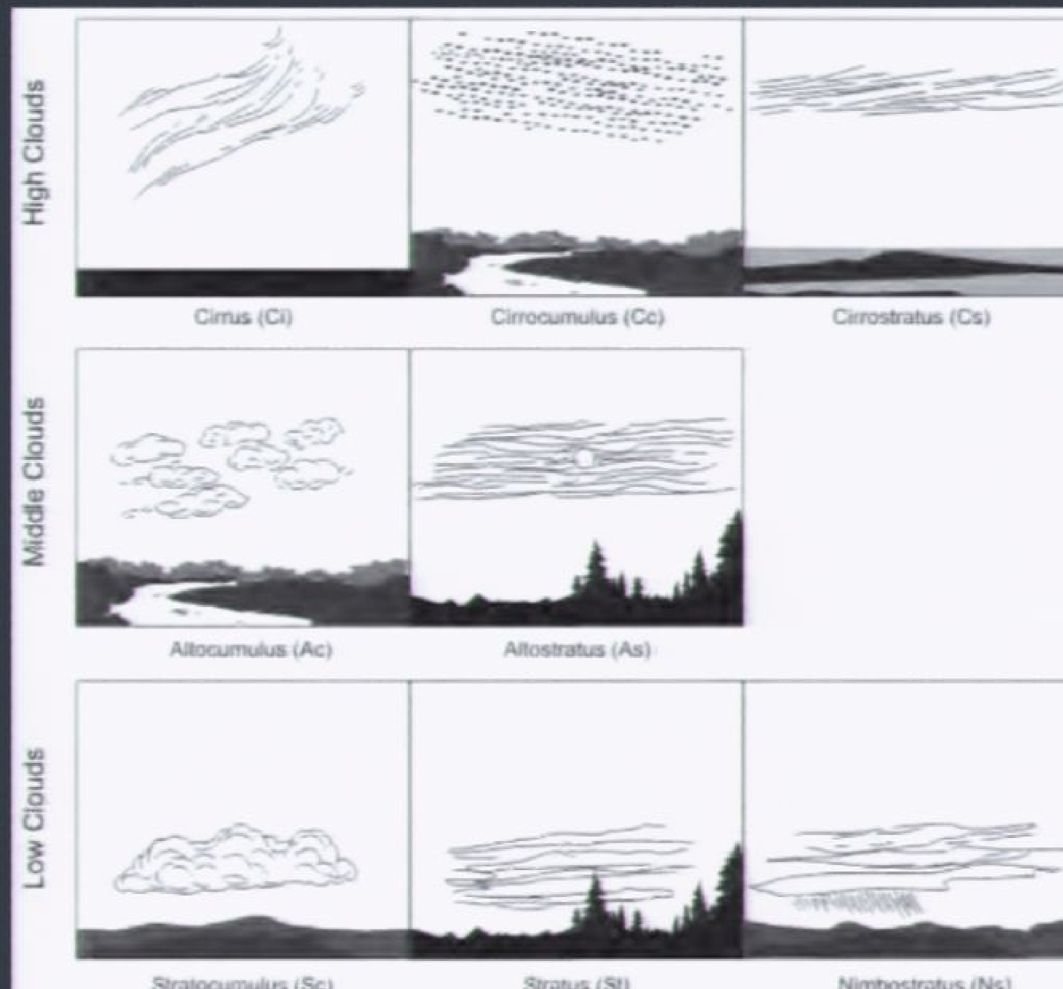

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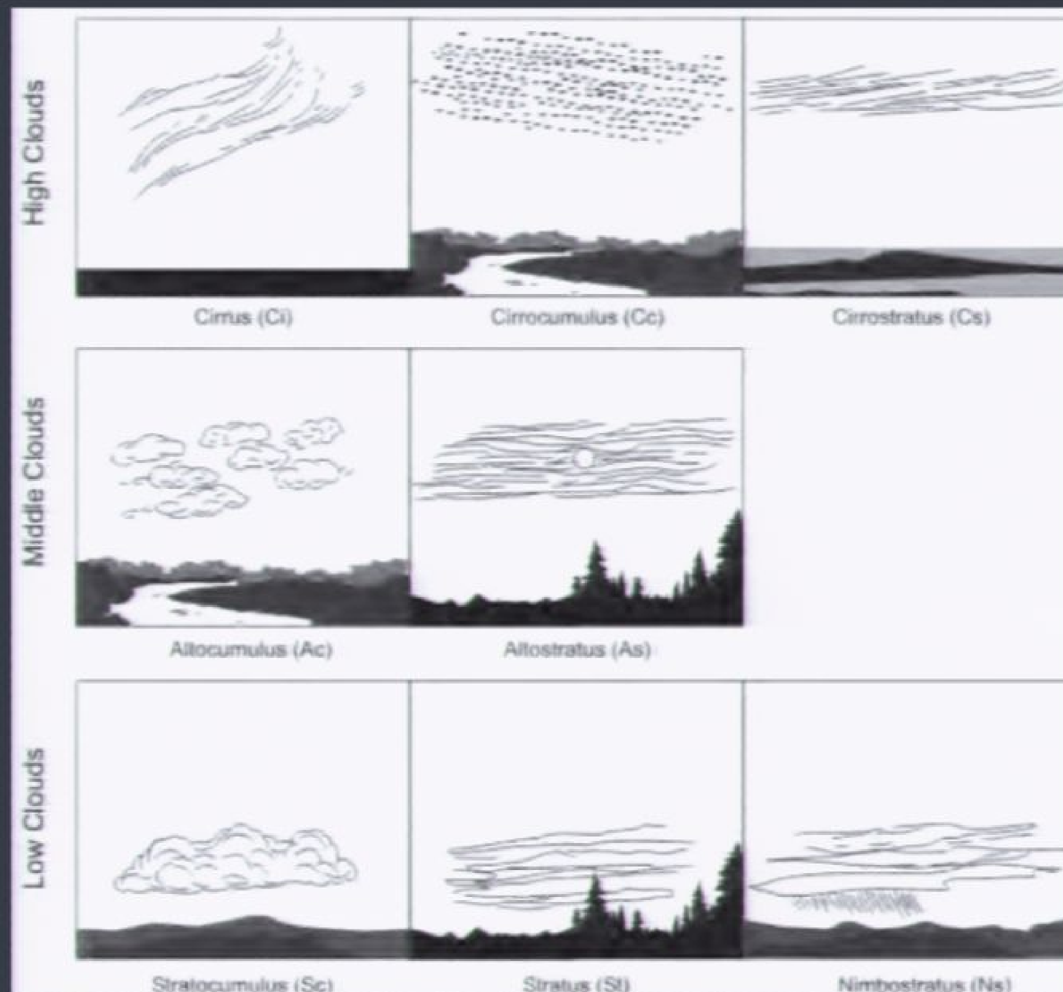

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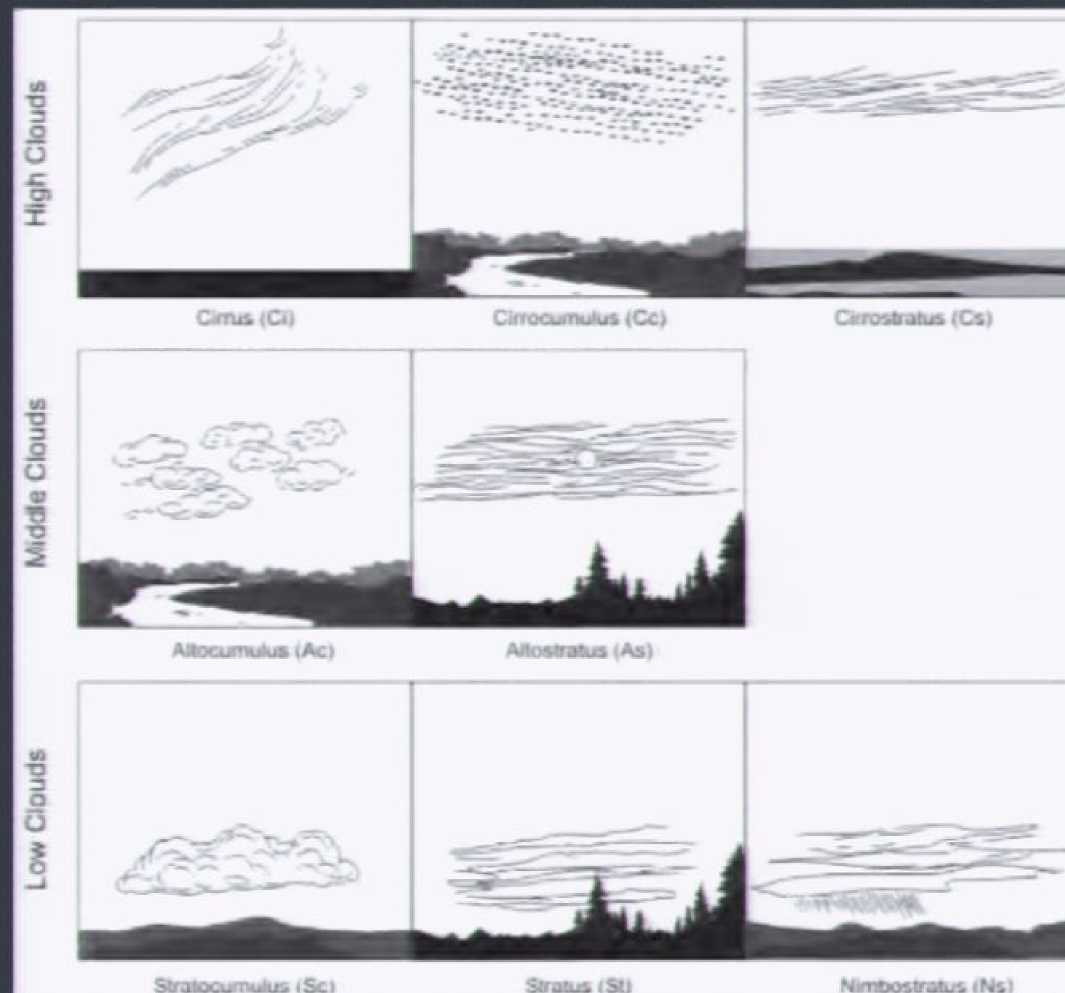

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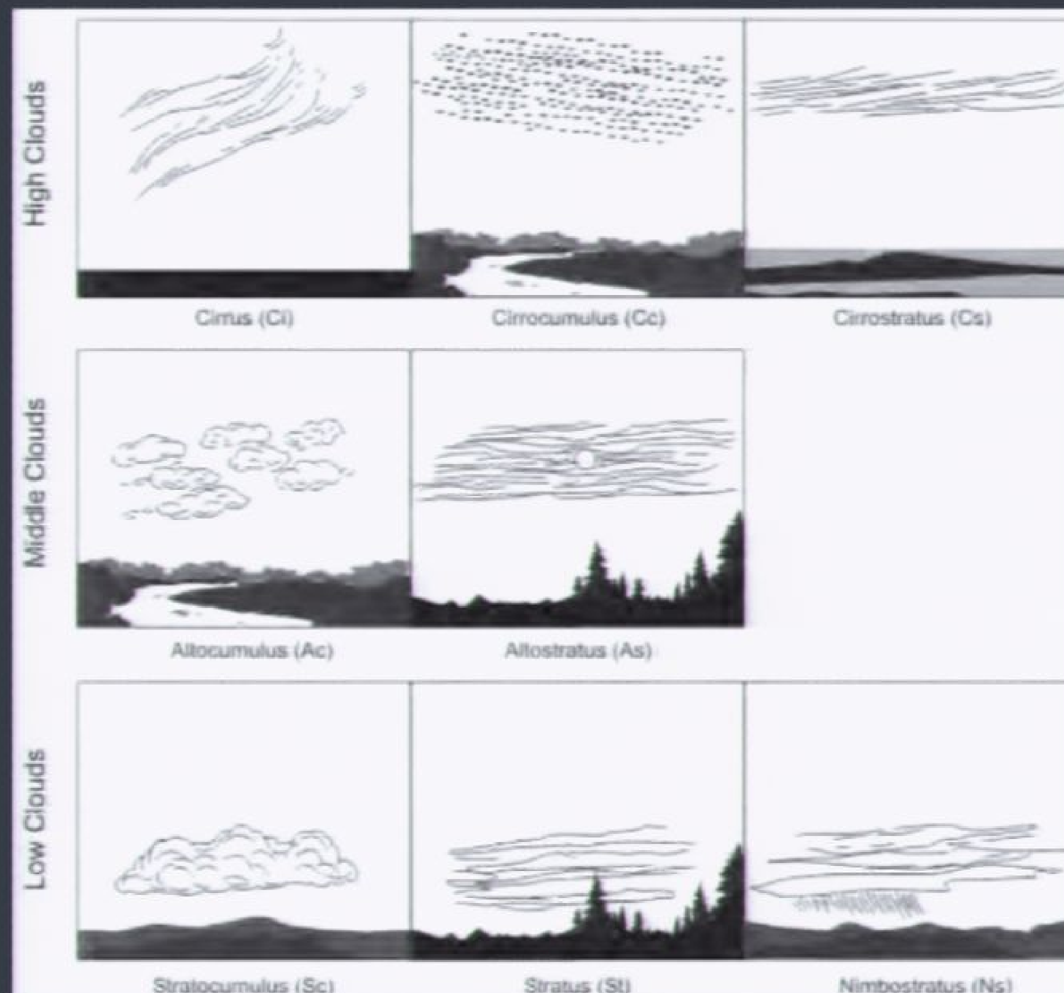

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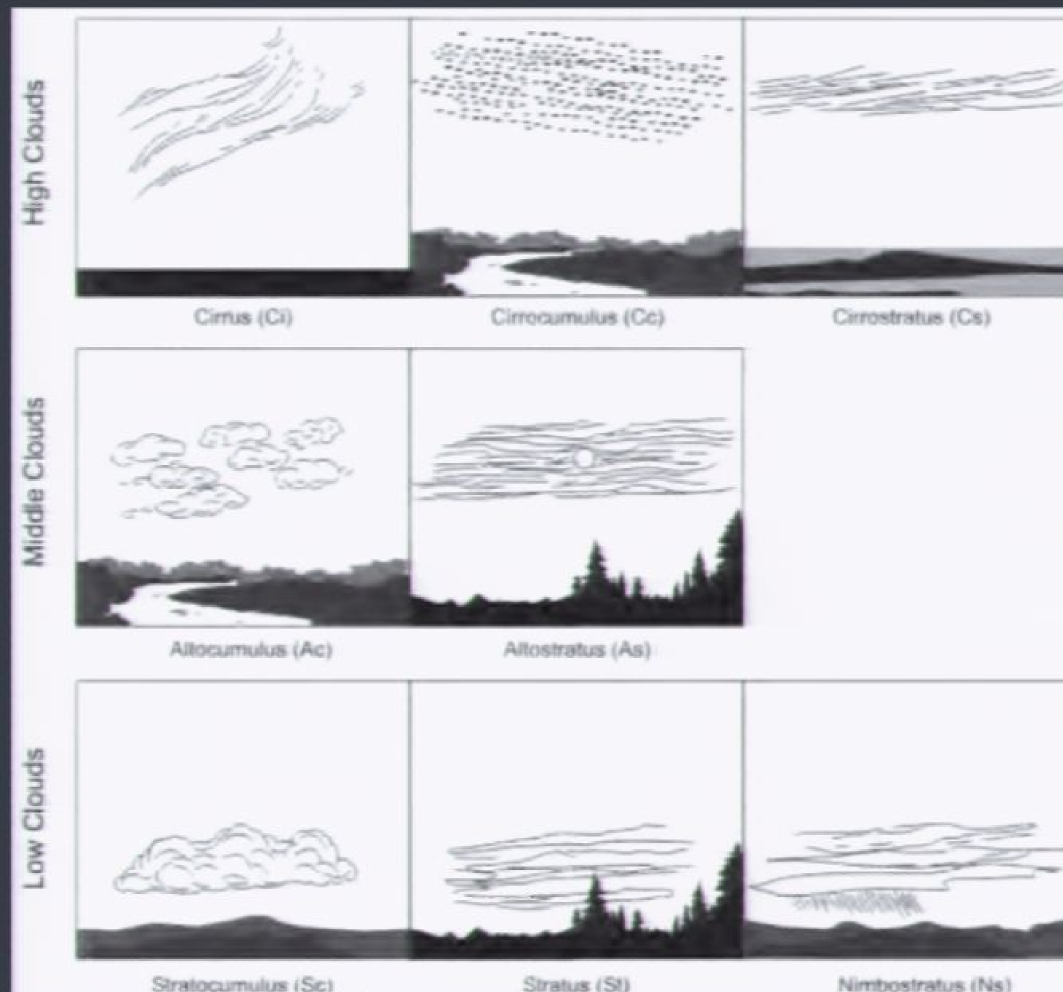

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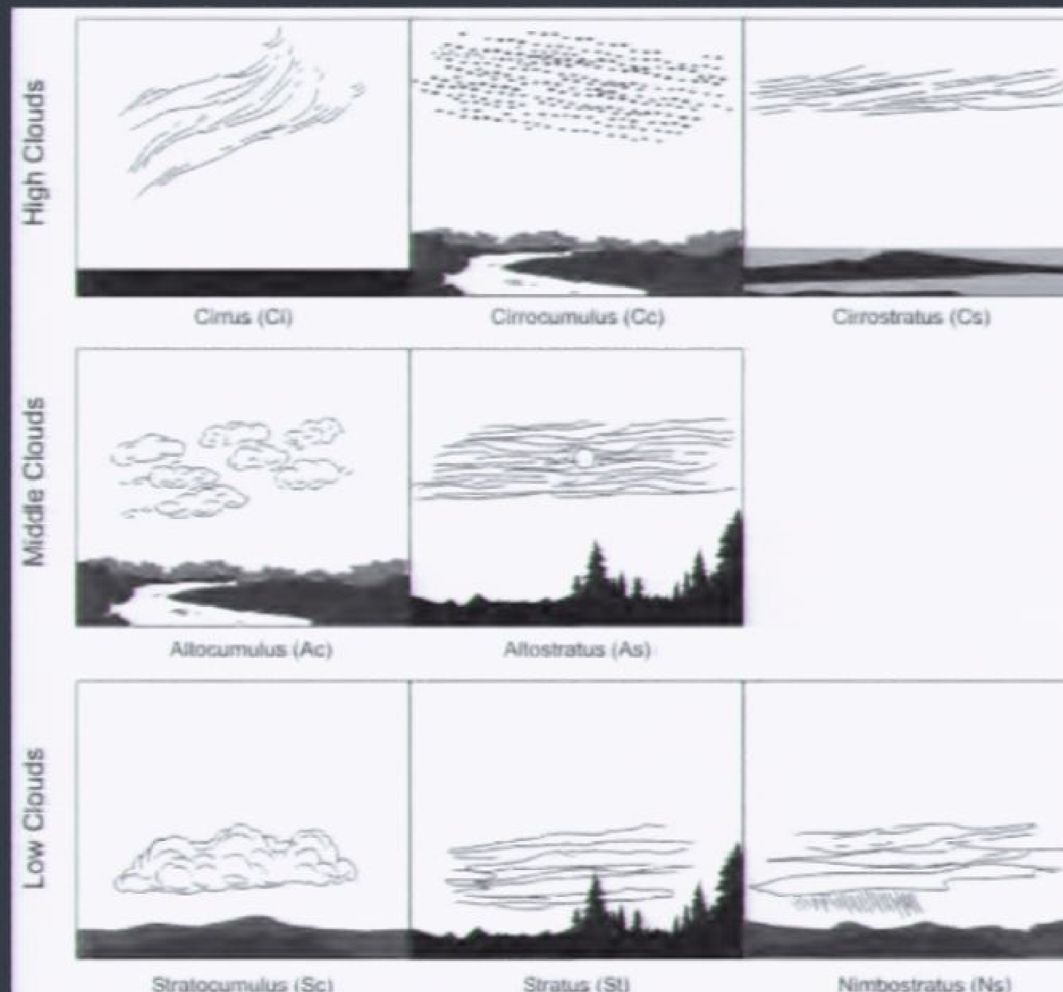

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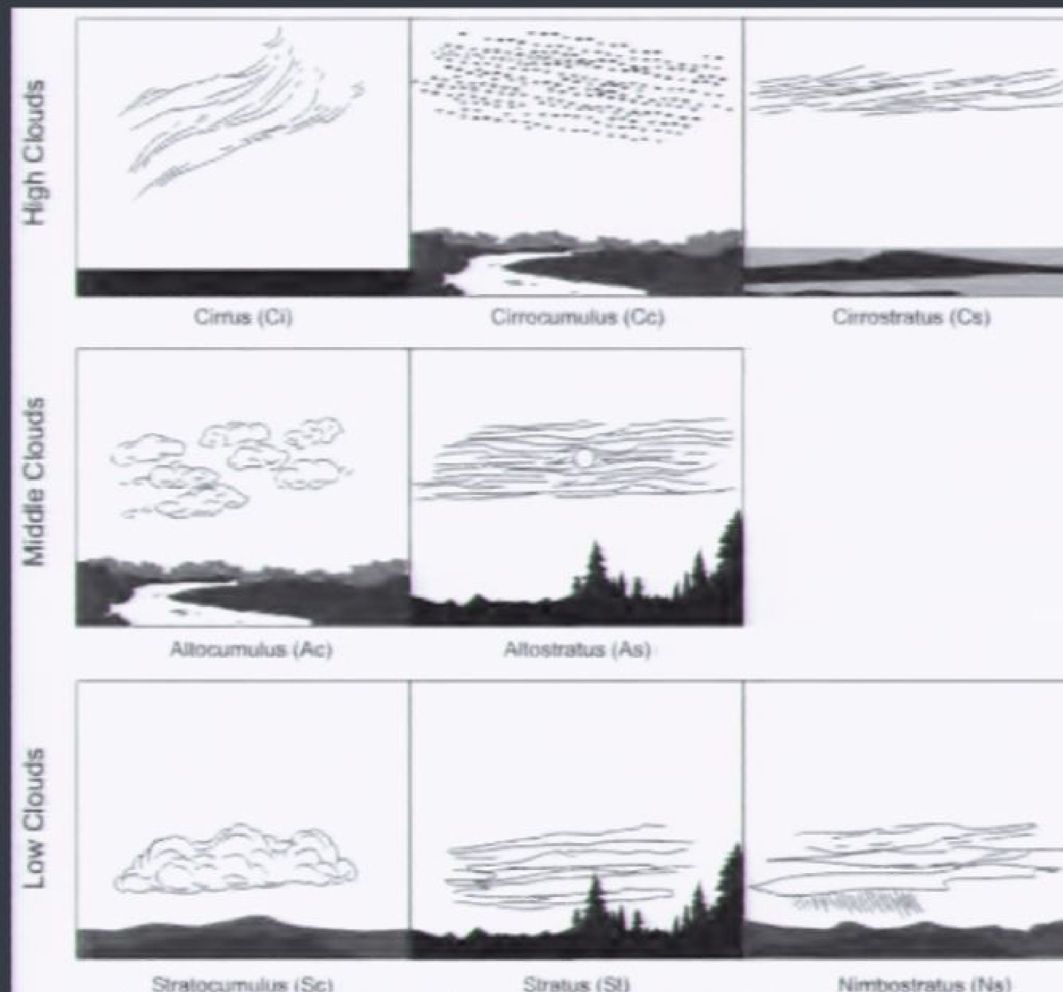

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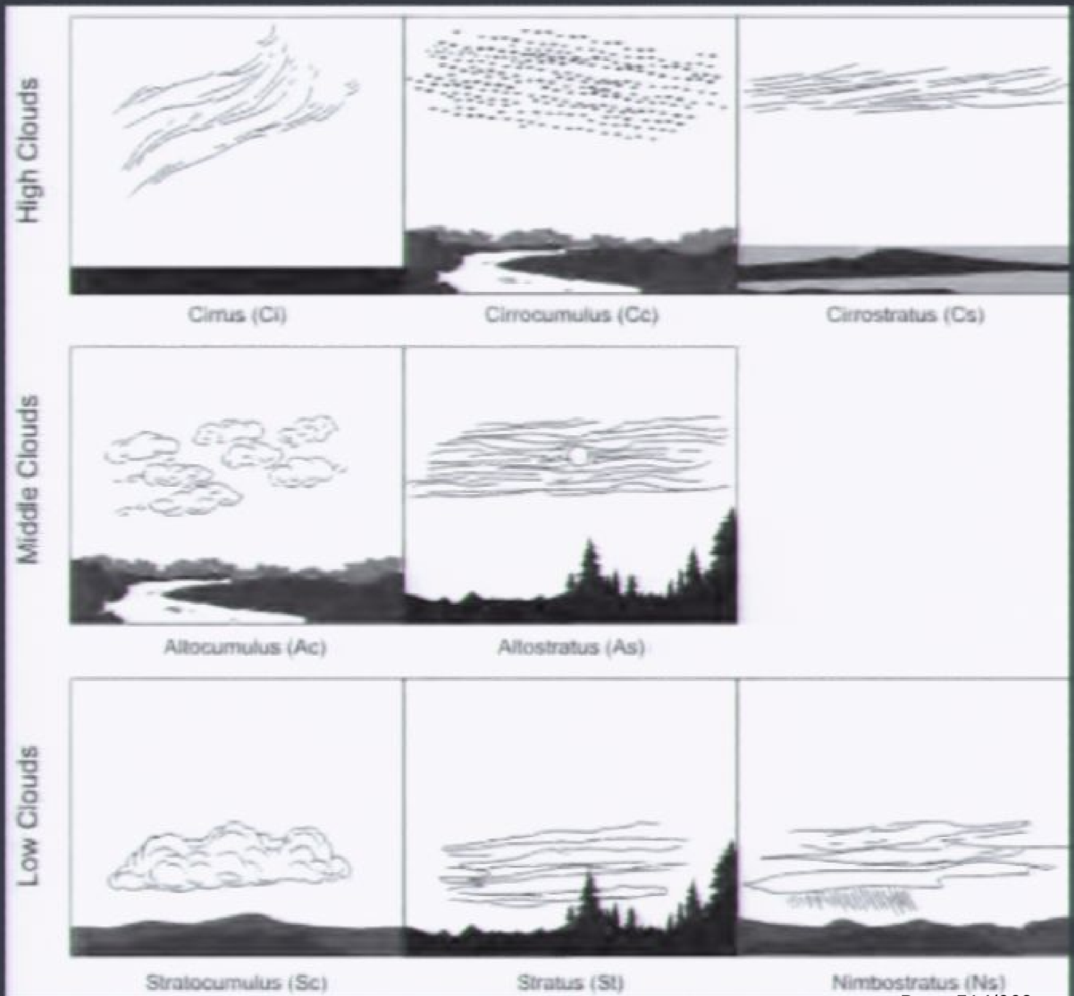

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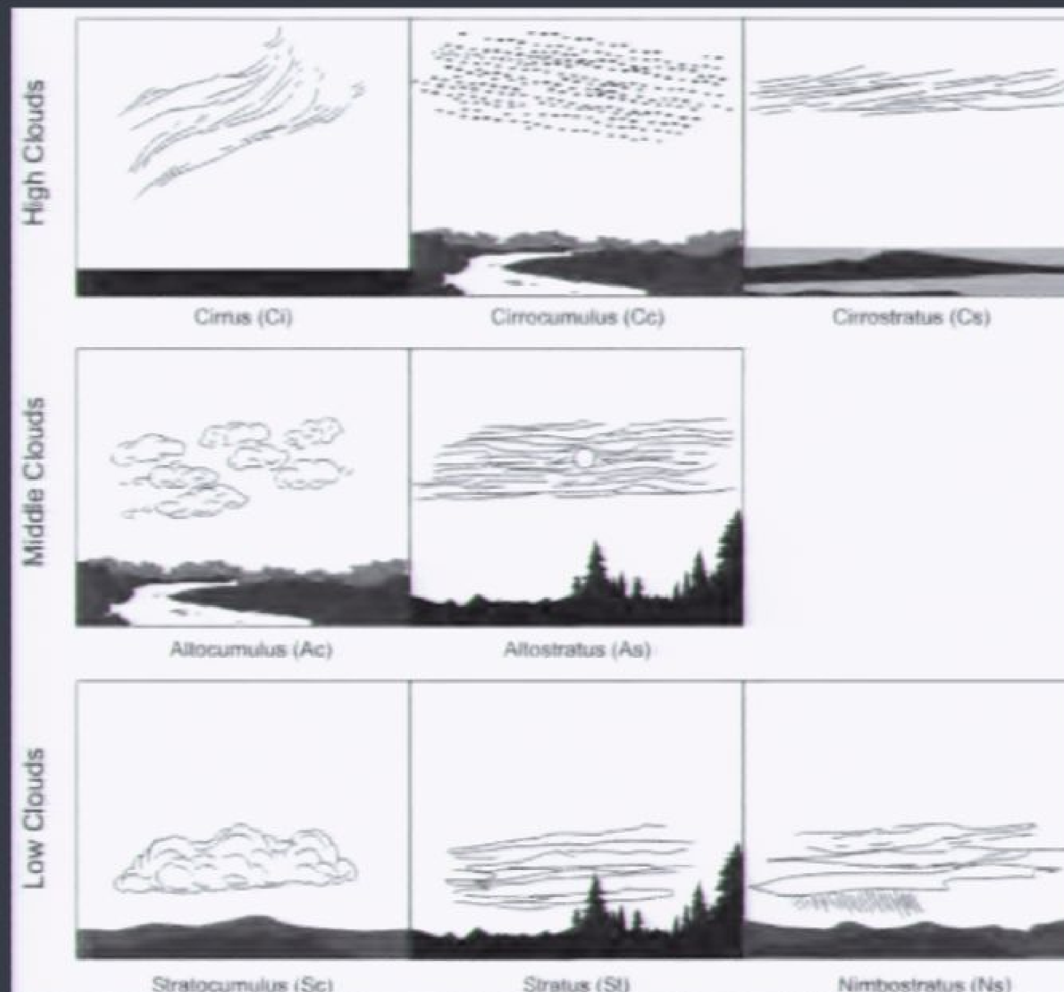

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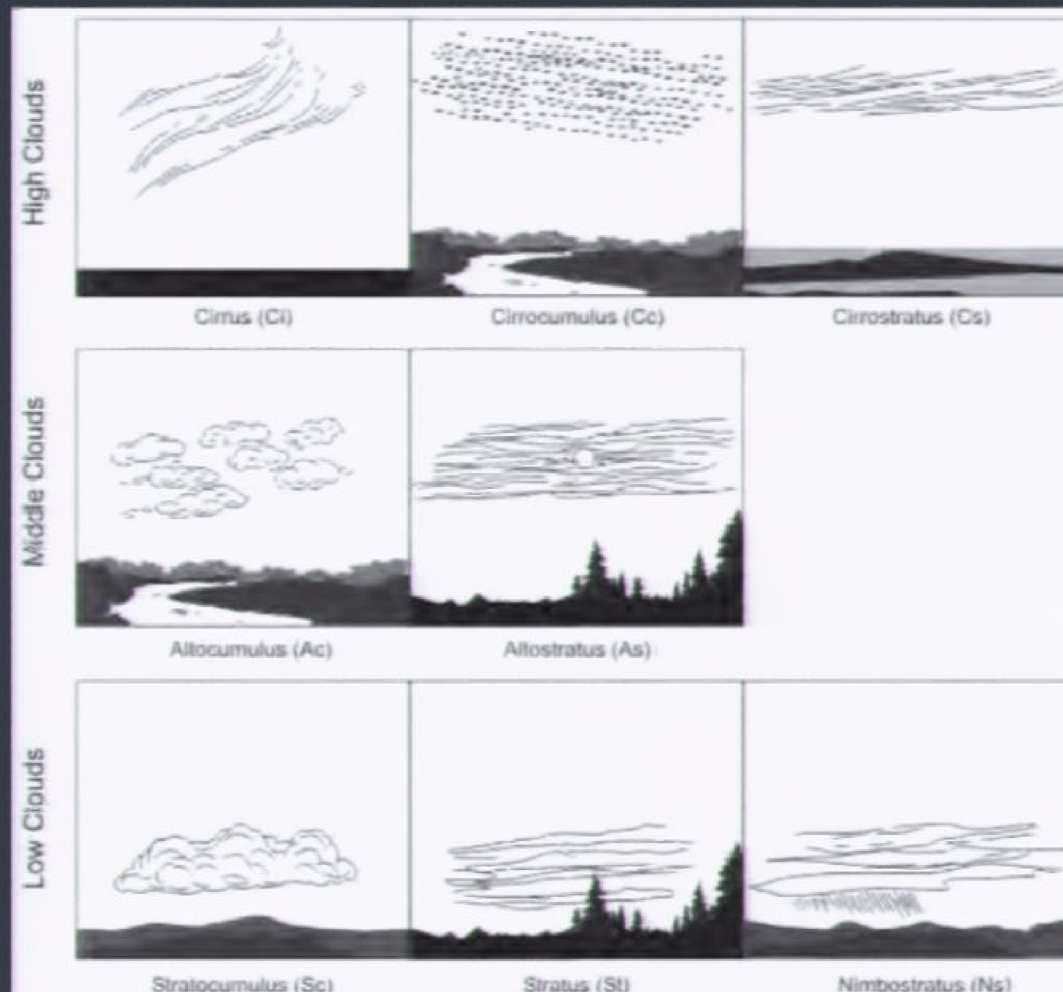

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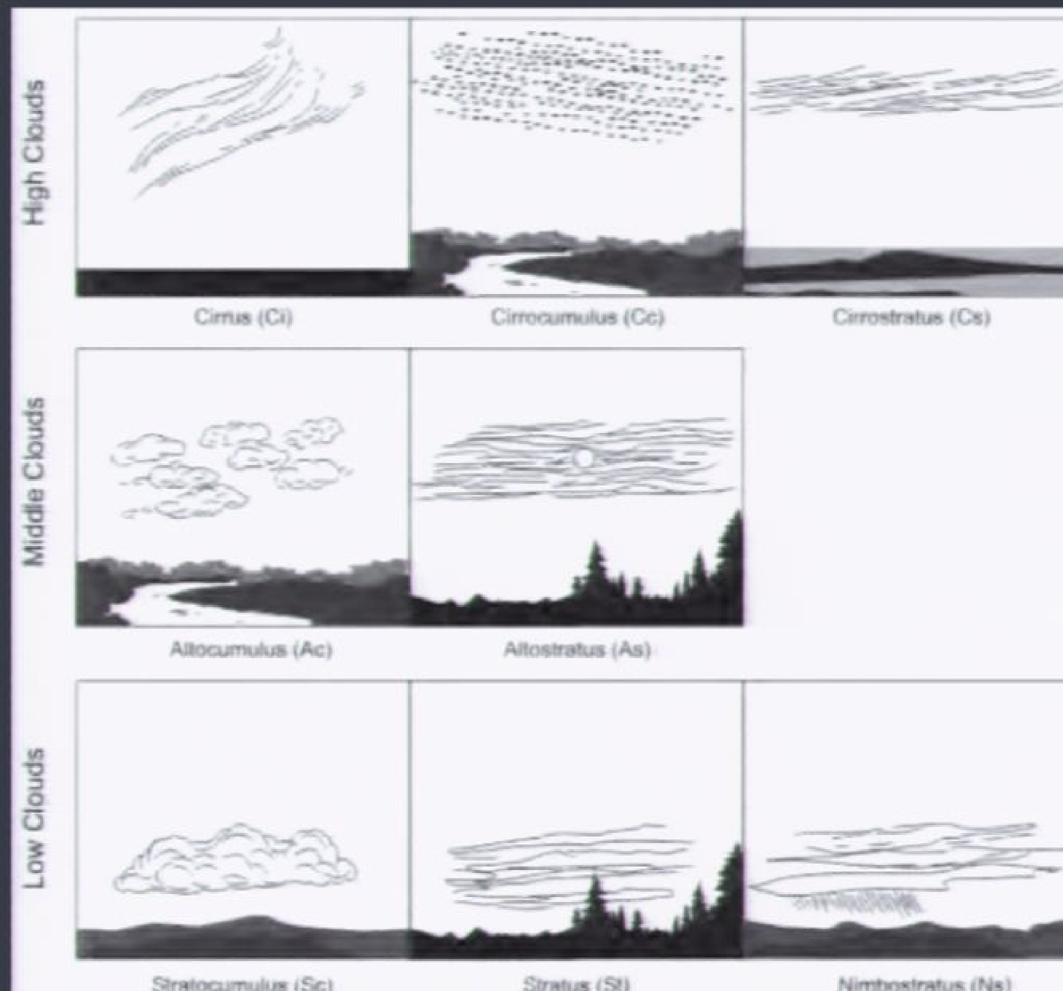

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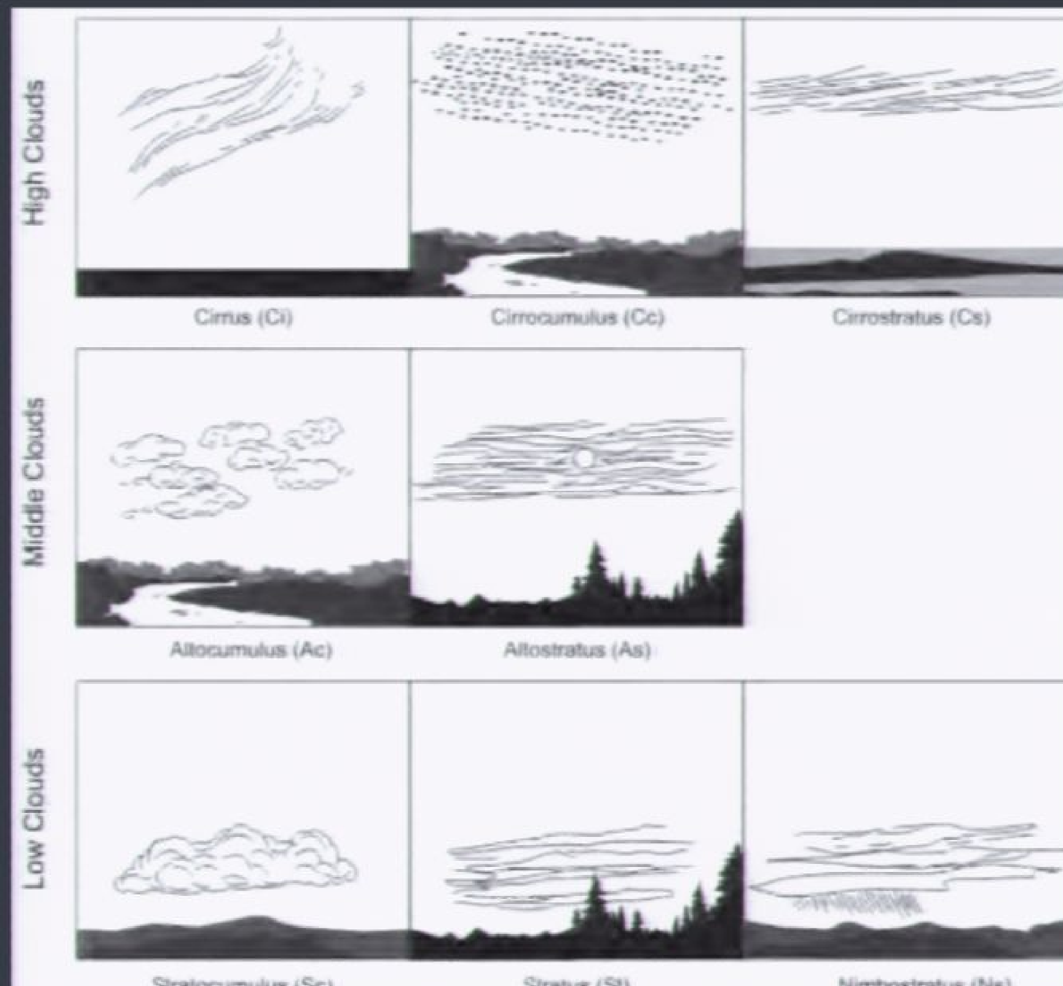

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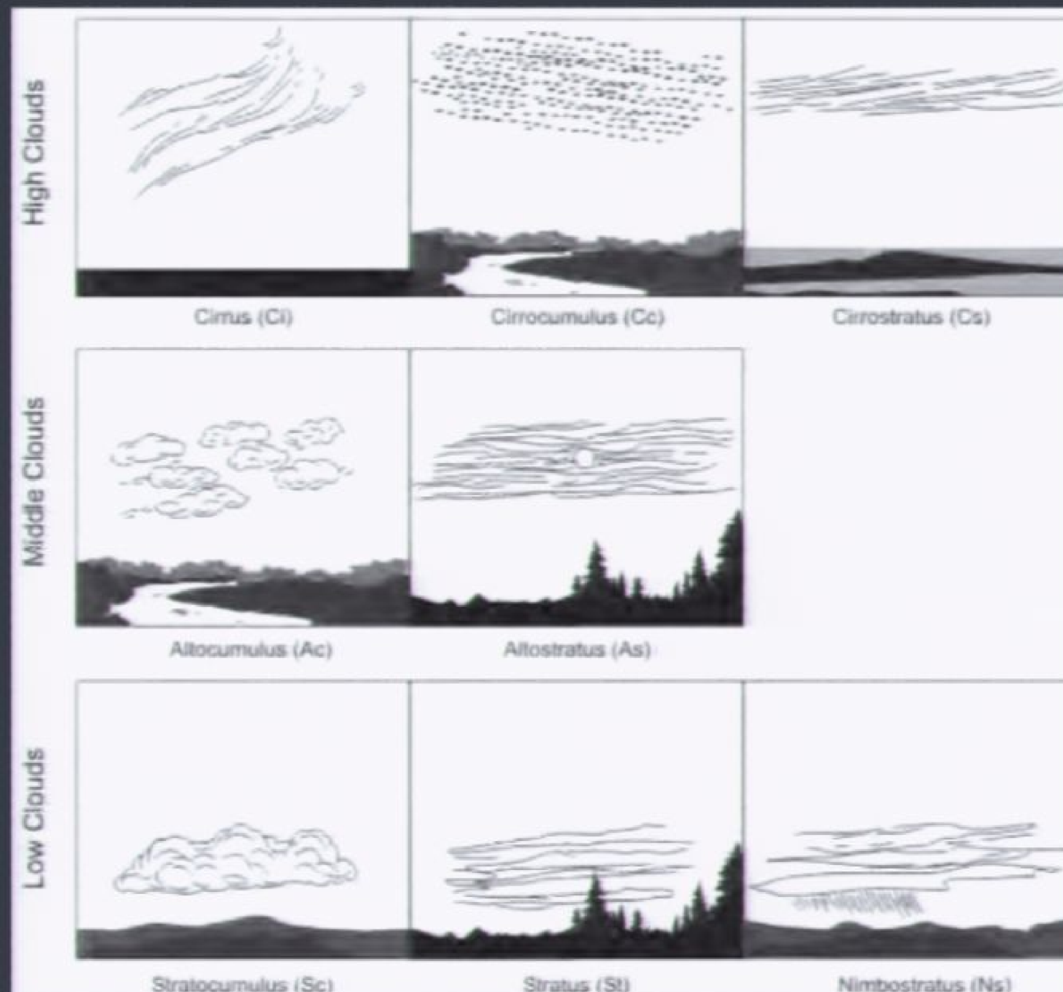

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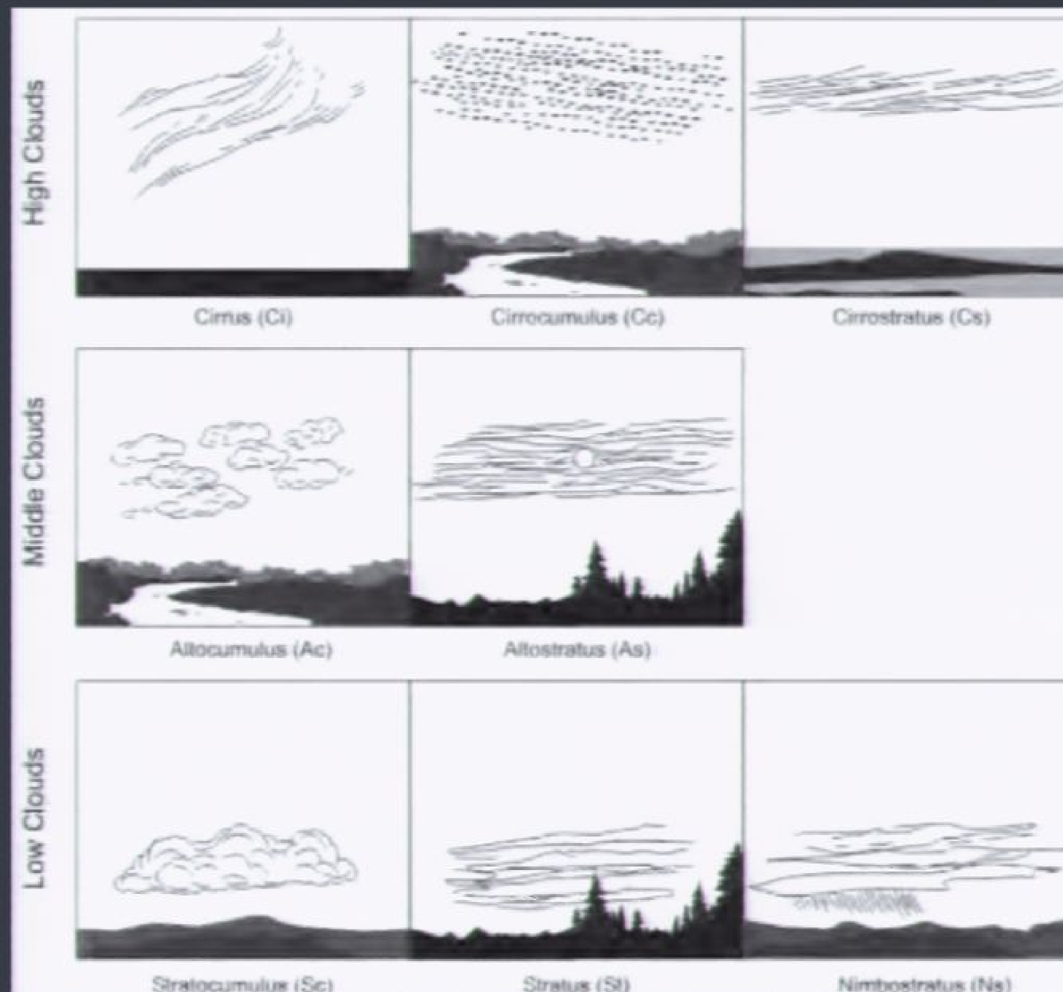

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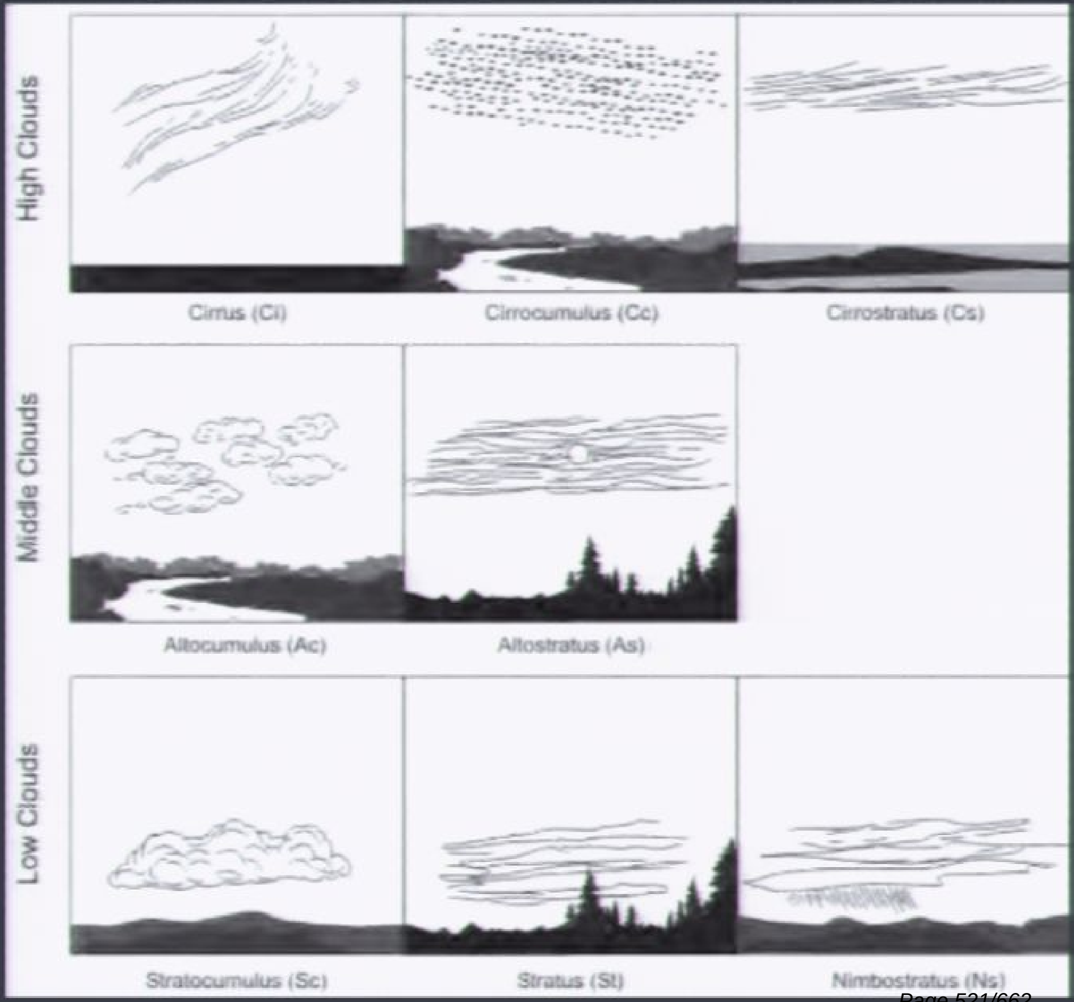

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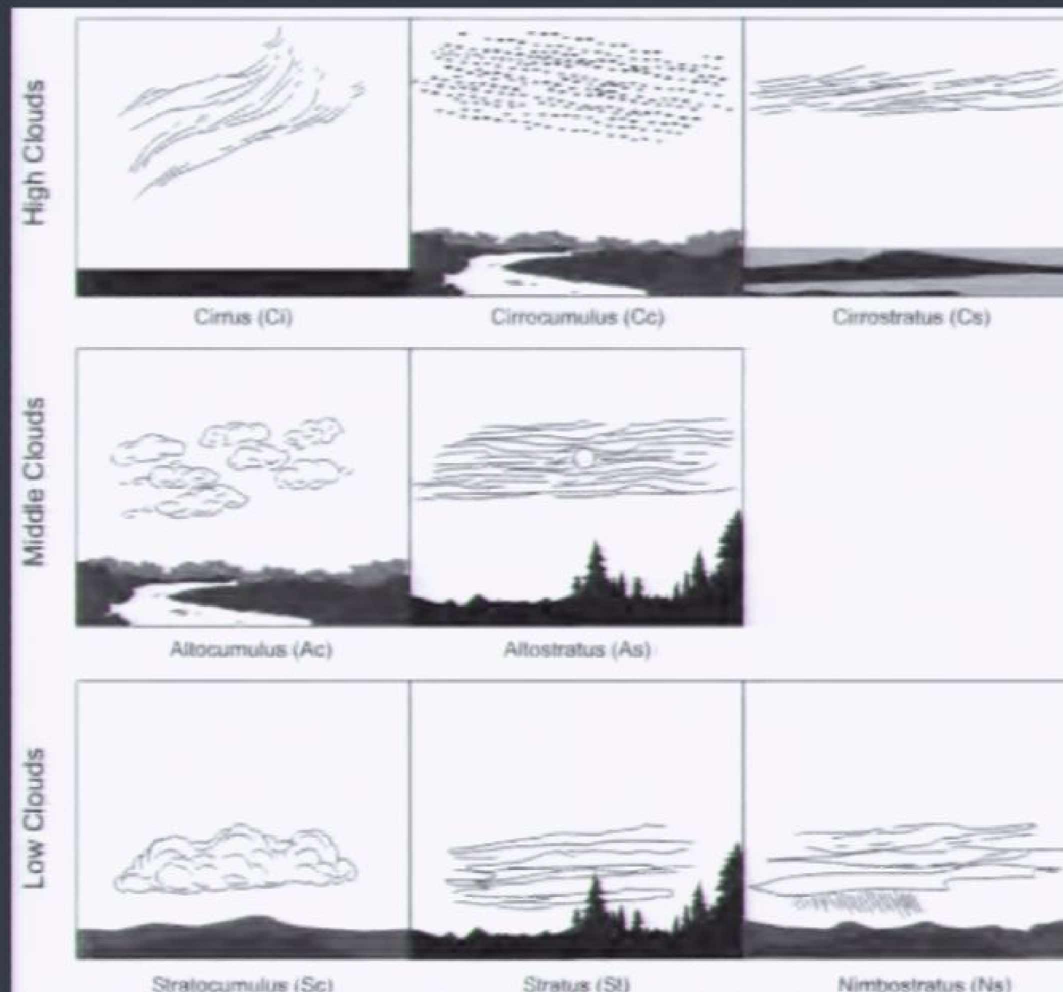

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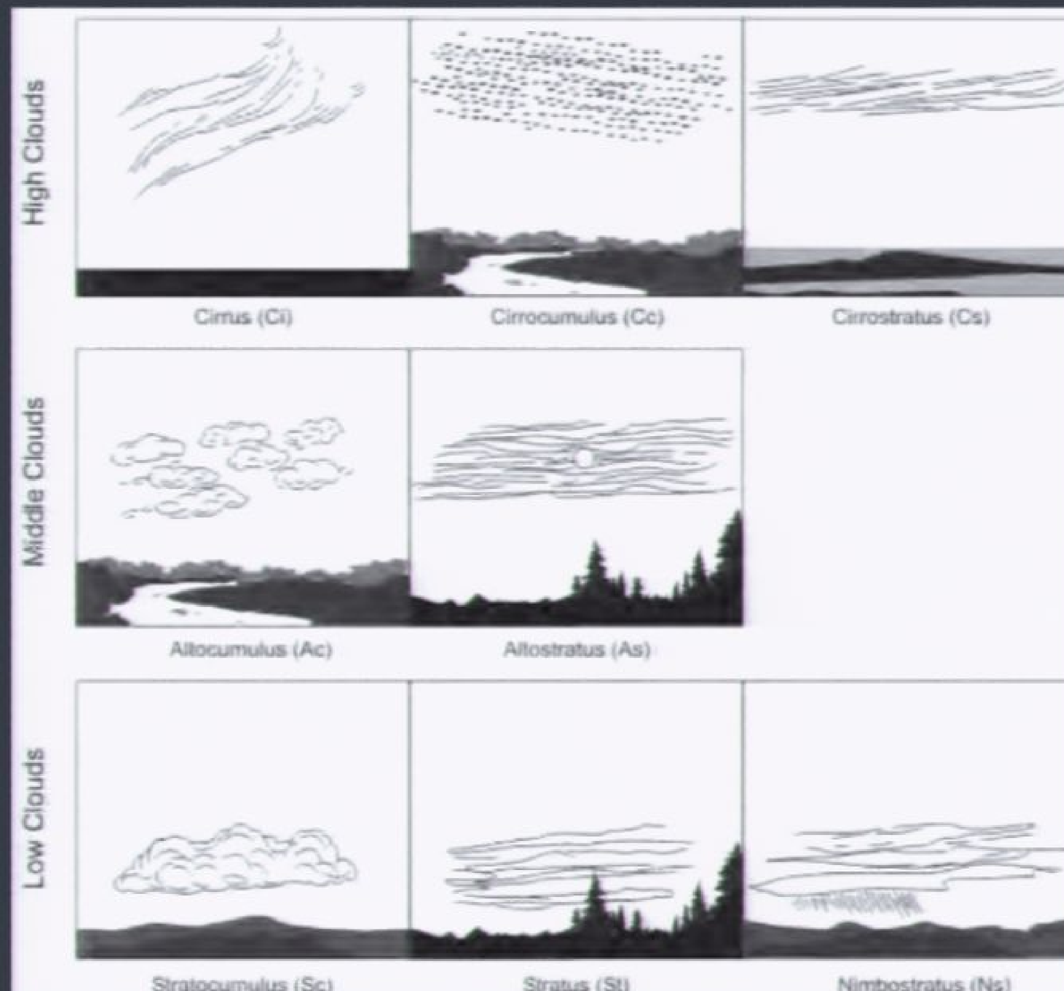

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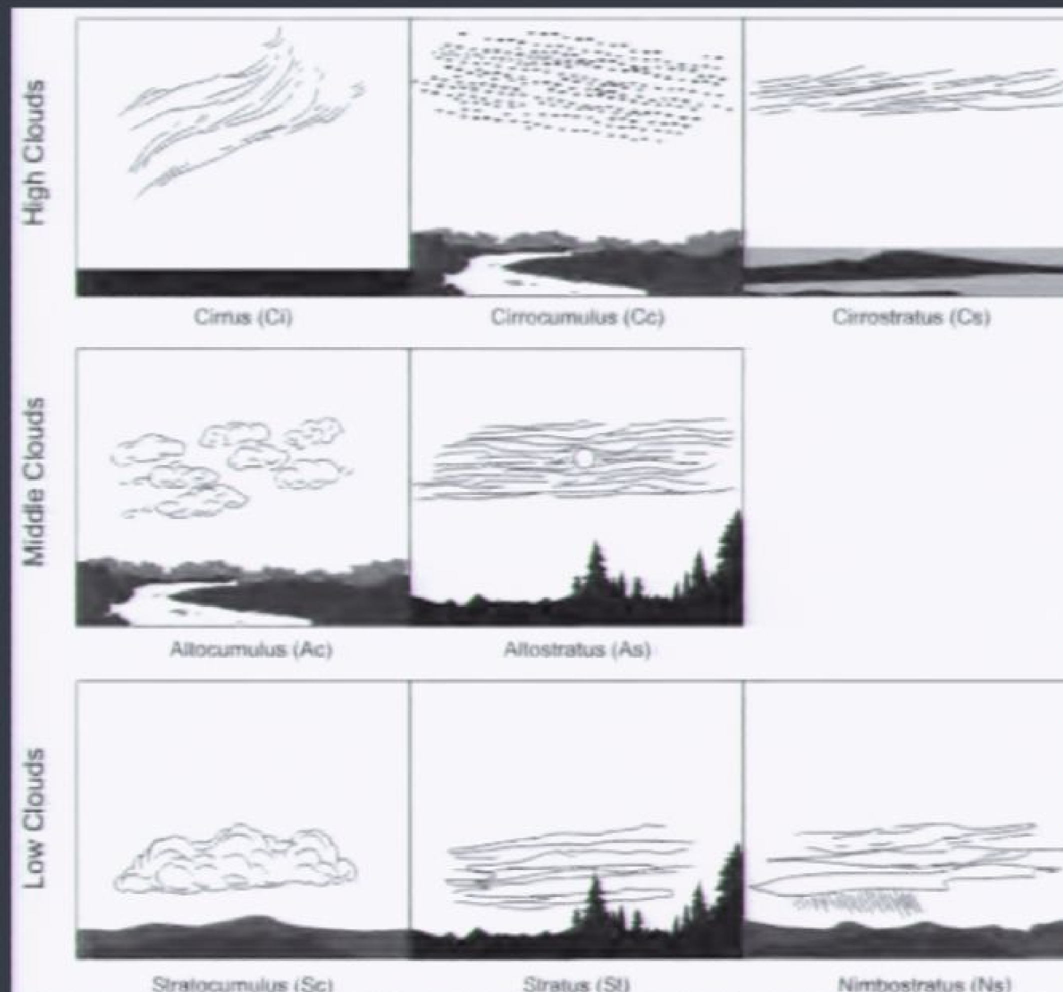

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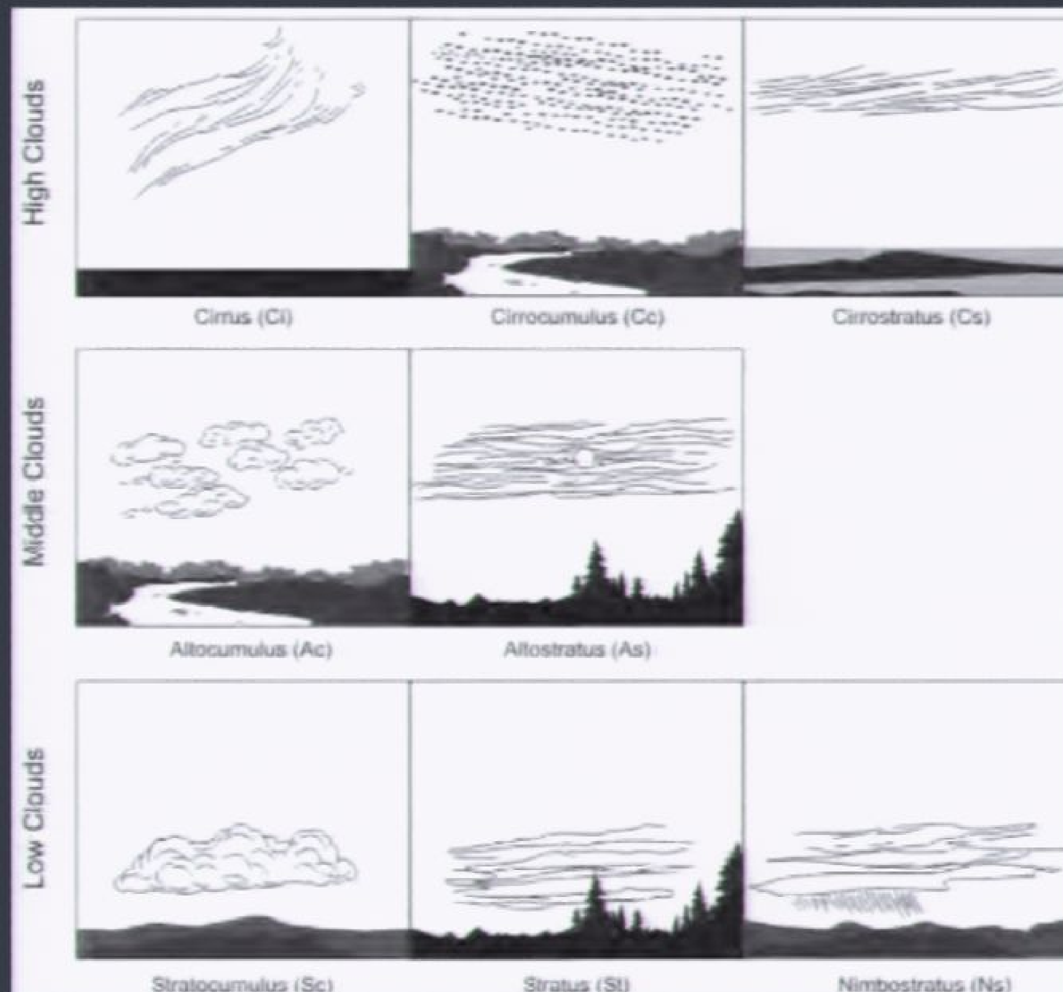

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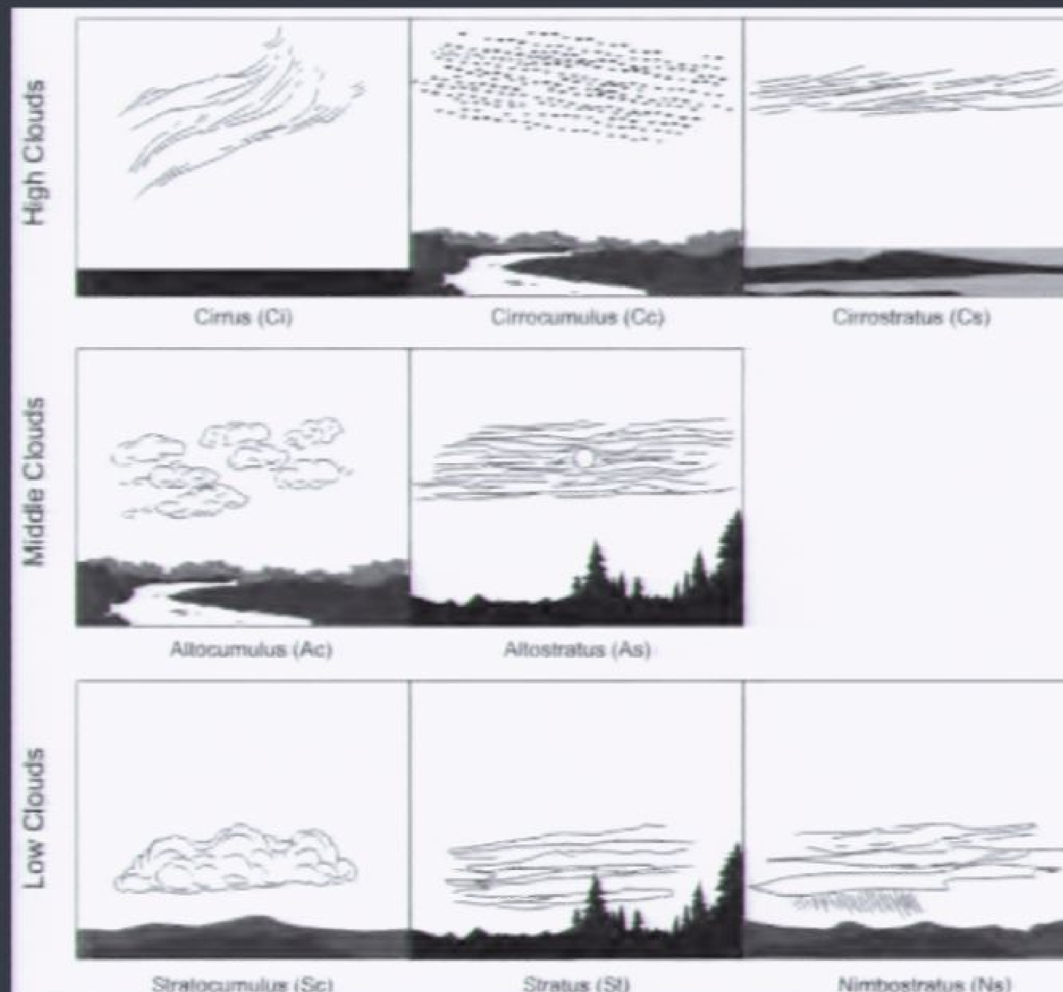

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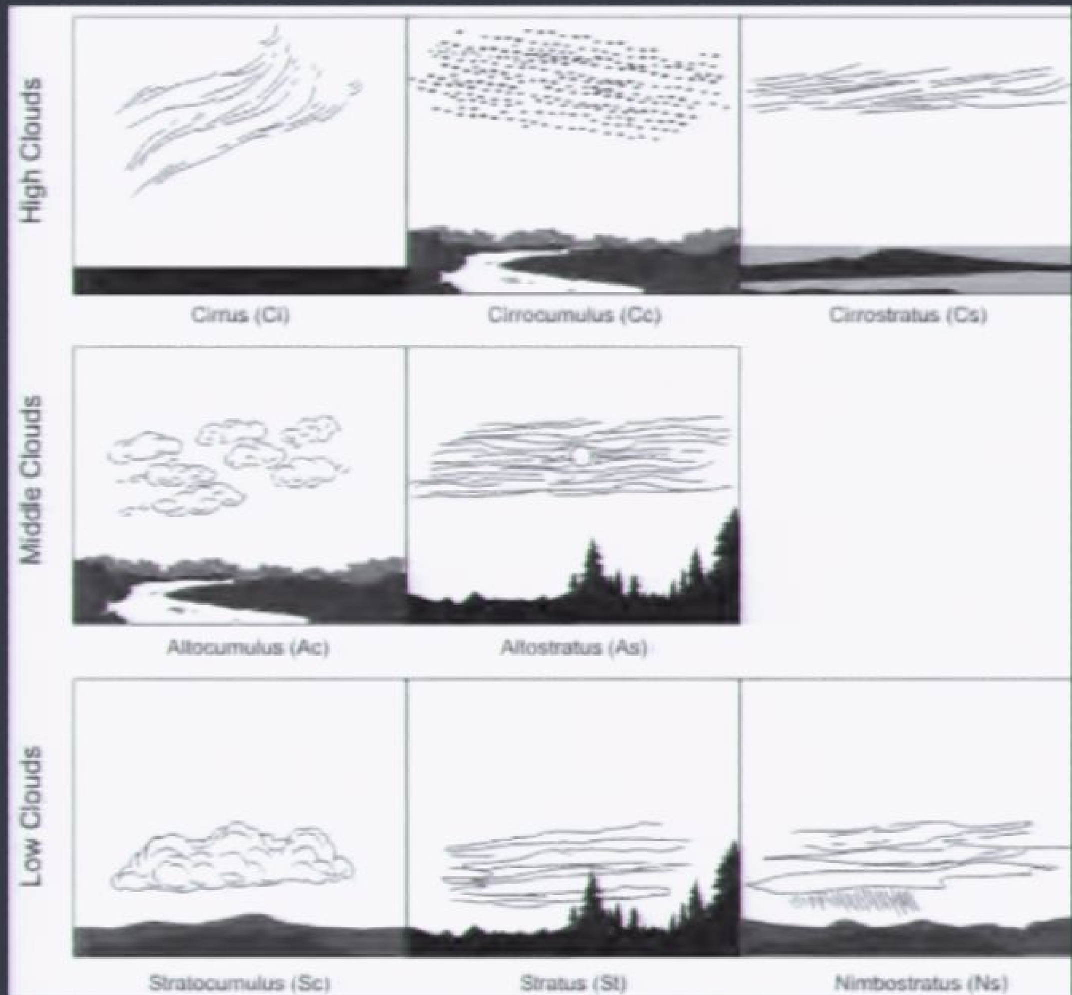

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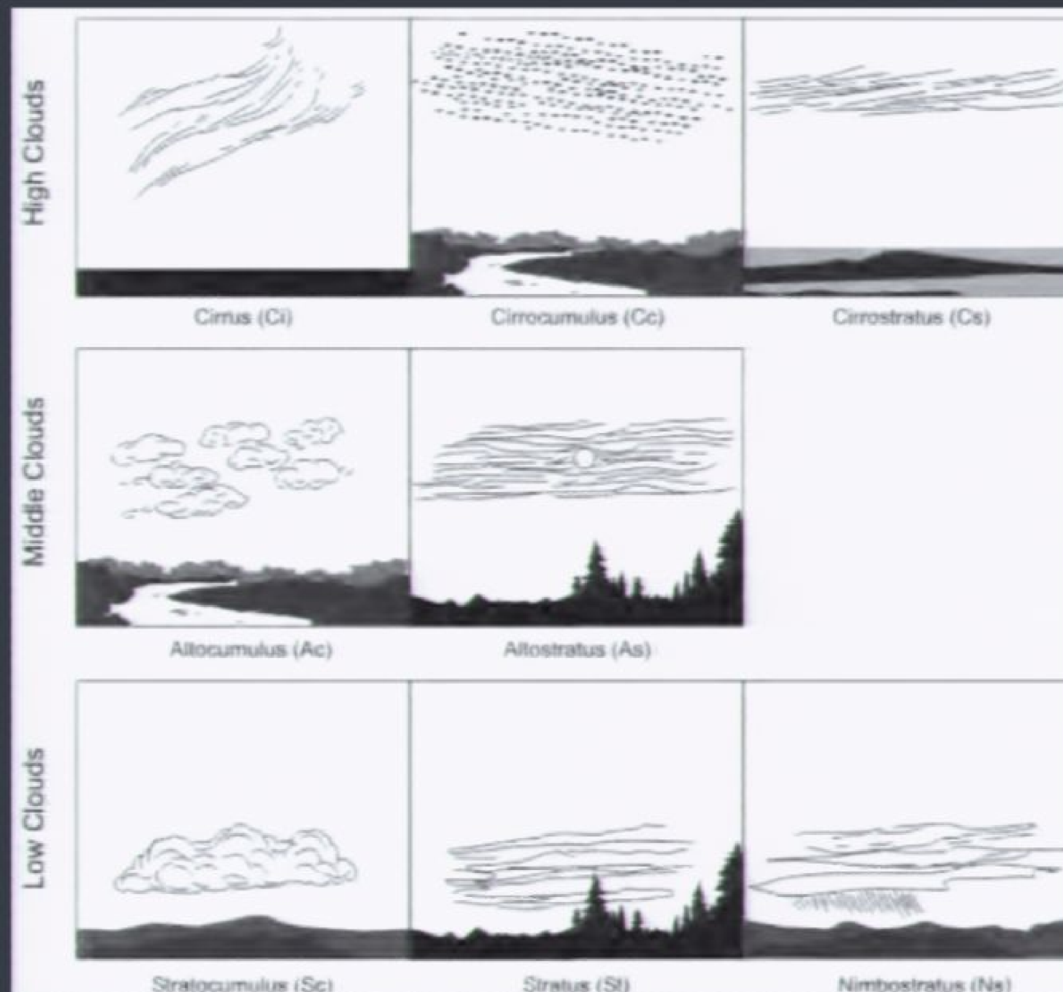

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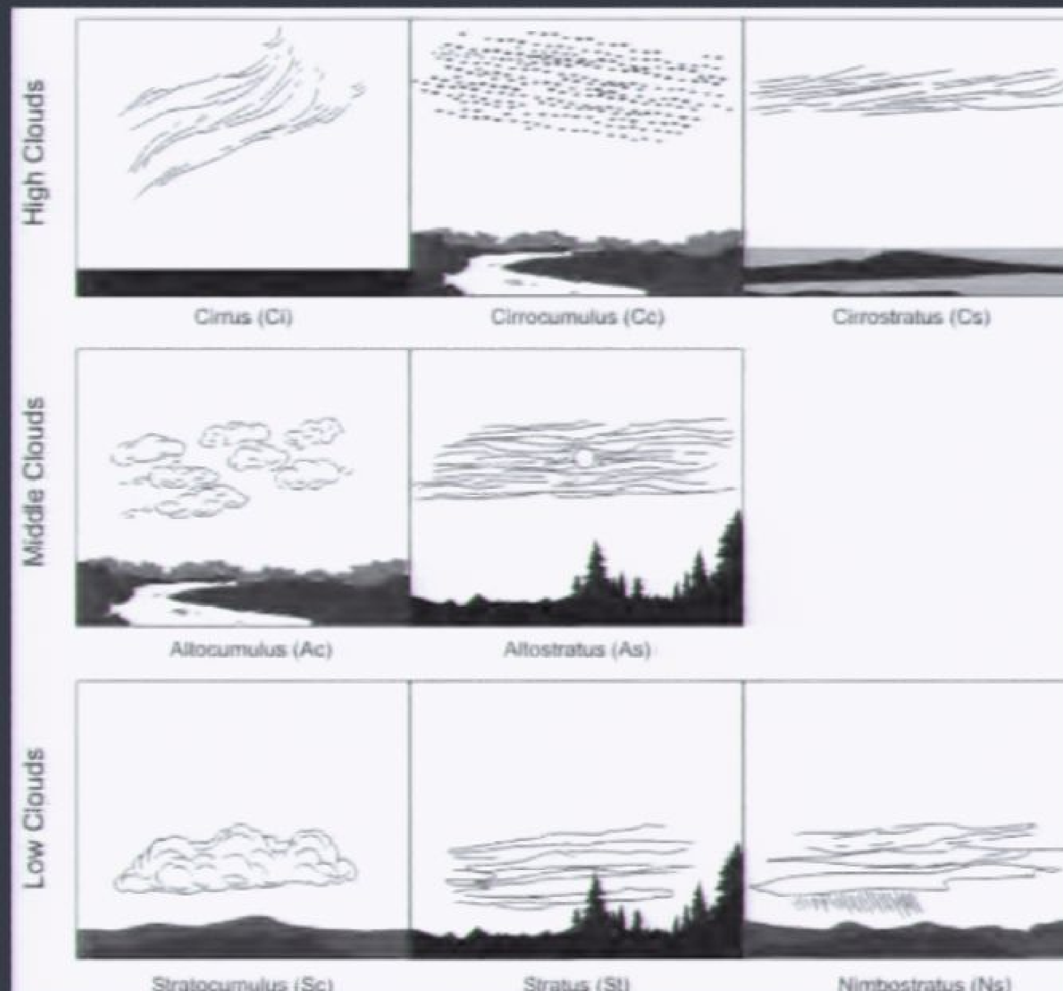

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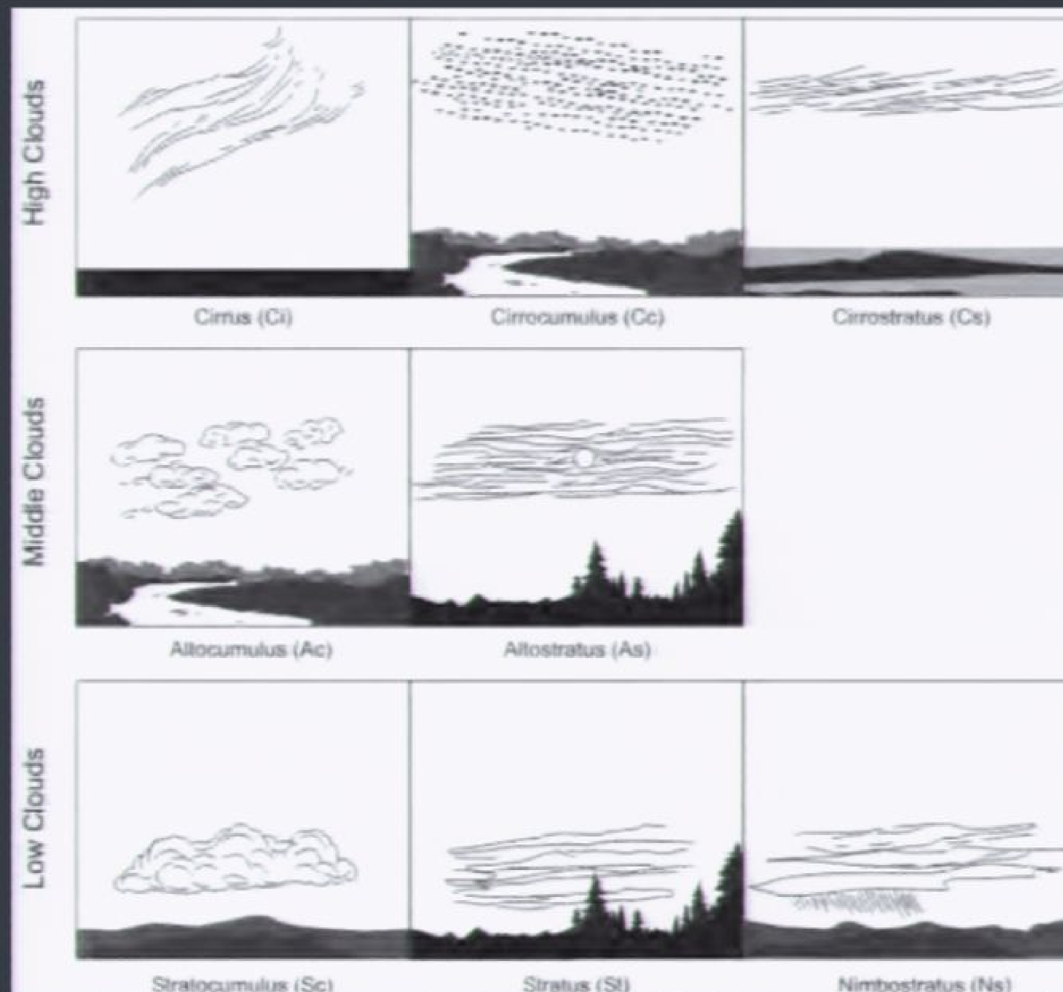

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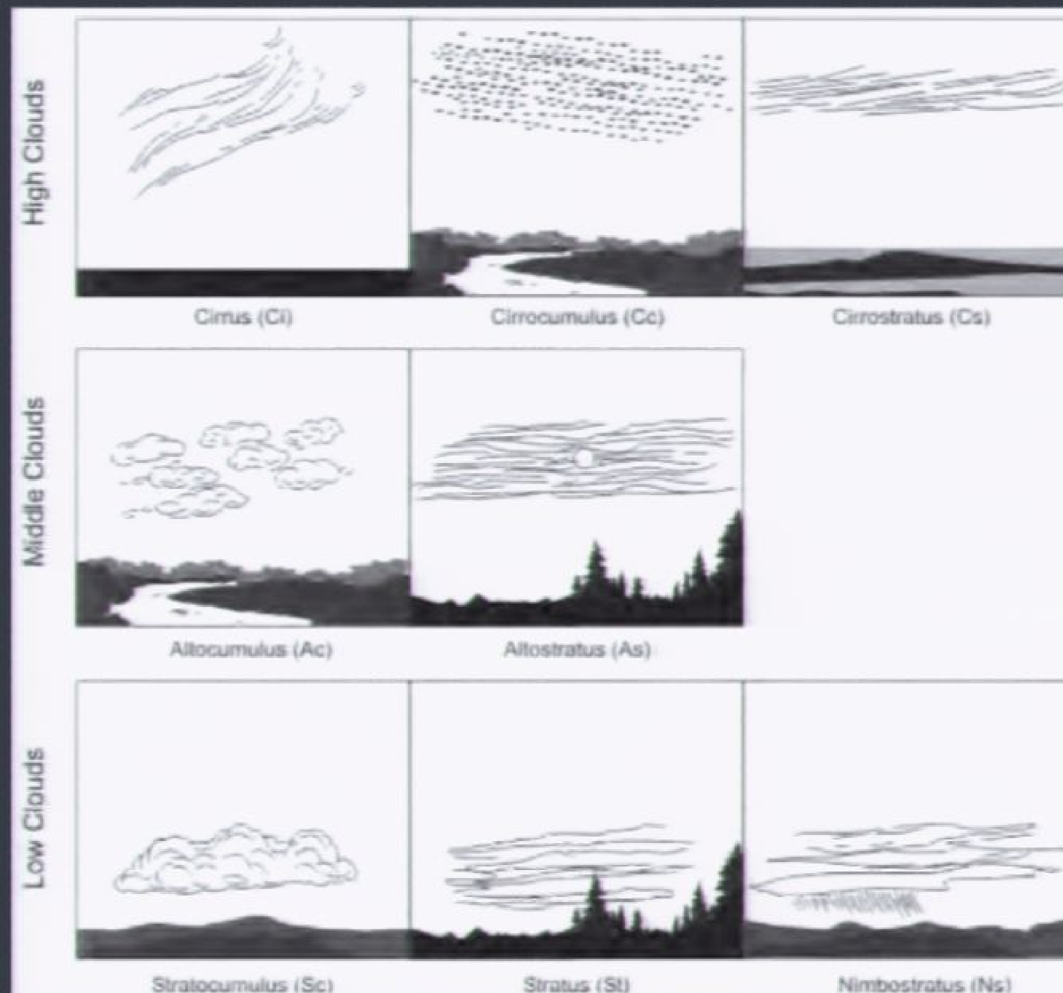

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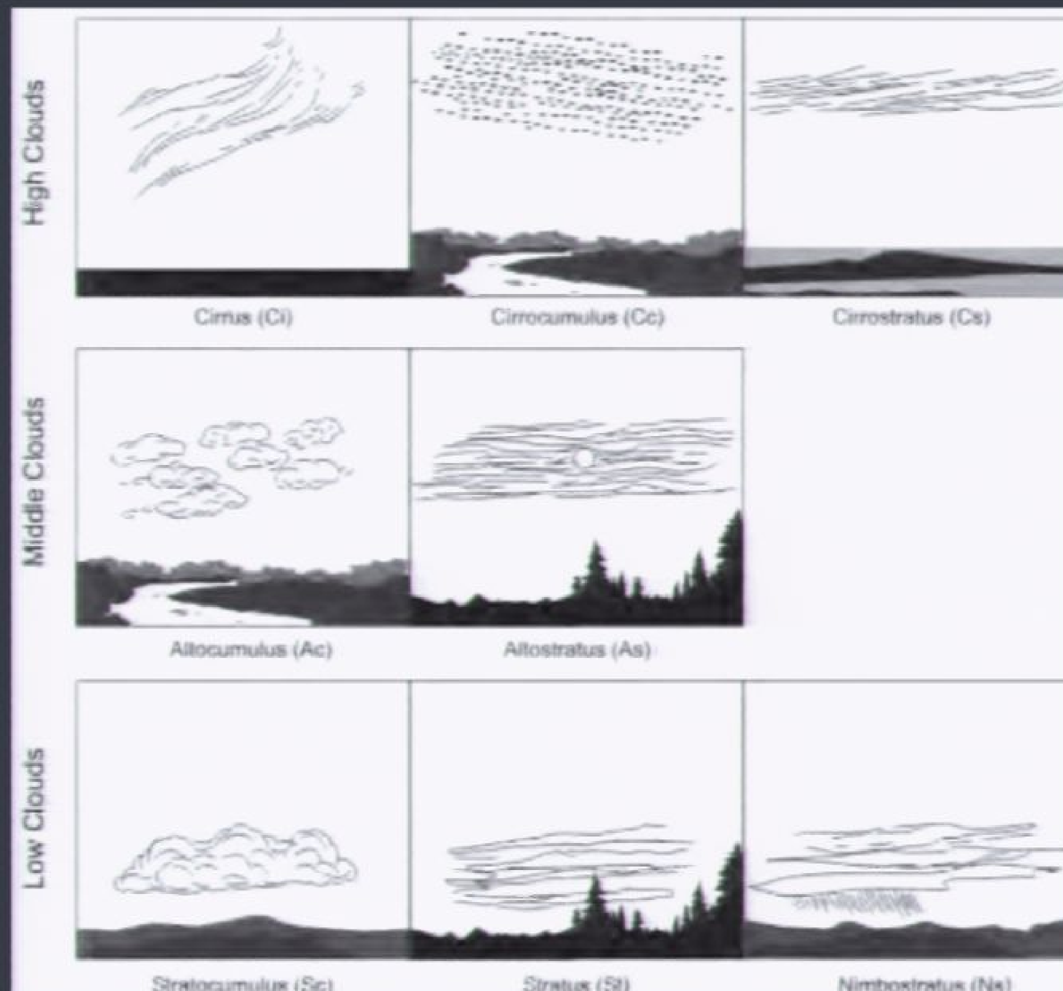

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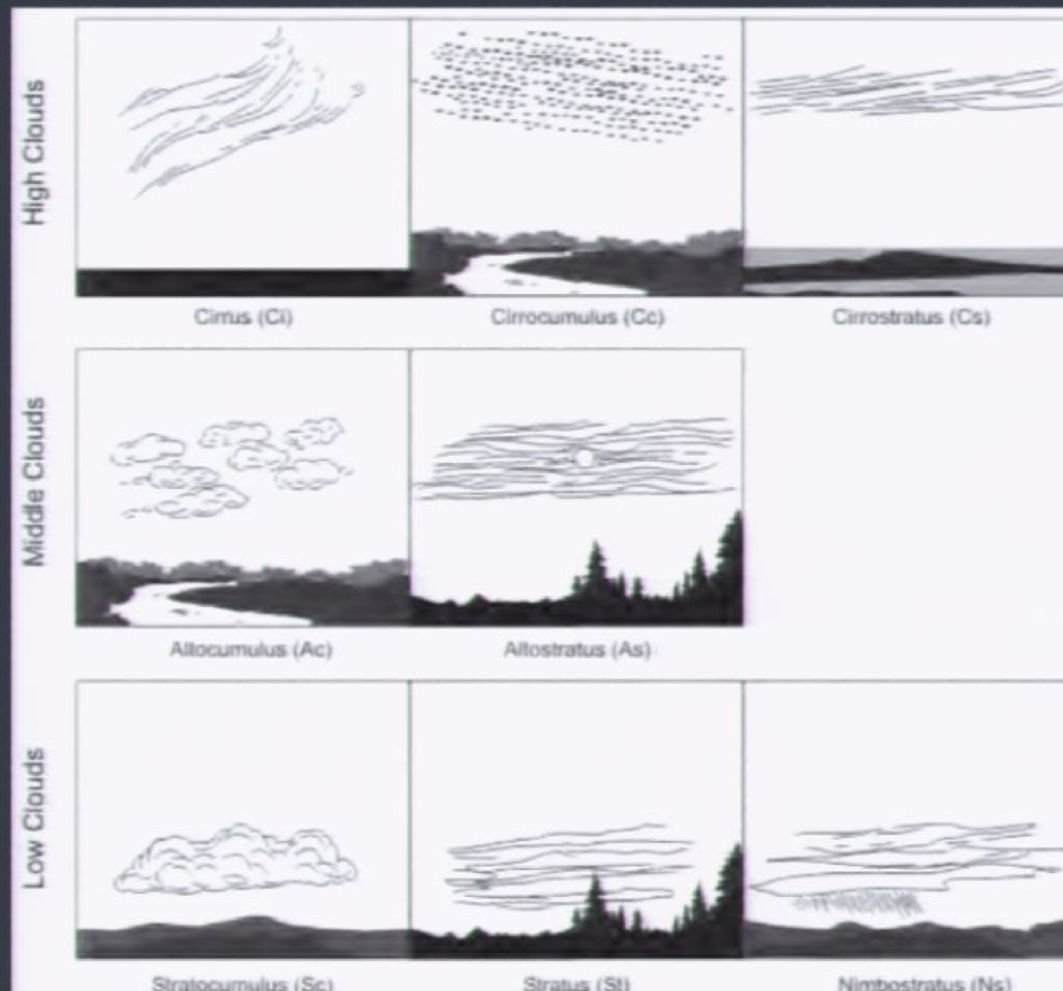

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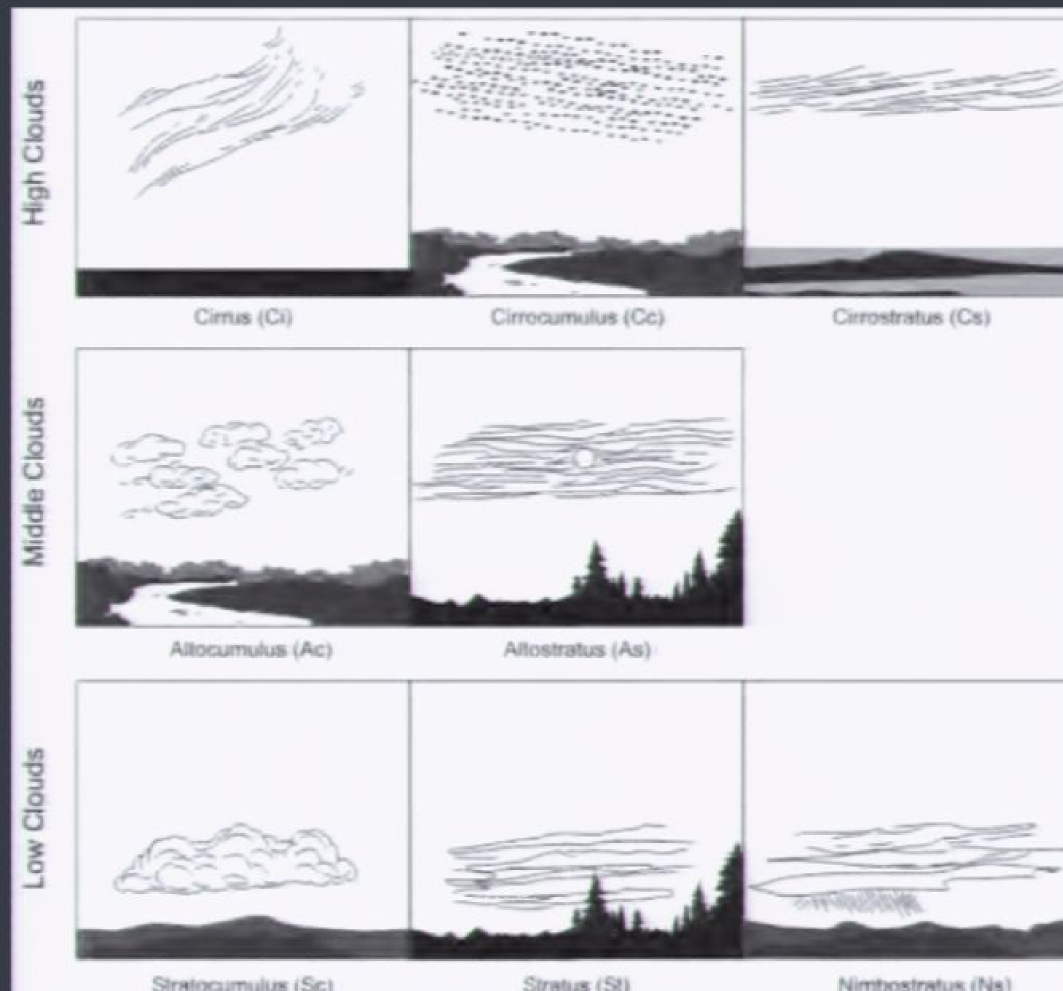

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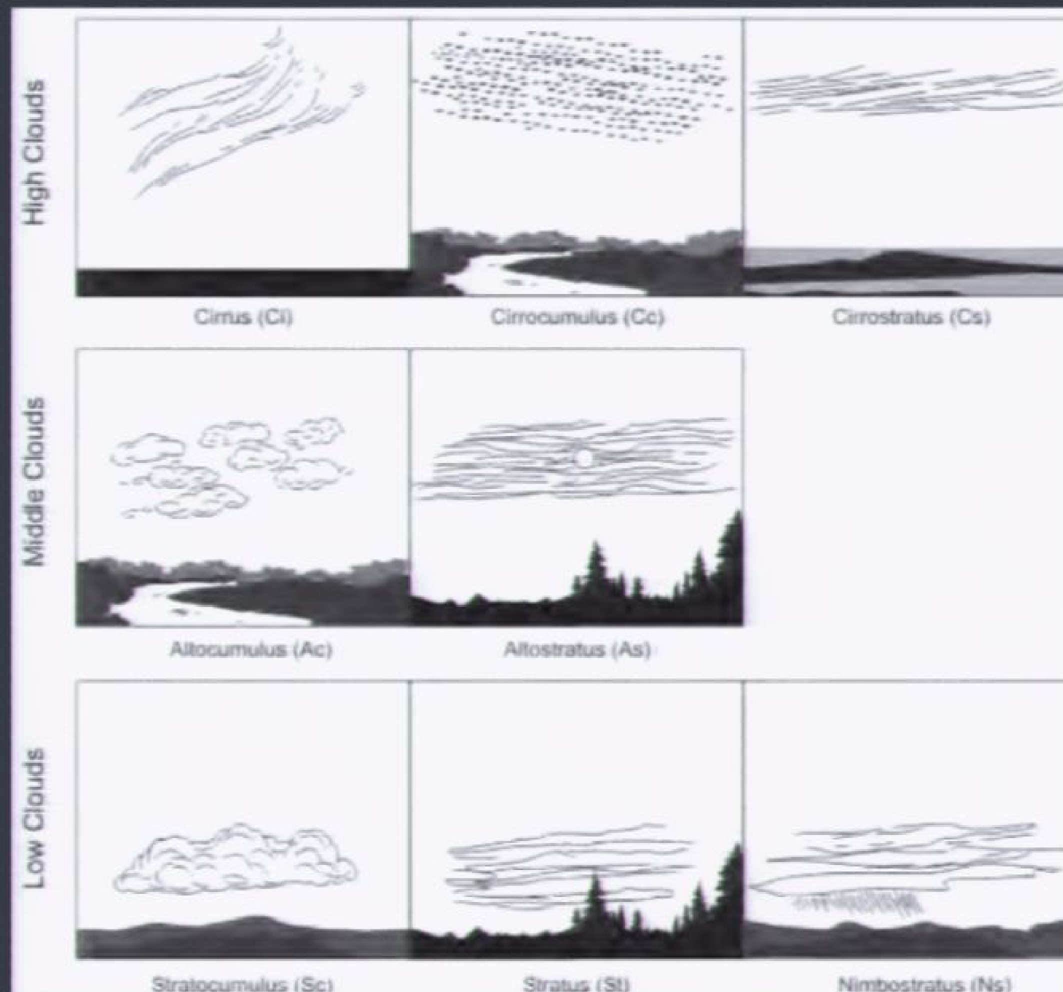

Why do clouds appear in different shapes?

- Different kind of particles and temperature
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  - warm clouds are softer-looking
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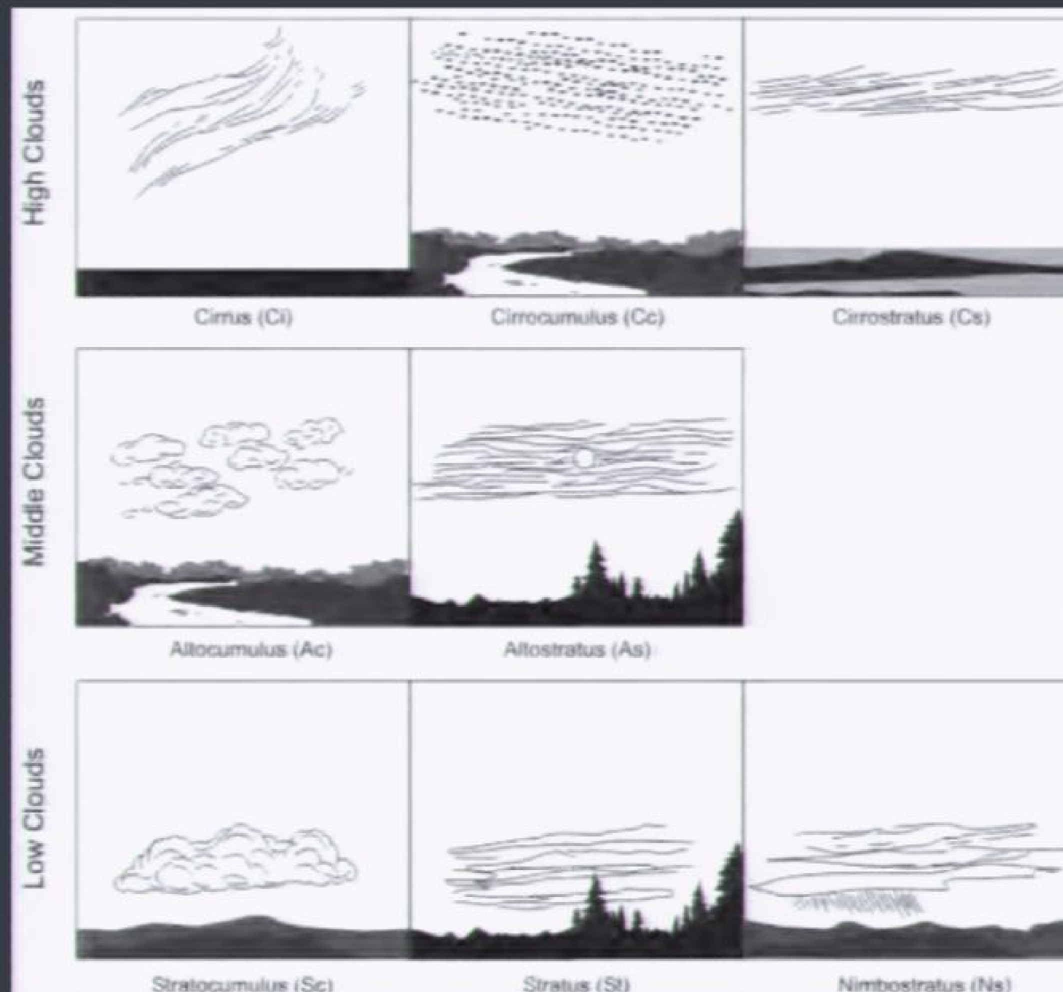

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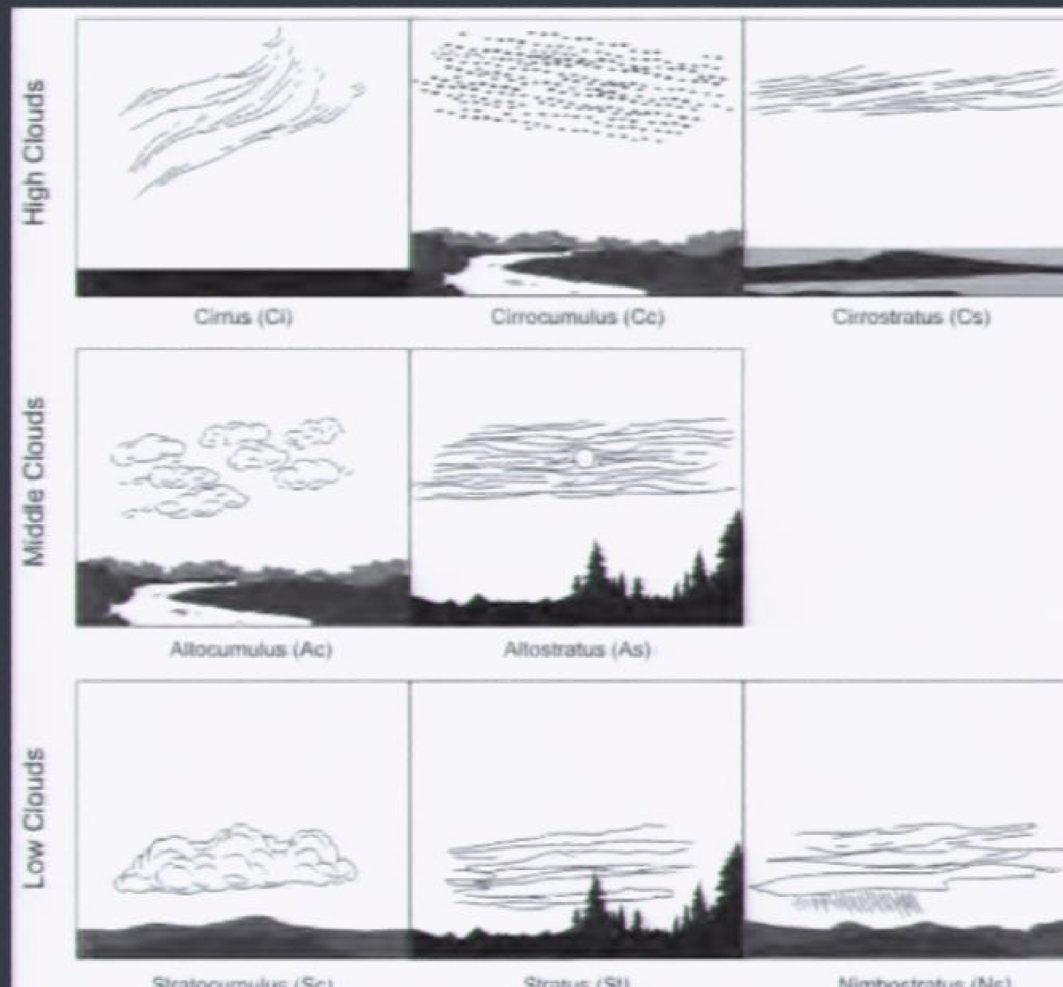

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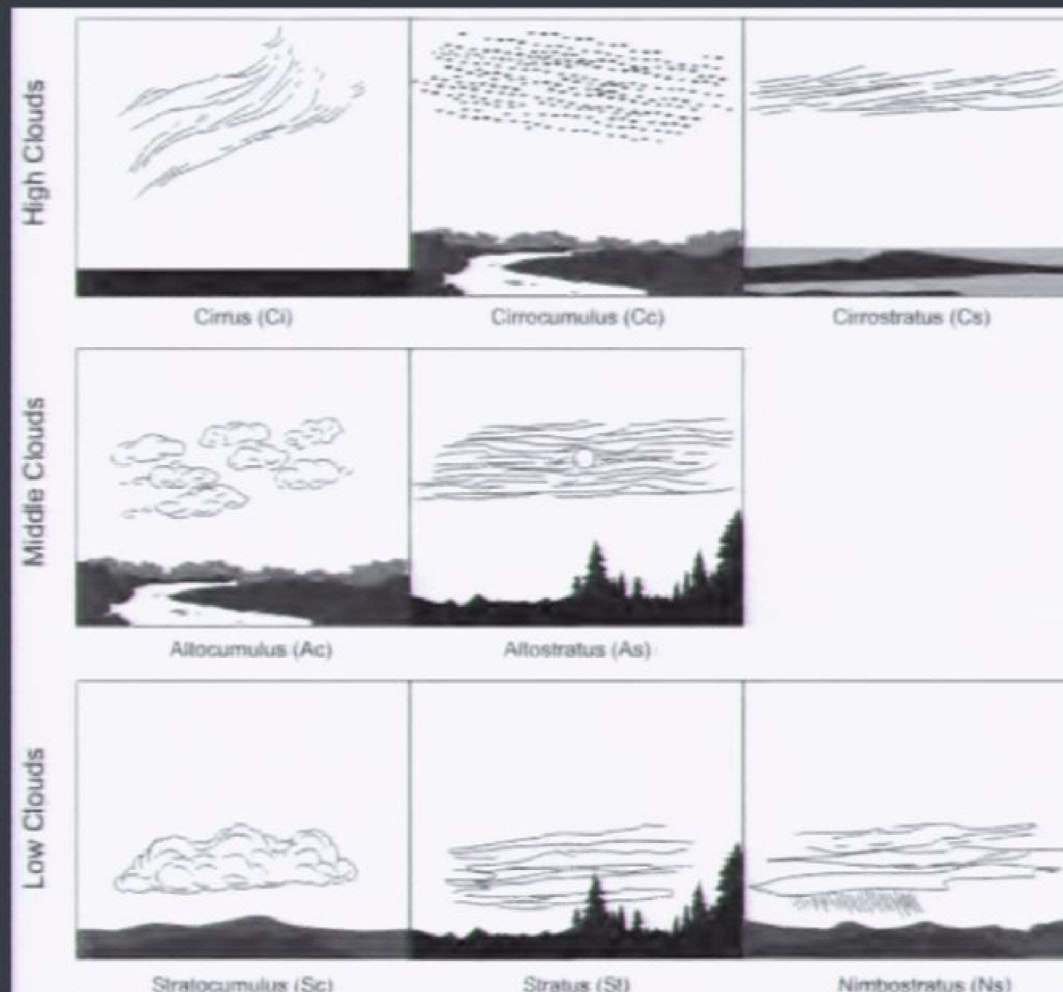

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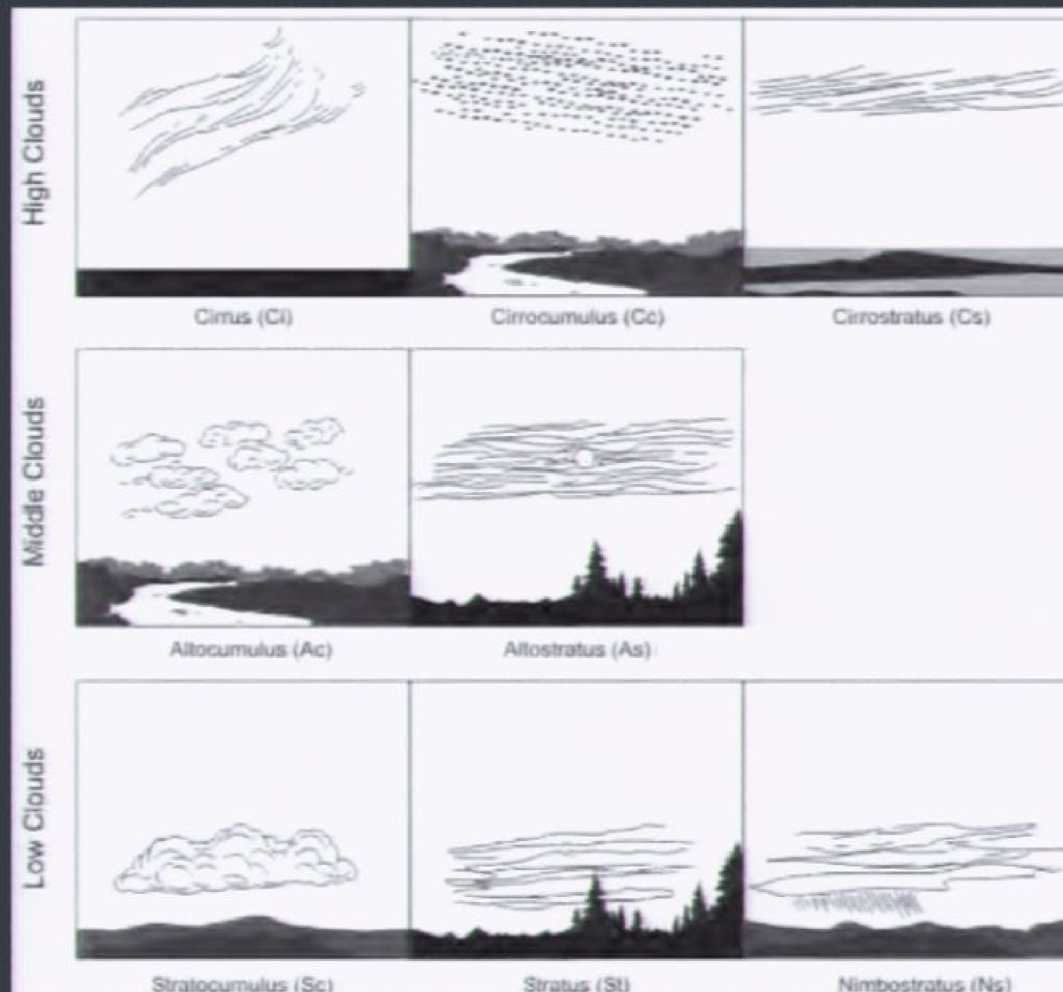

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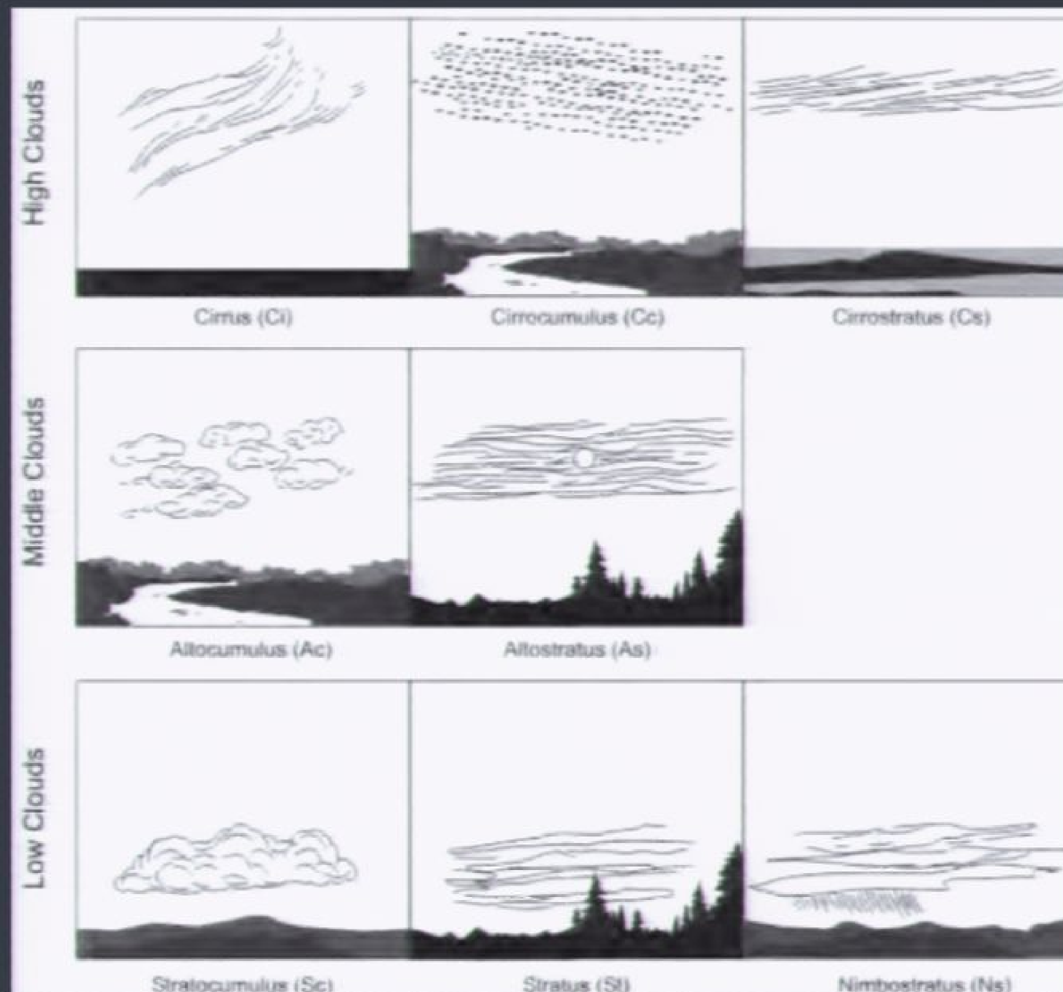

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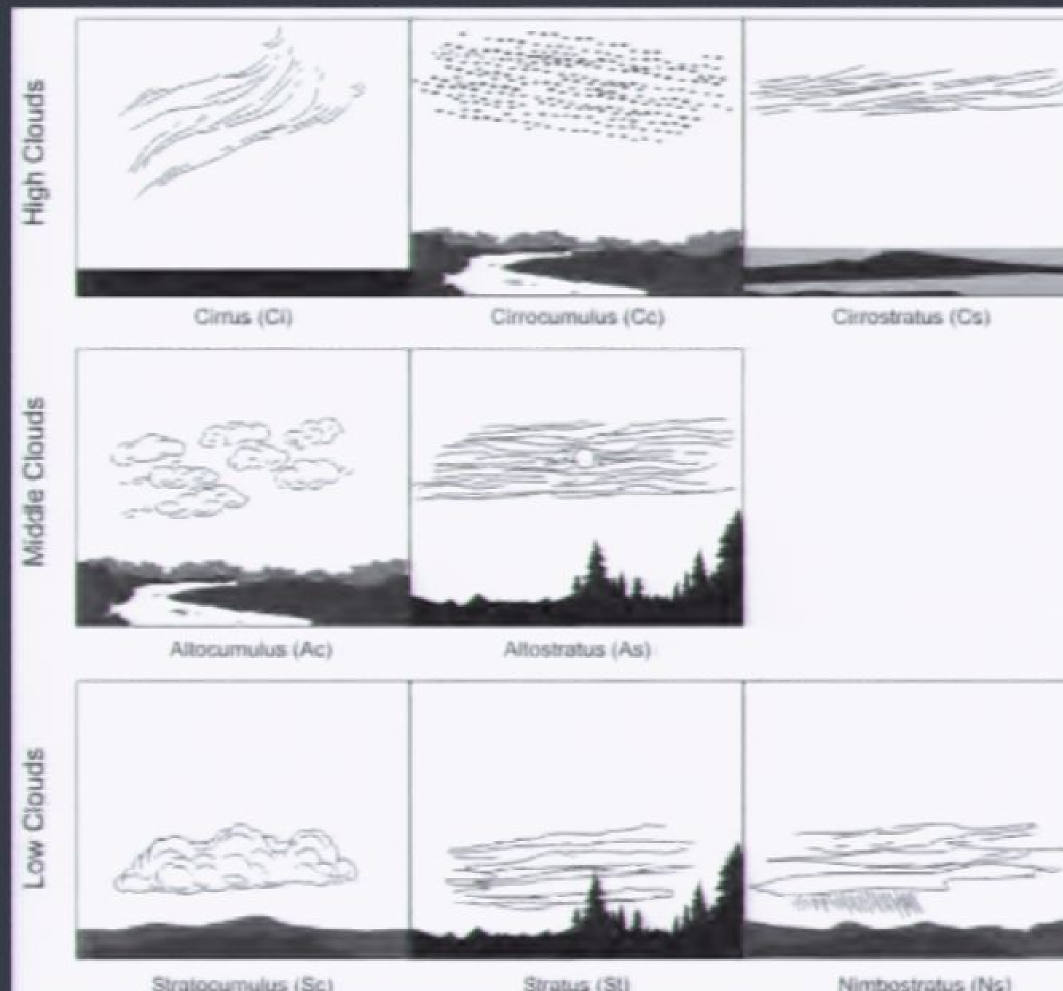

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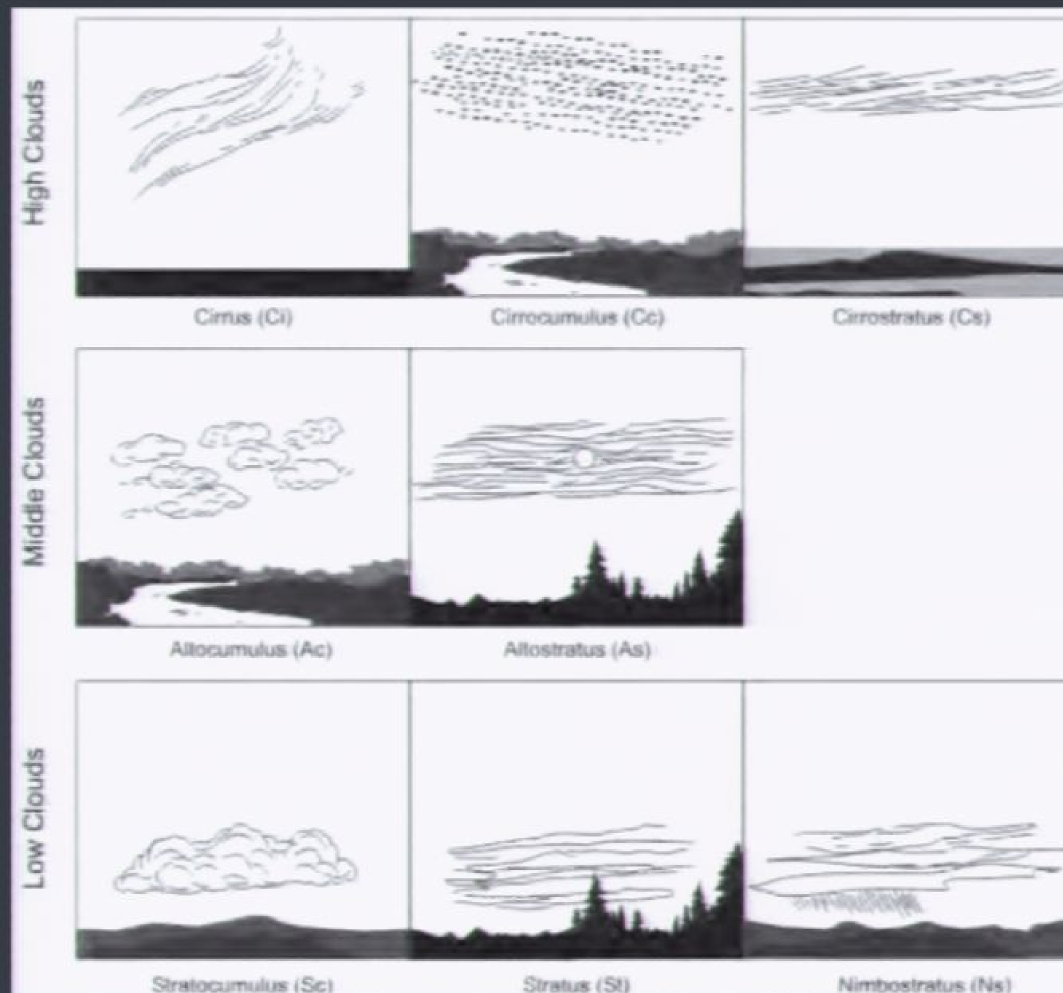

Noctilucent clouds

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Noctilucent clouds

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- Highest clouds in Earth's atmosphere
- 76 to 85 kilometers high (47 to 53 mi)
- Visible only when illuminated by sunlight from below the horizon while the lower layers of the atmosphere are in Earth's shadow

Clouds on other planets

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  - Sulfur Dioxide and drops of sulfuric acid
  - Completely opaque

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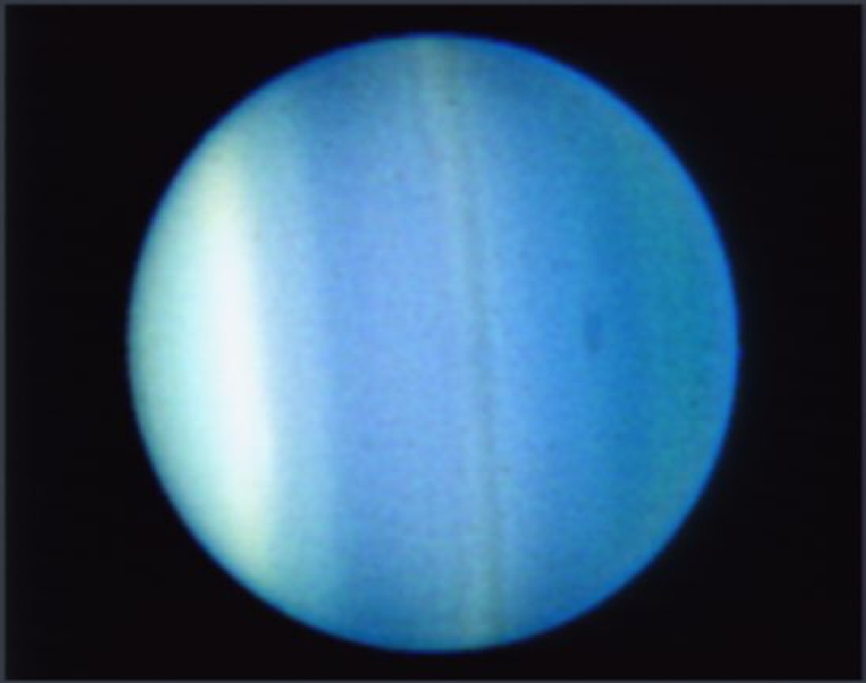

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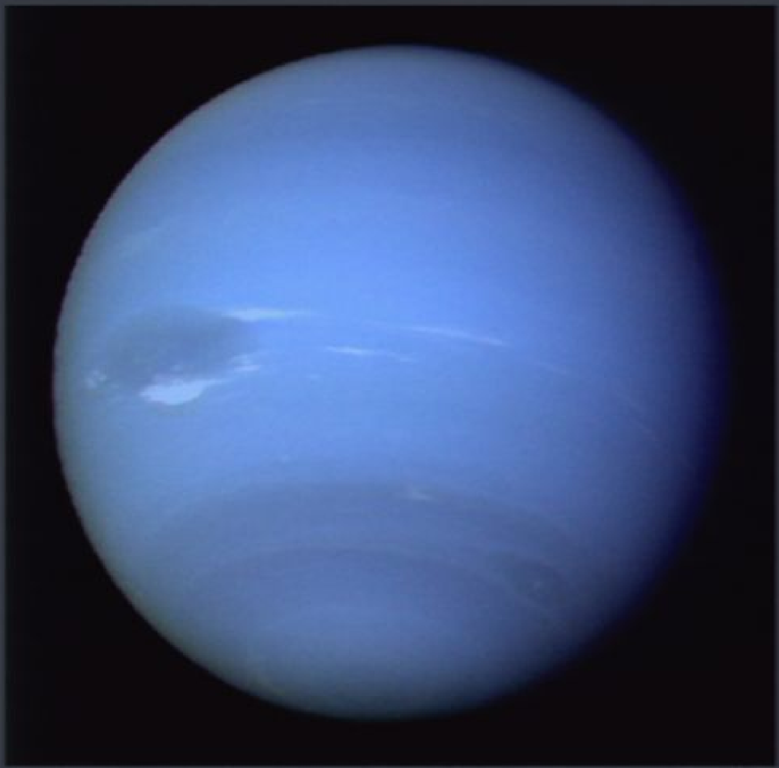
- Uranus
  - Methane crystals
- Neptune
  - Mainly frozen methane



Conclusion

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Conclusion

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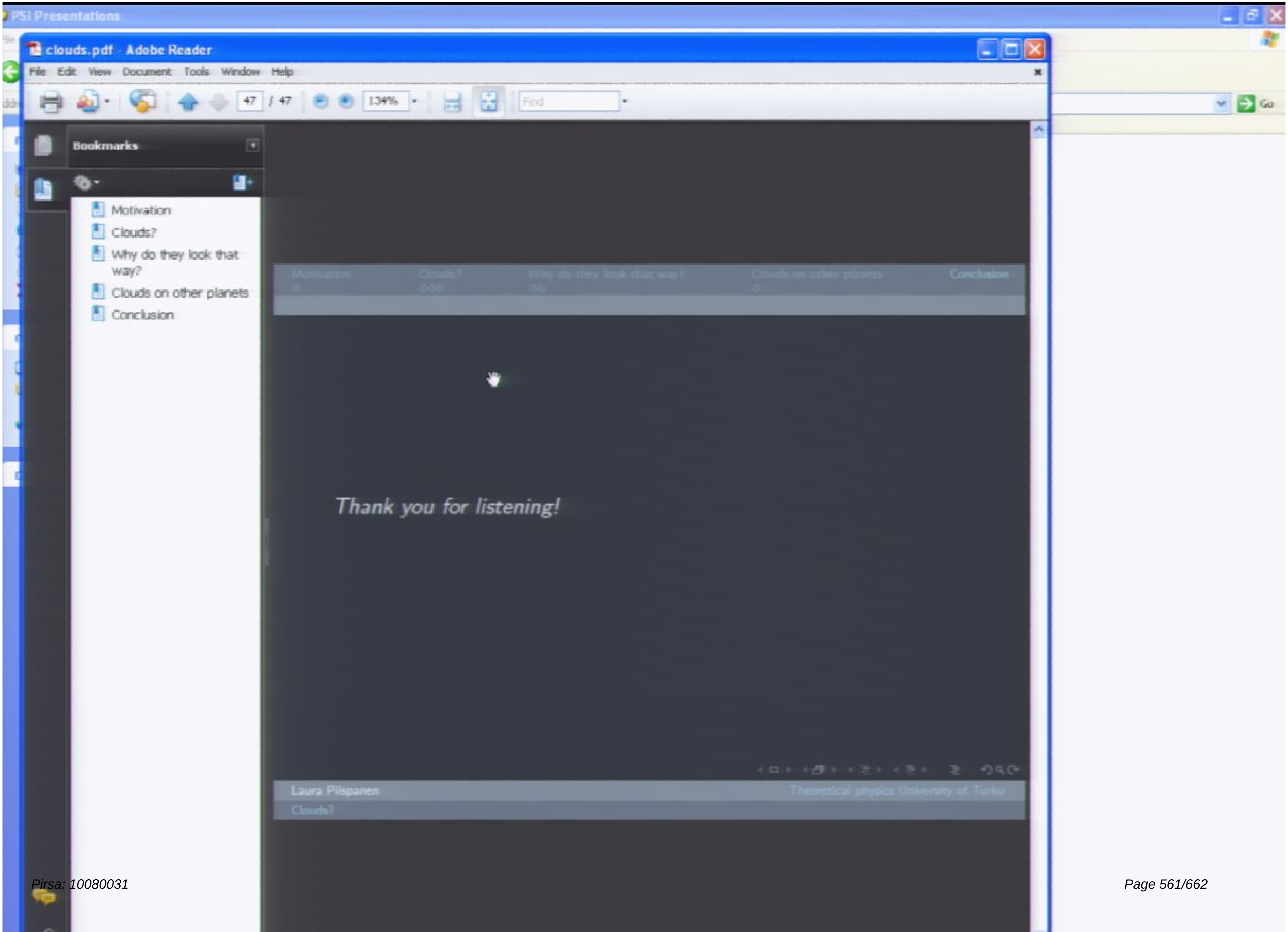
- There are clouds in different altitudes
- Clouds can consist of different kind of particles
- There are "clouds" on other planets
- You can't jump on a cloud and stay on it!

Thank you for listening!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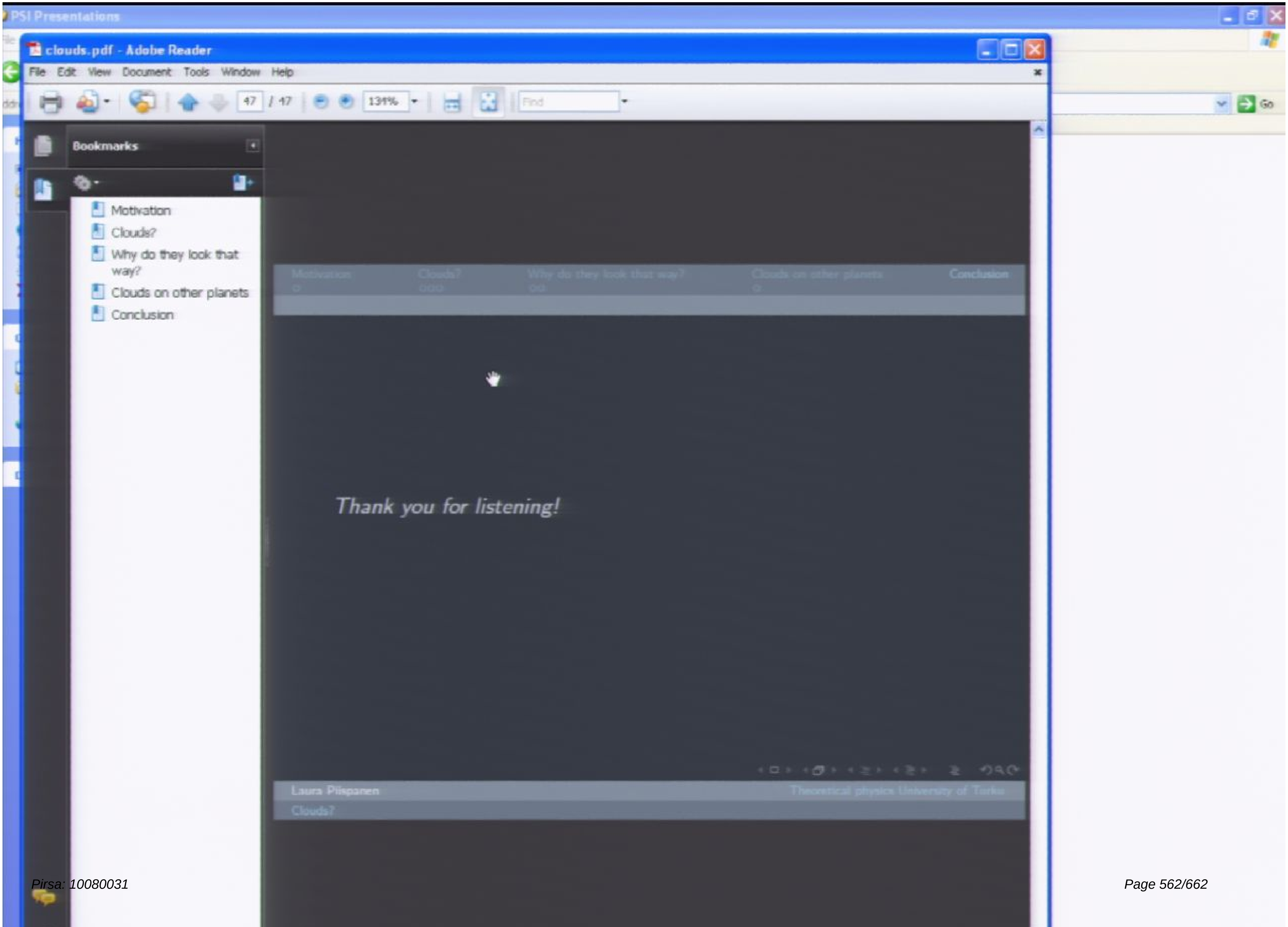
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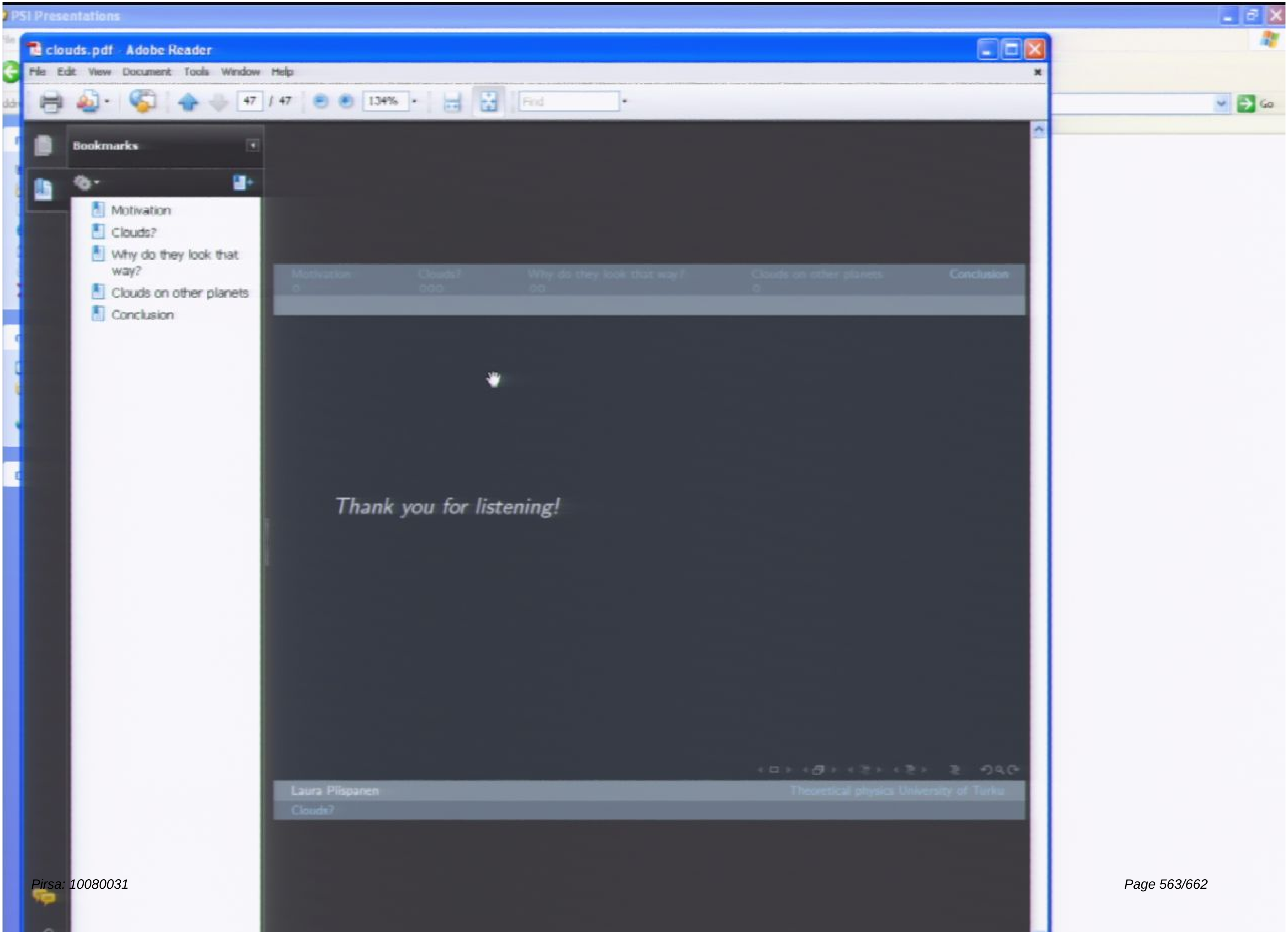

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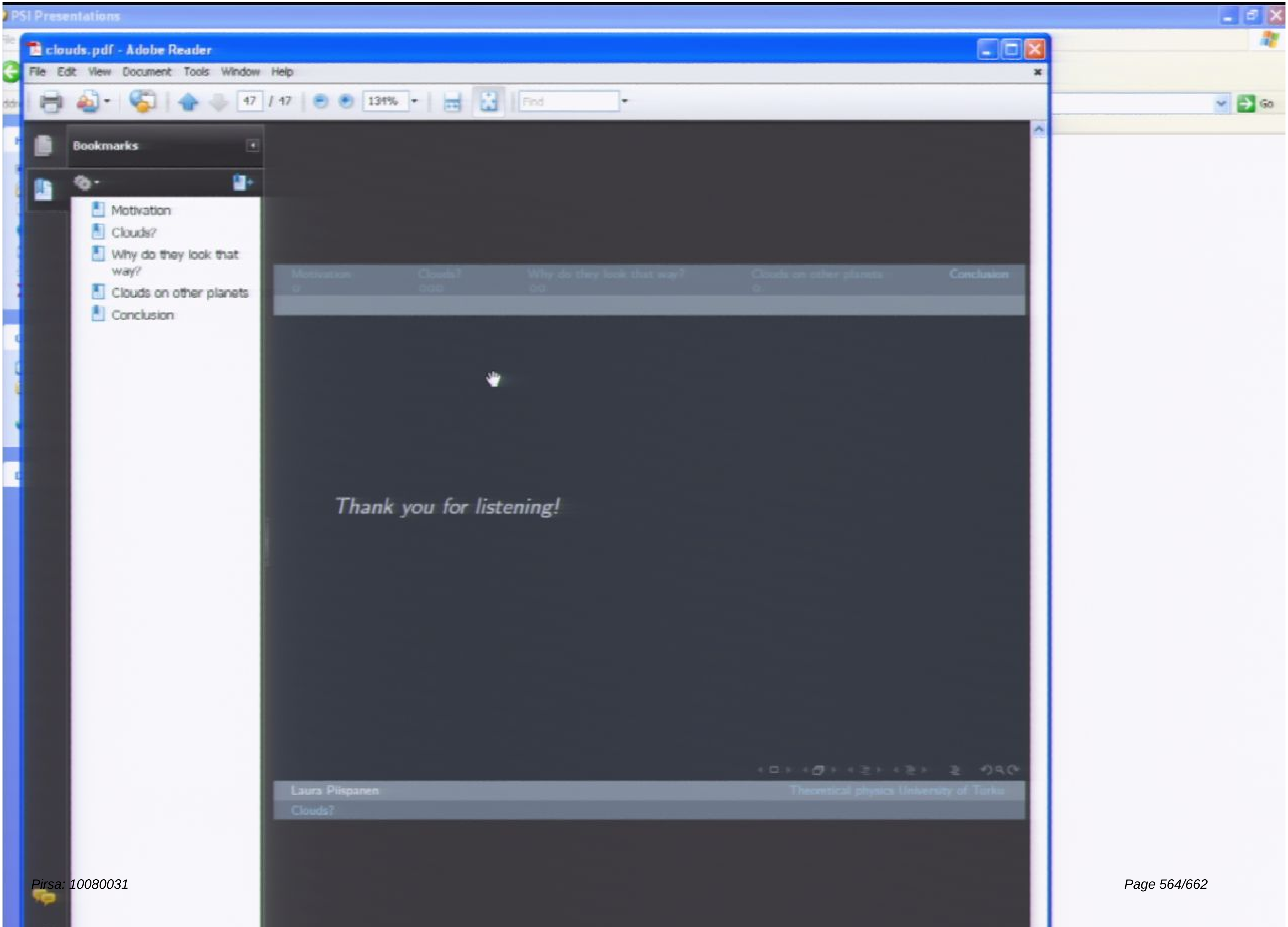
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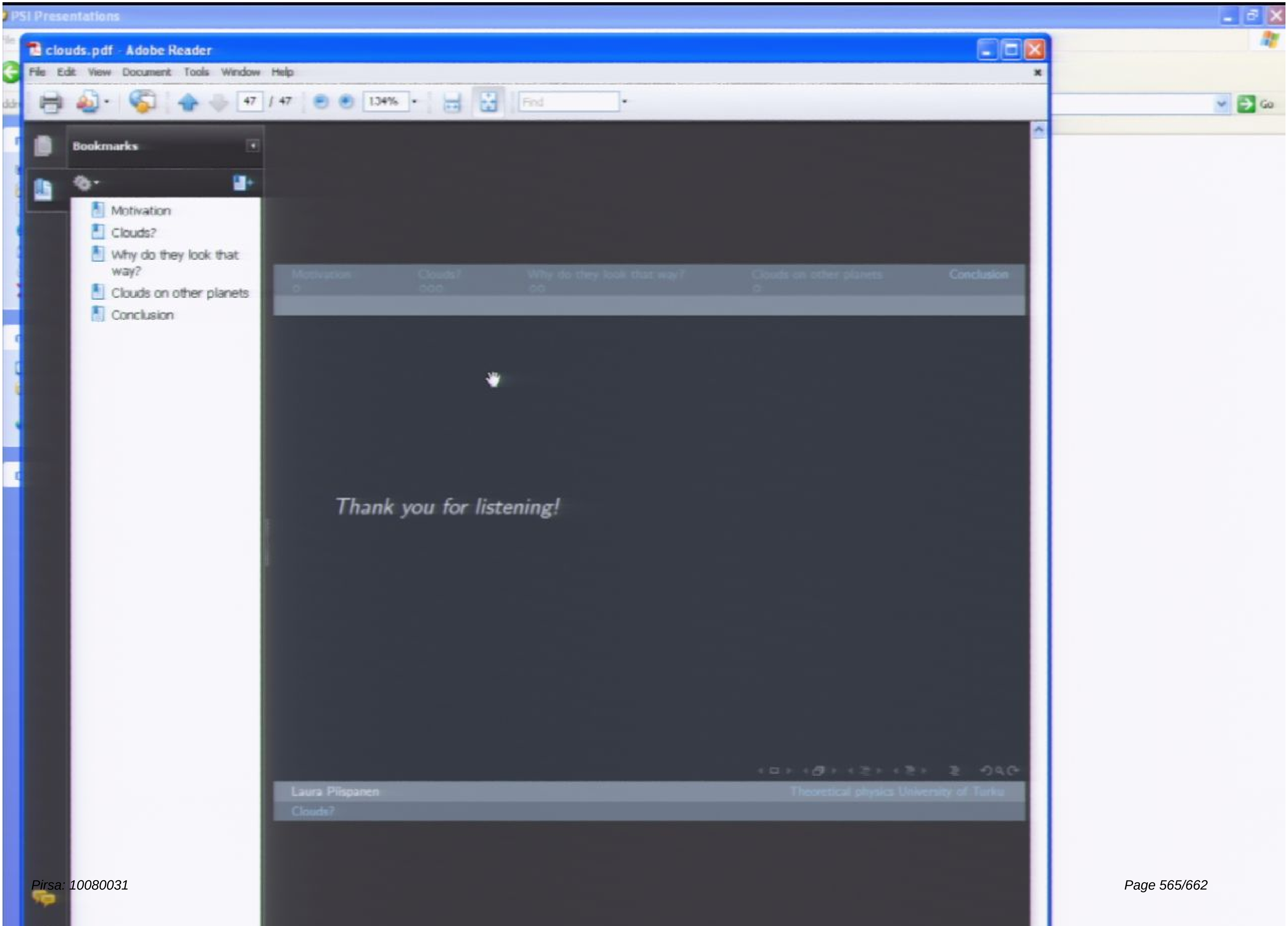
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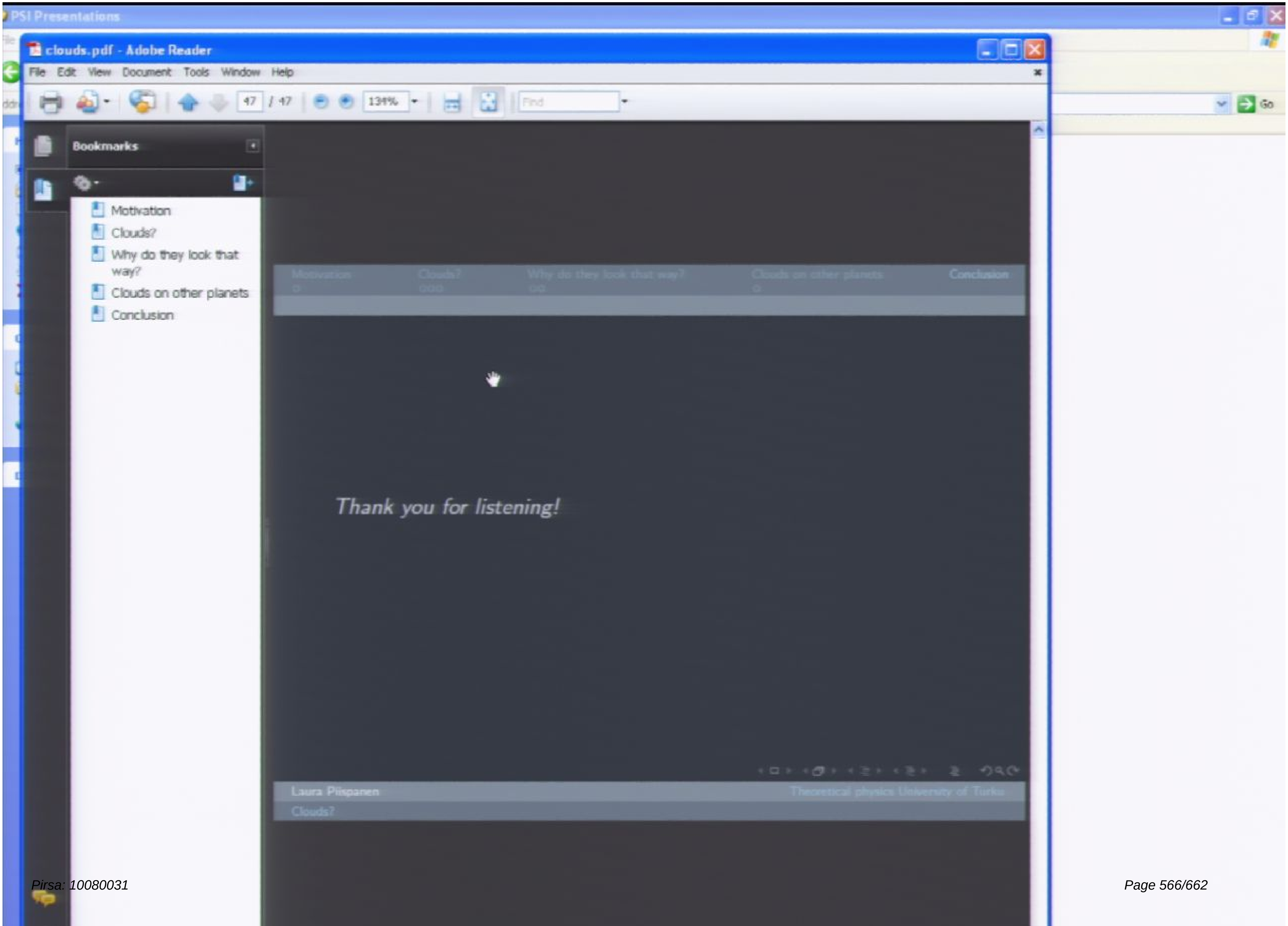
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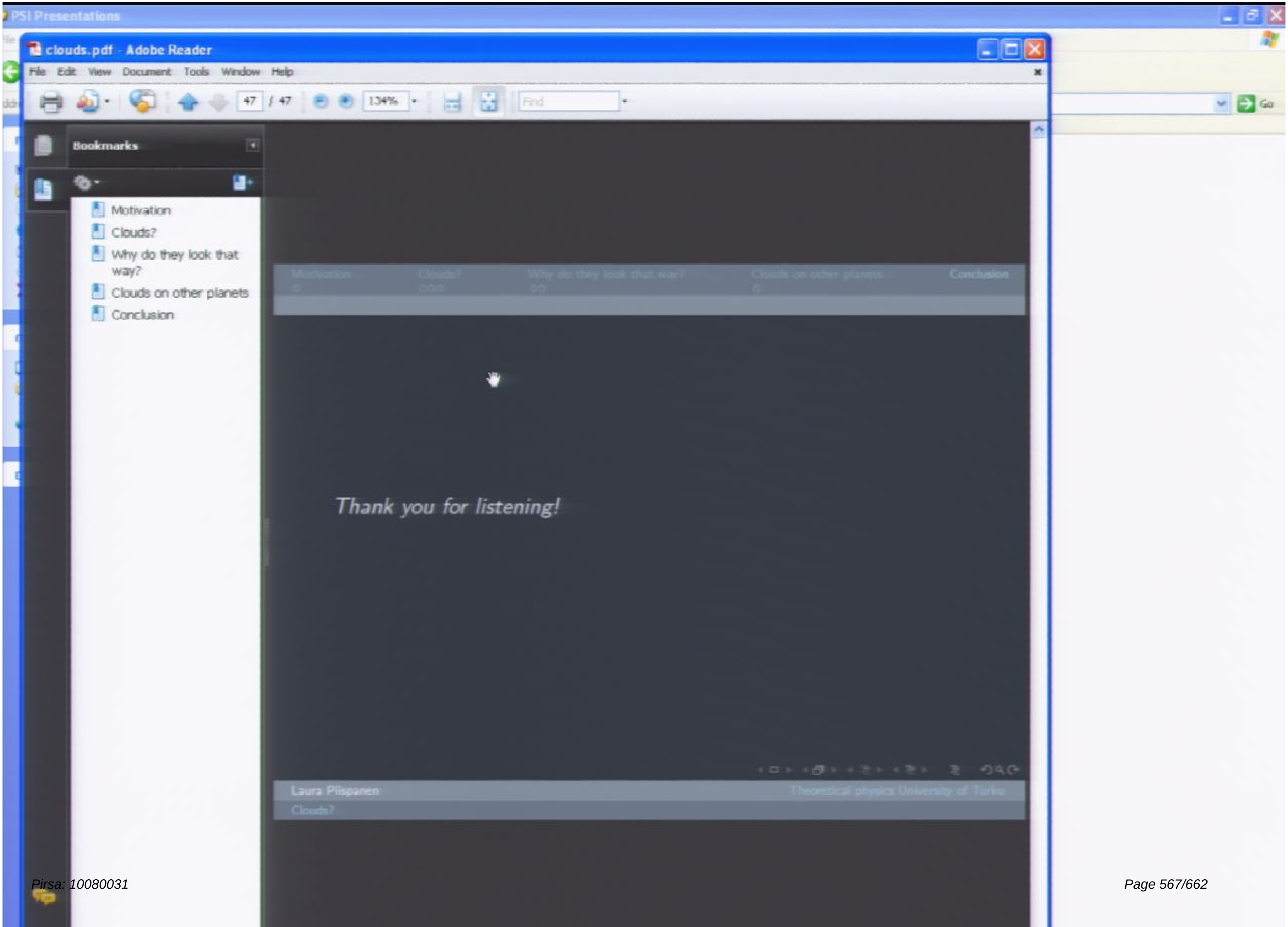
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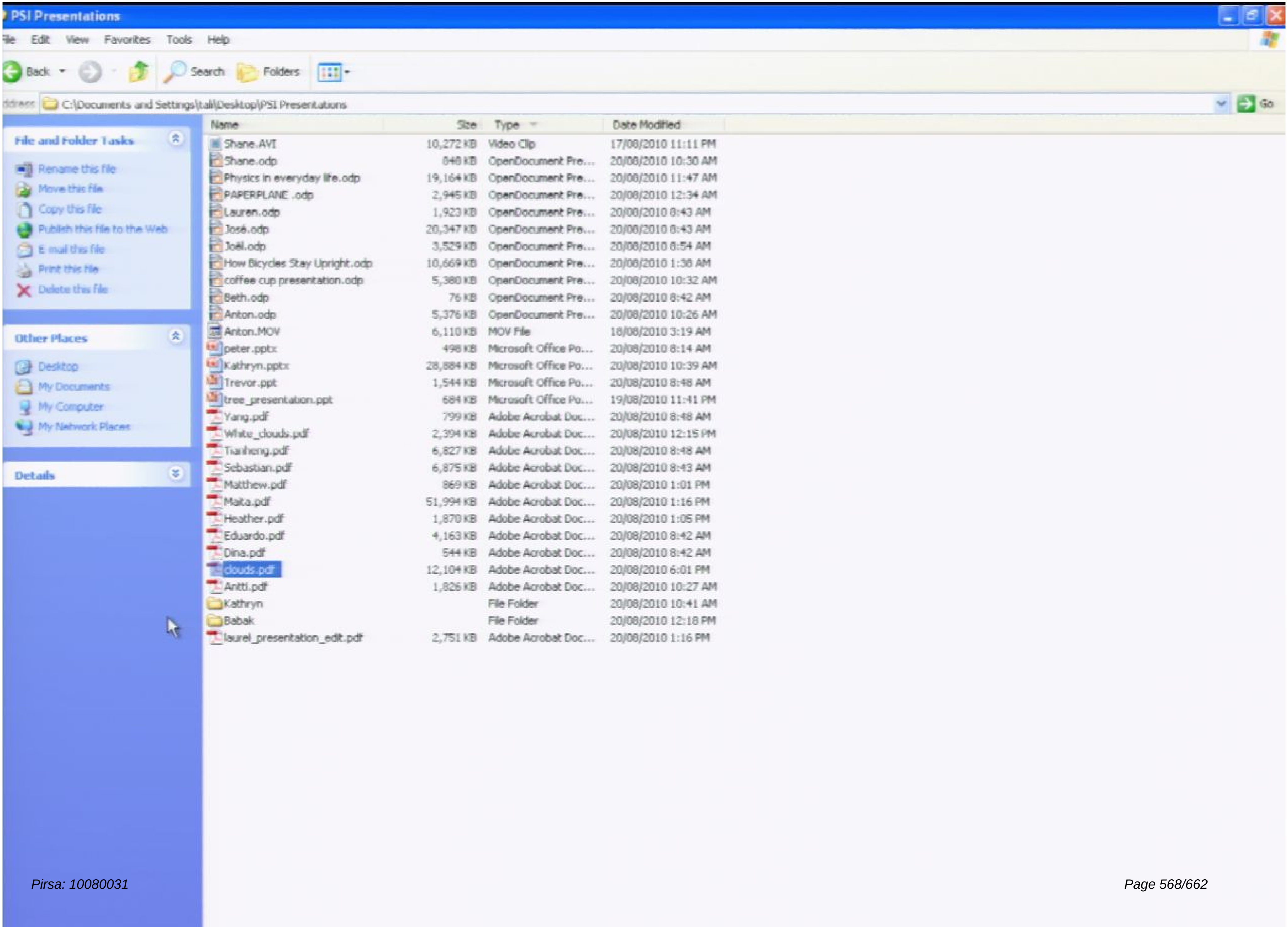
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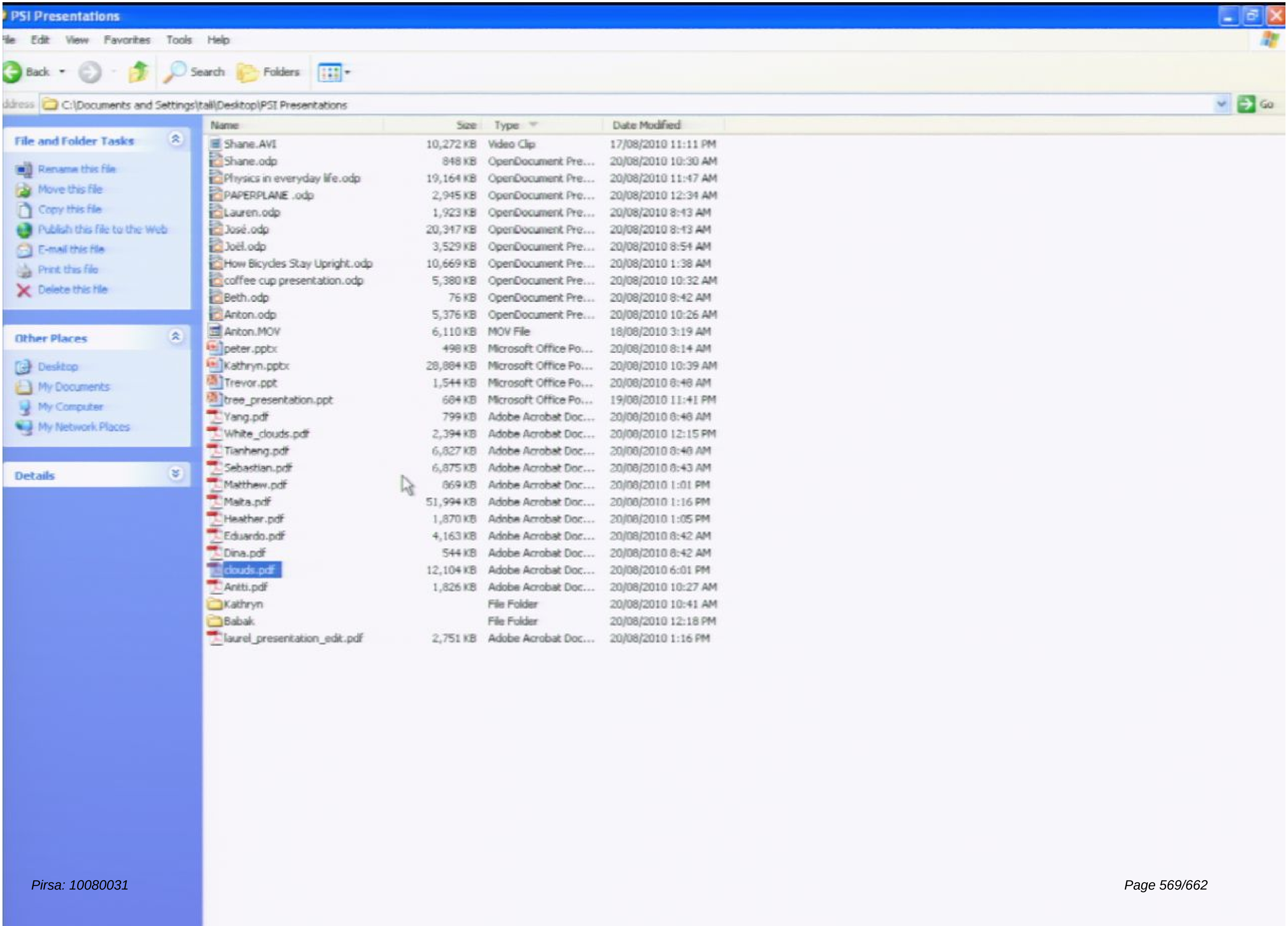
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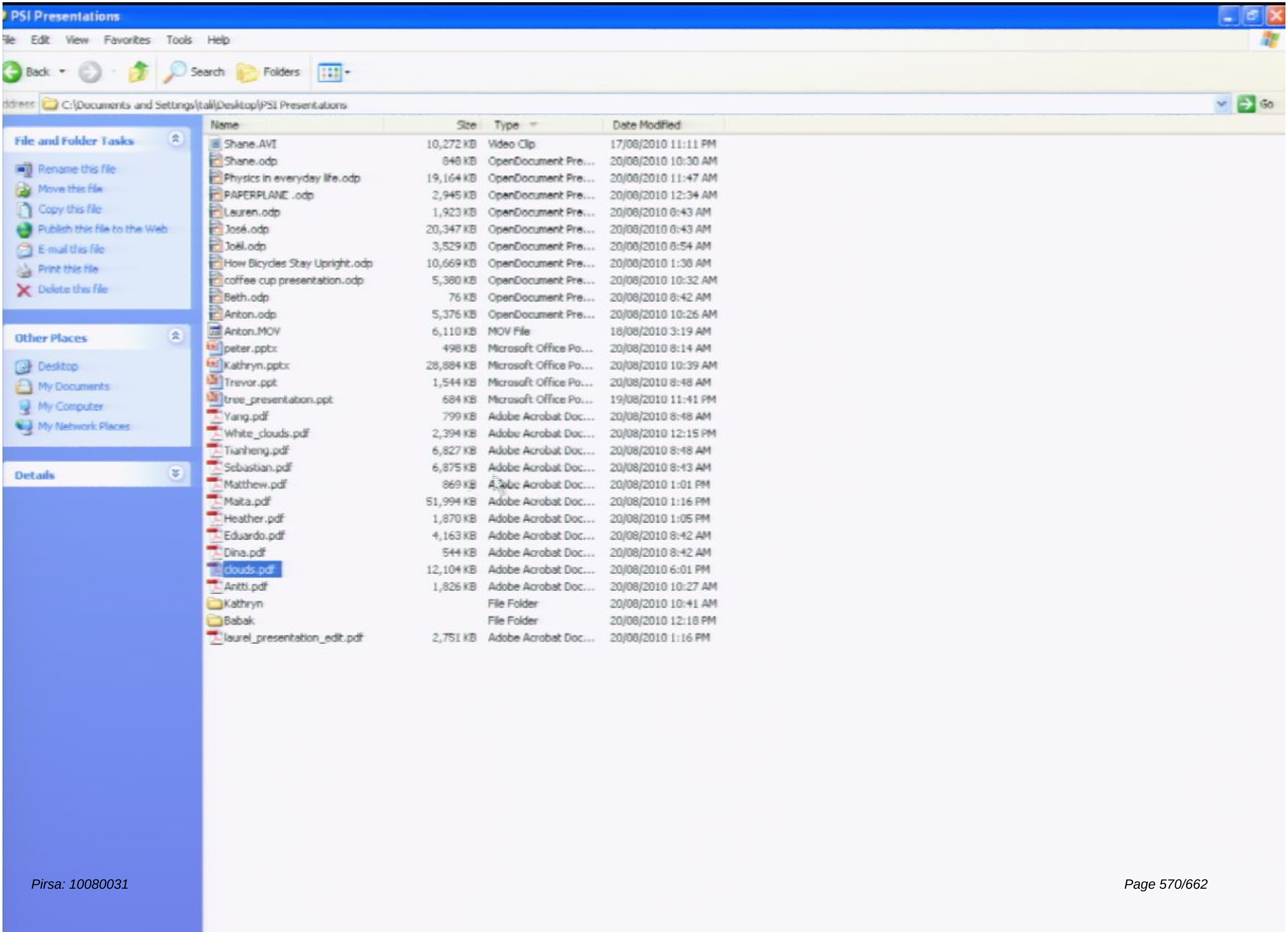
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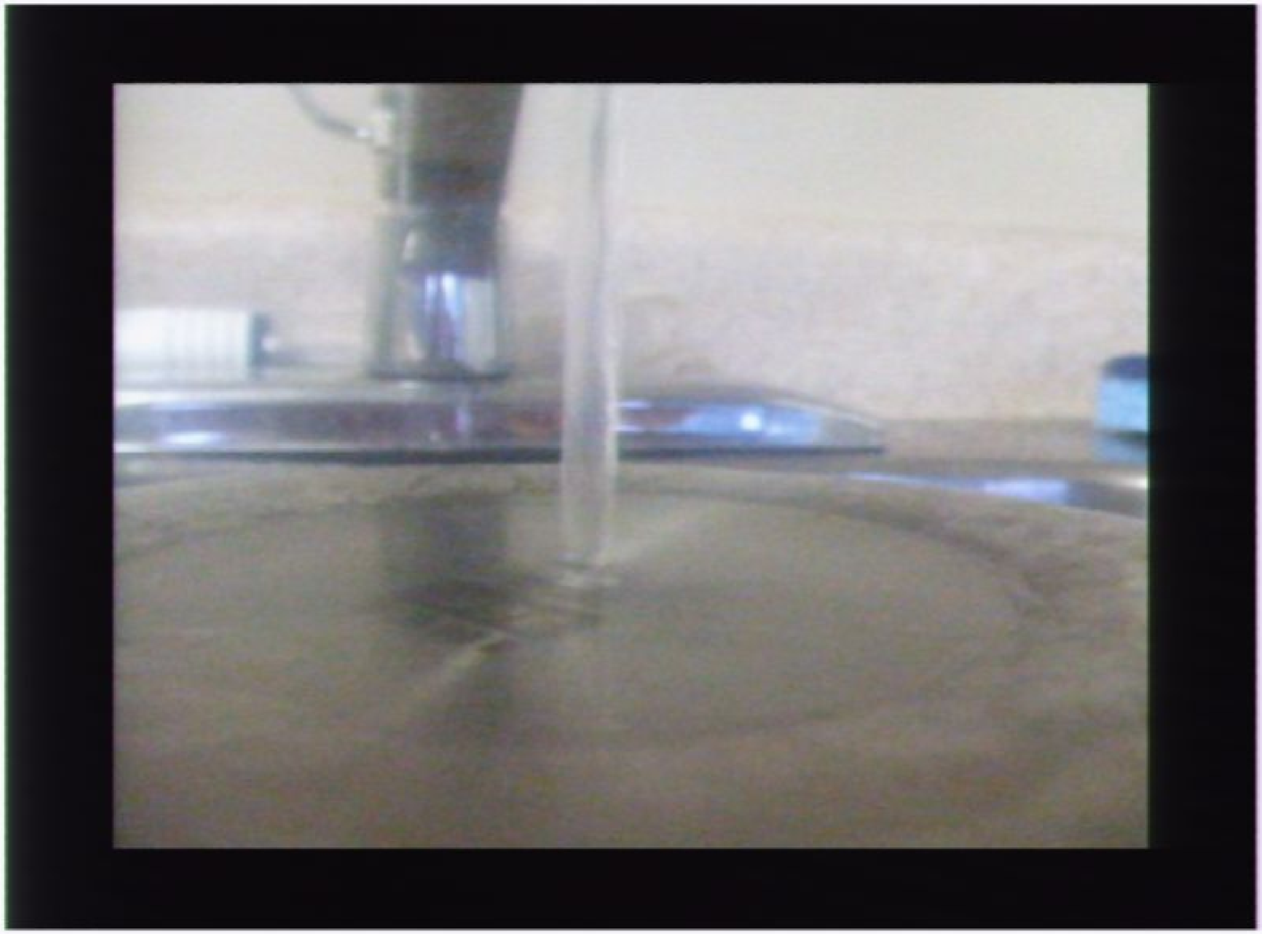
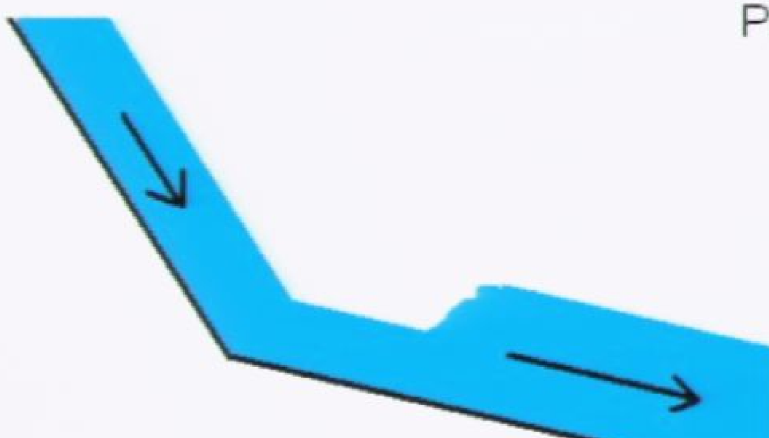


Photograph from Ohio University's Fluid Mechanics Laboratory. Athens, Ohio USA

Photograph from Ohio University's Fluid Mechanics Laboratory. Athens, Ohio USA

where do we see Hydraulic Jumps in nature?

Photograph from Wiki



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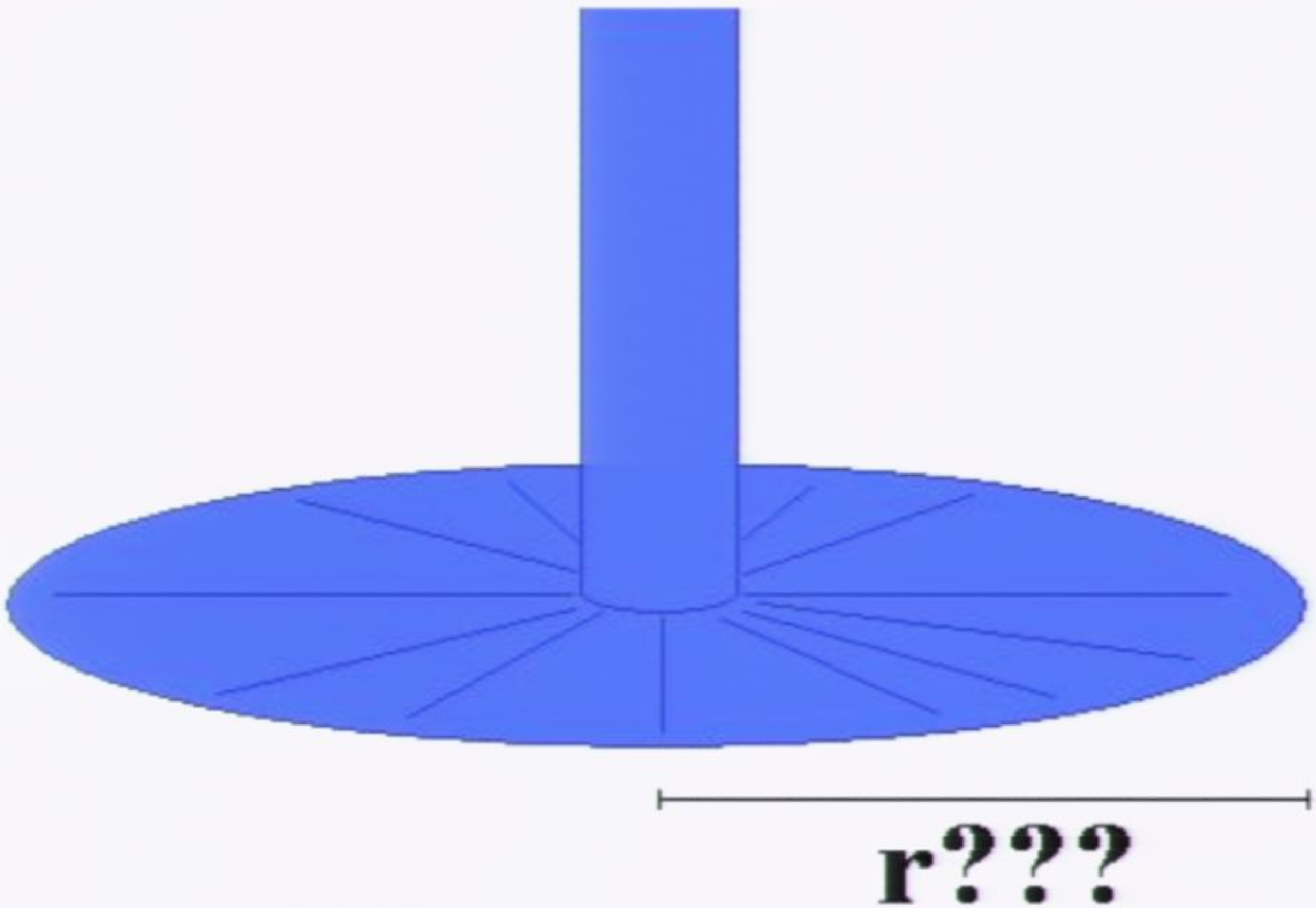

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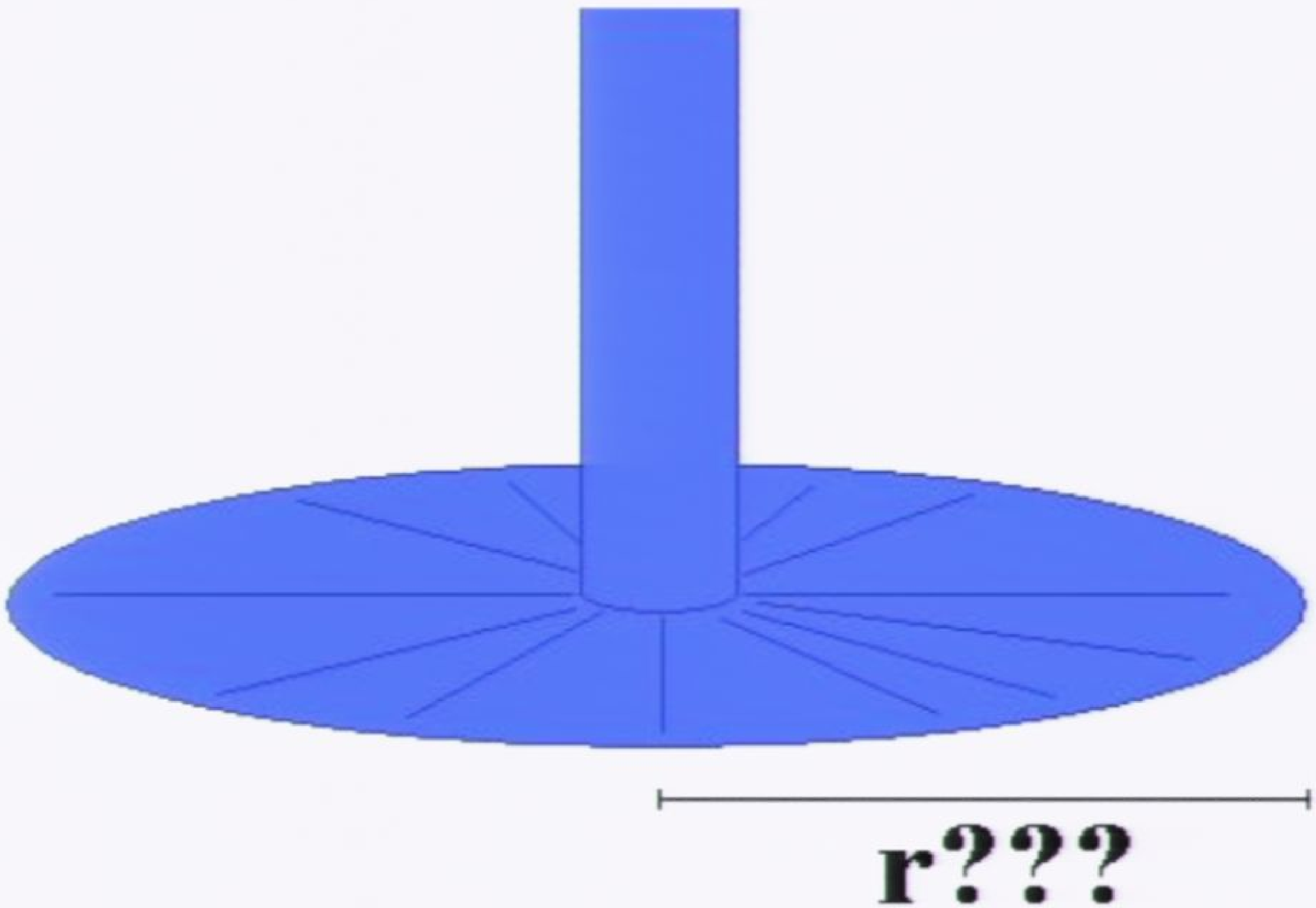
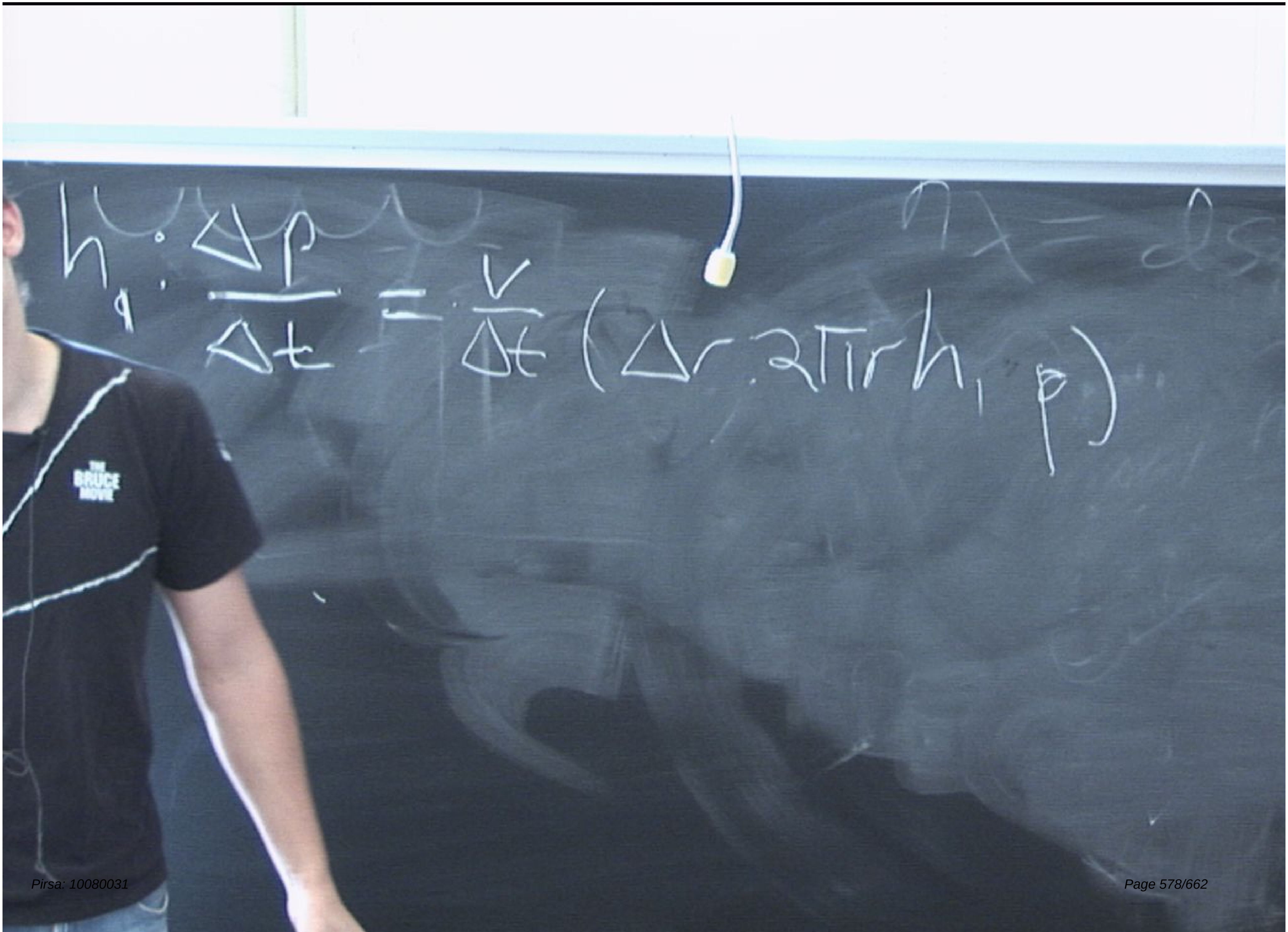
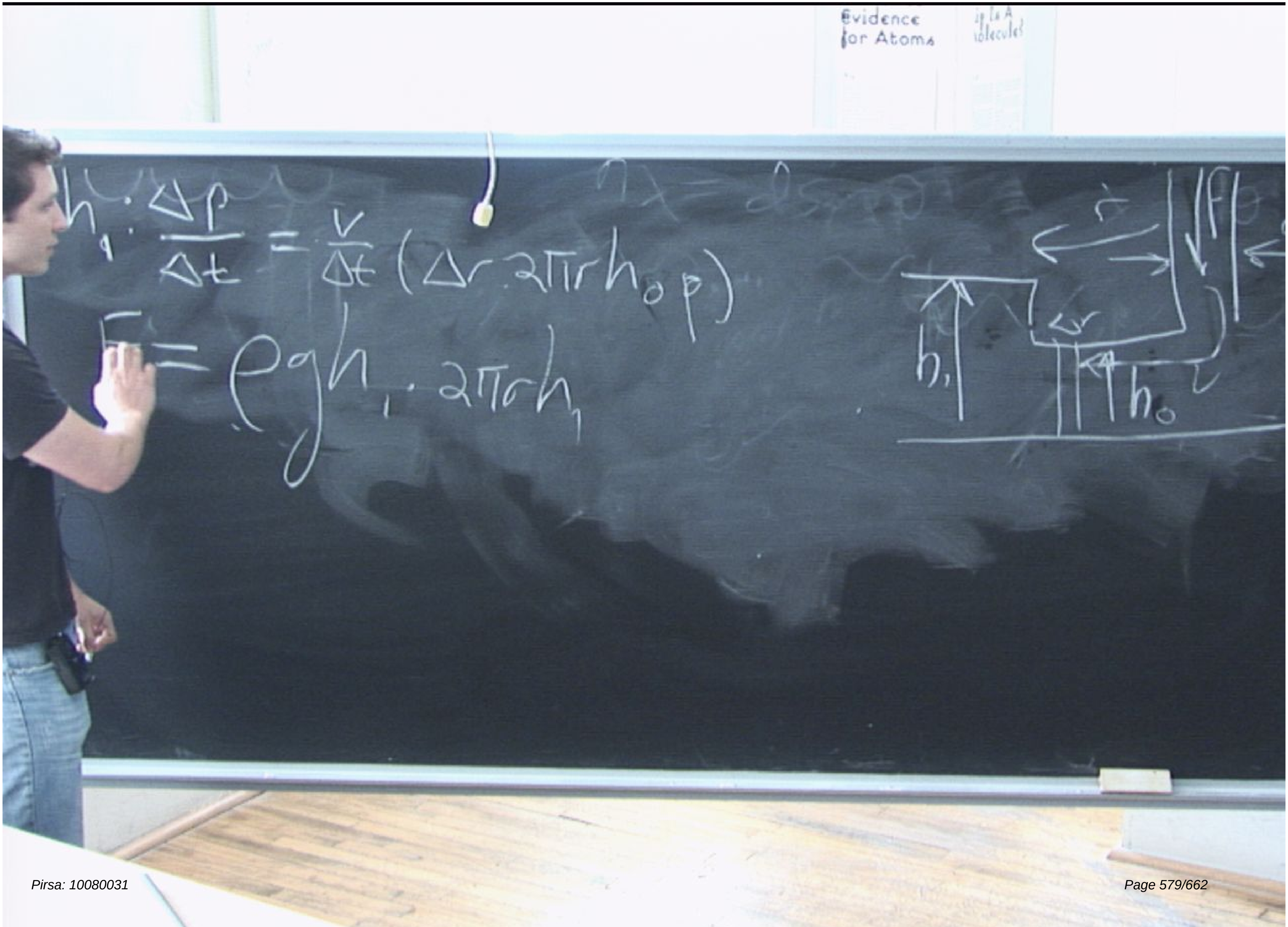


$$h_q ; \frac{\Delta p}{\Delta t}$$


h1 : Δp/Δt = V/Δt (Δr · 2πr h1 · p)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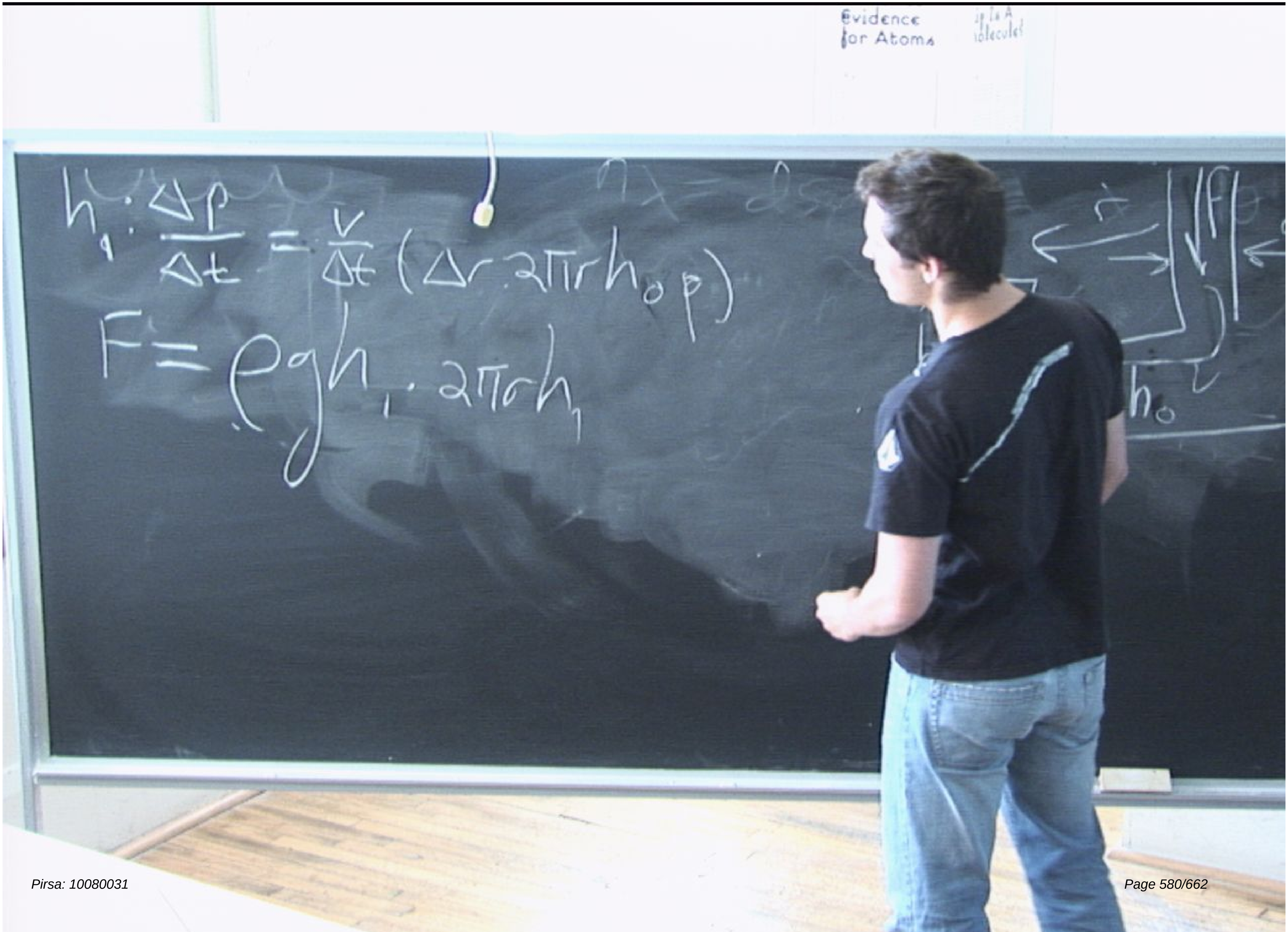
for Atoms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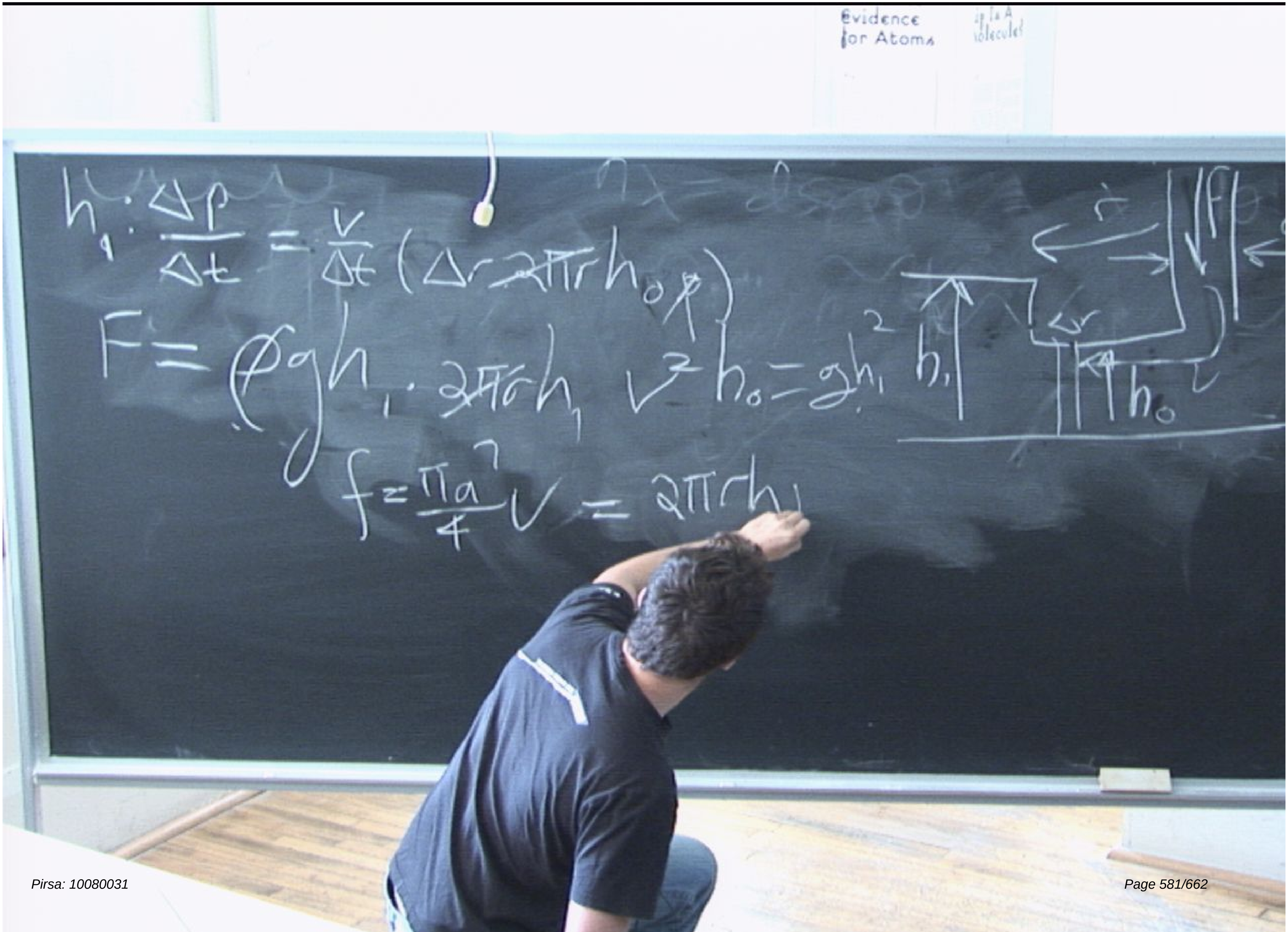
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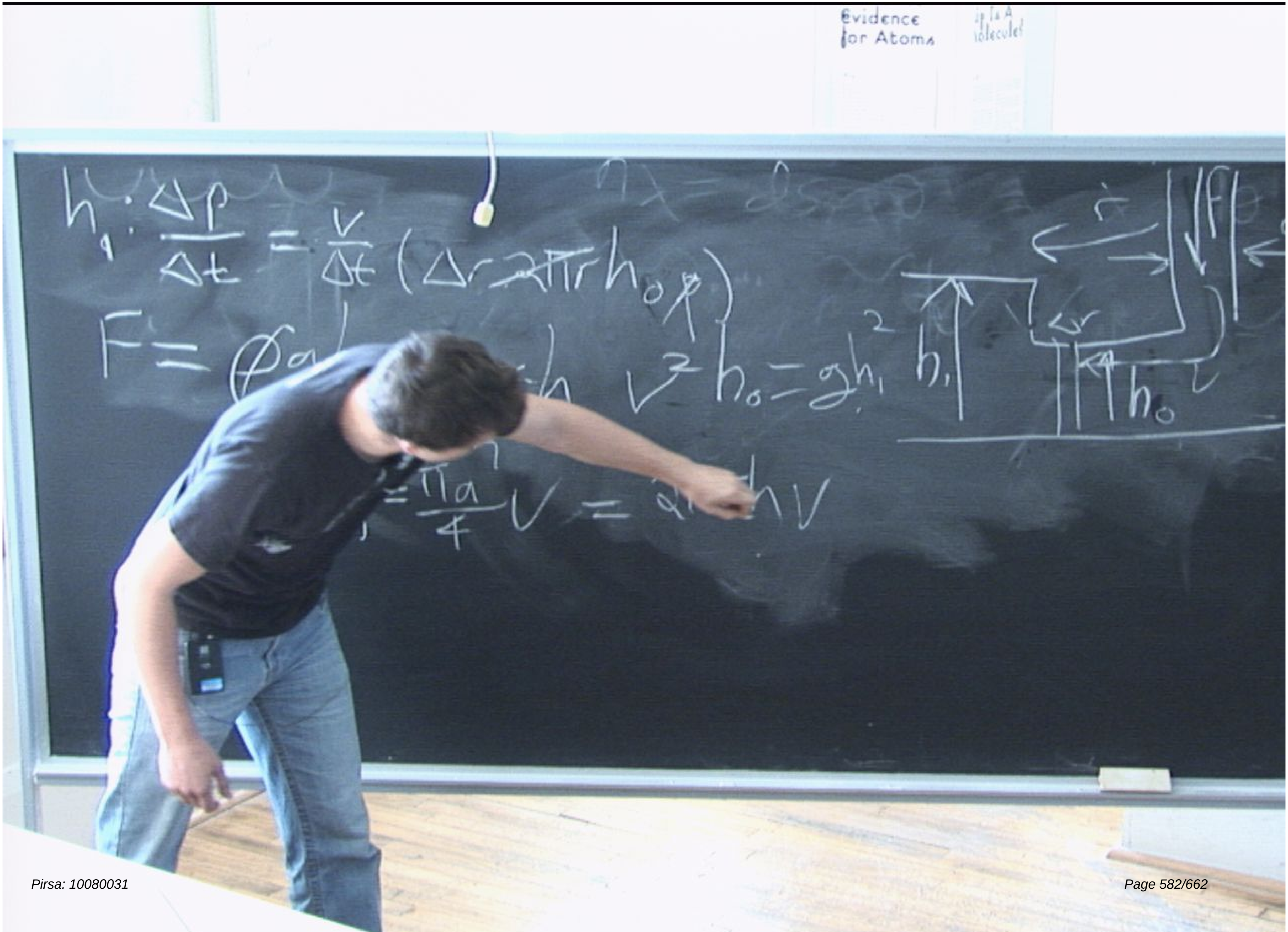
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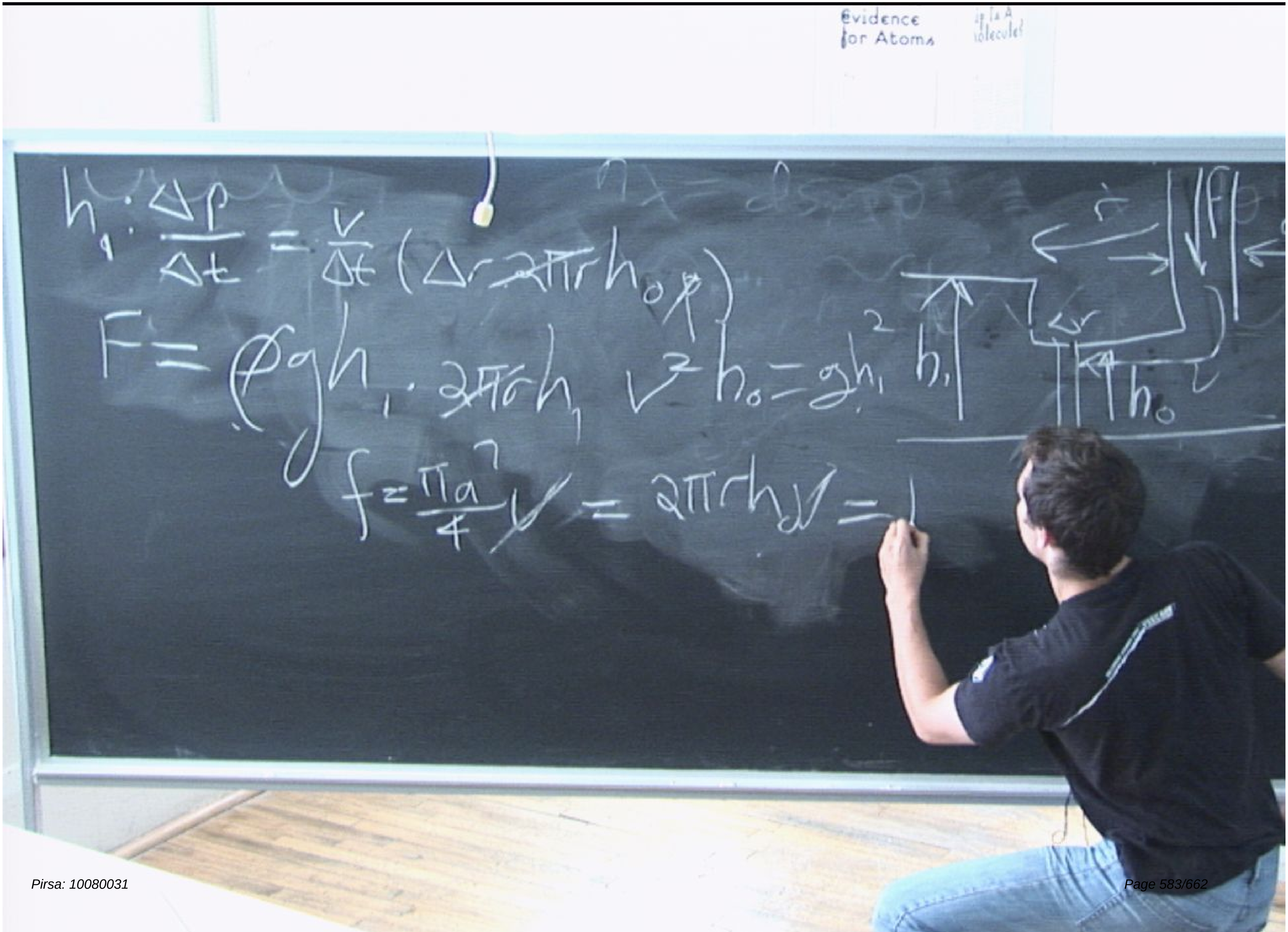
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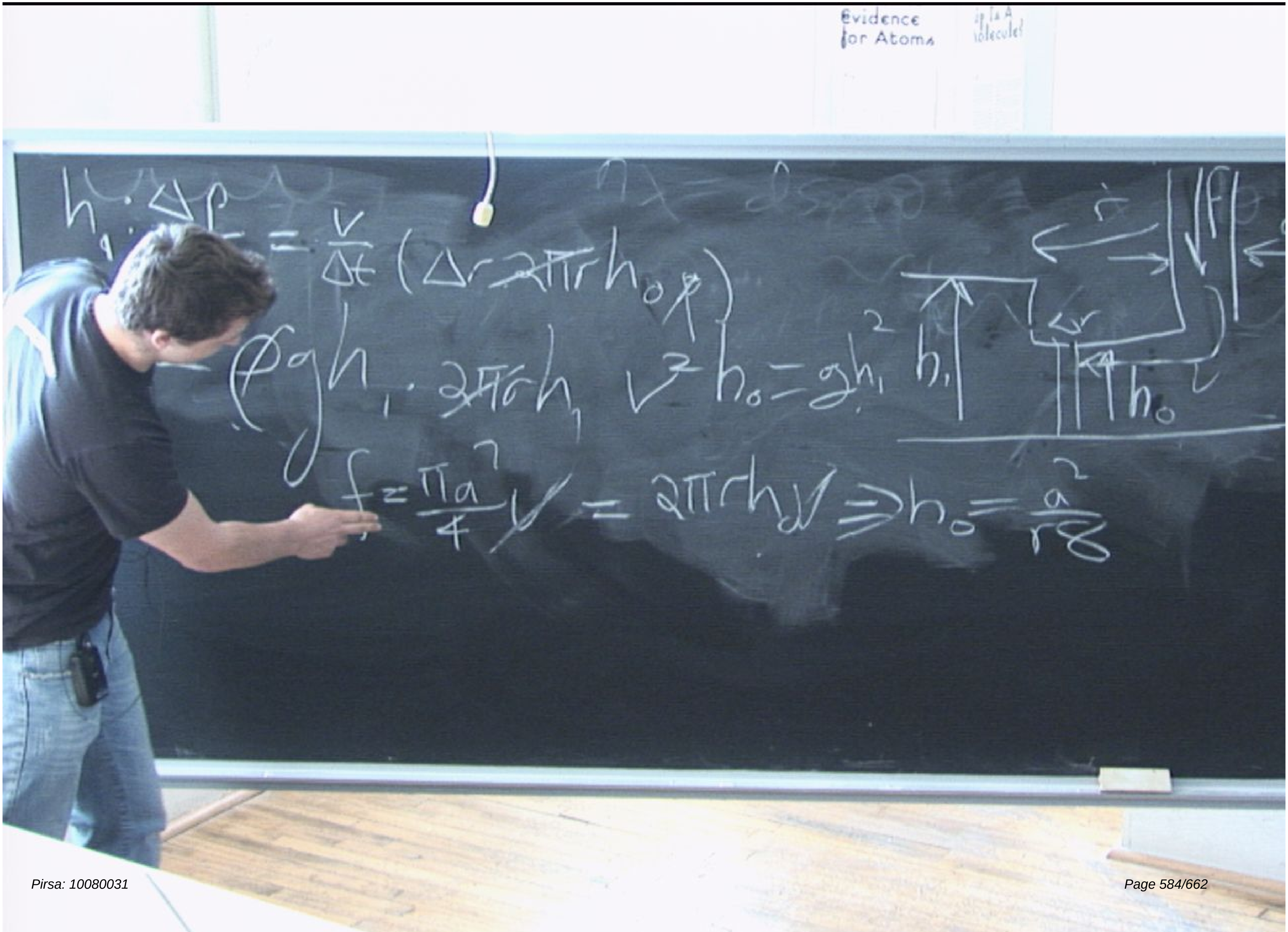
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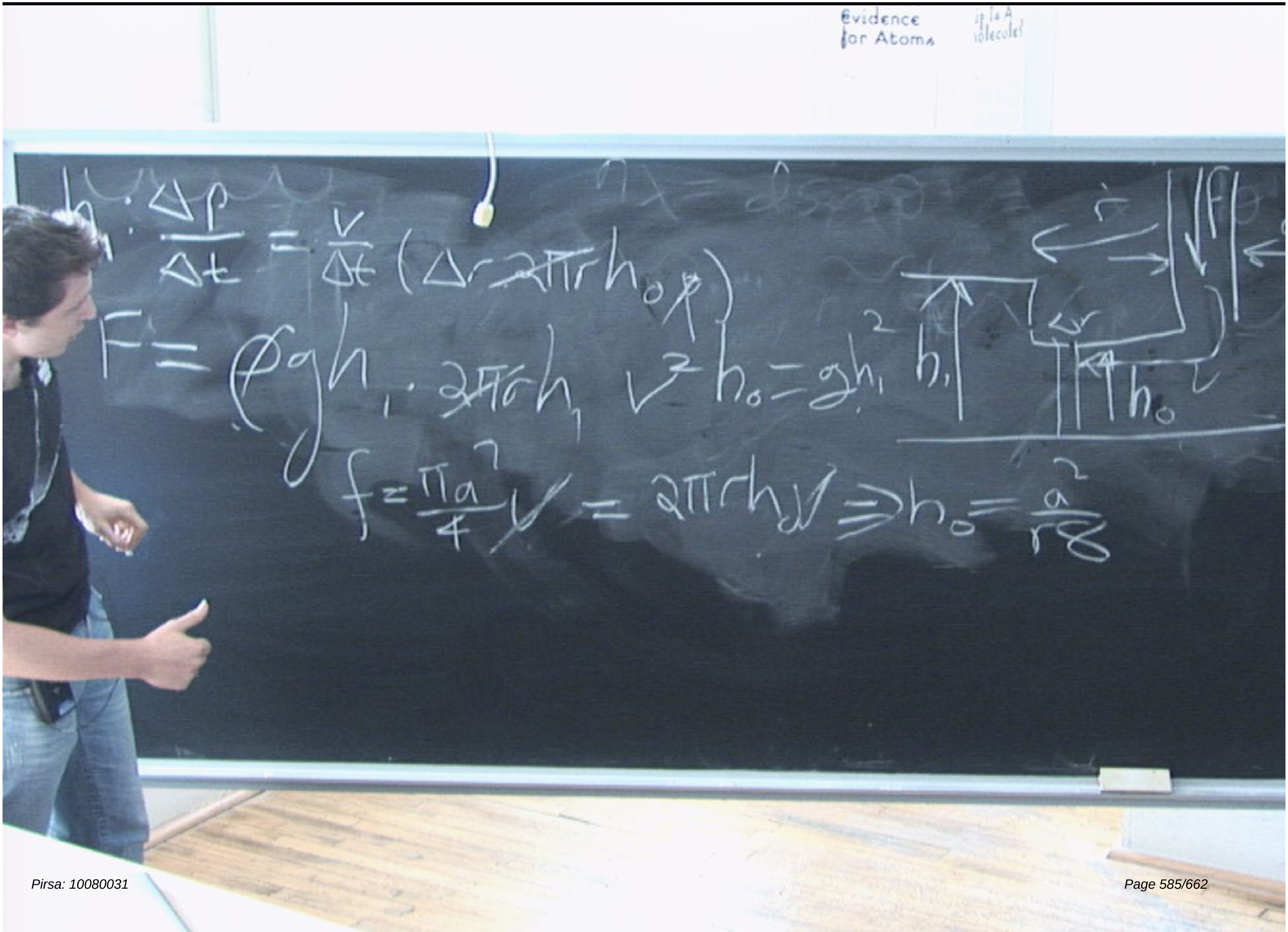
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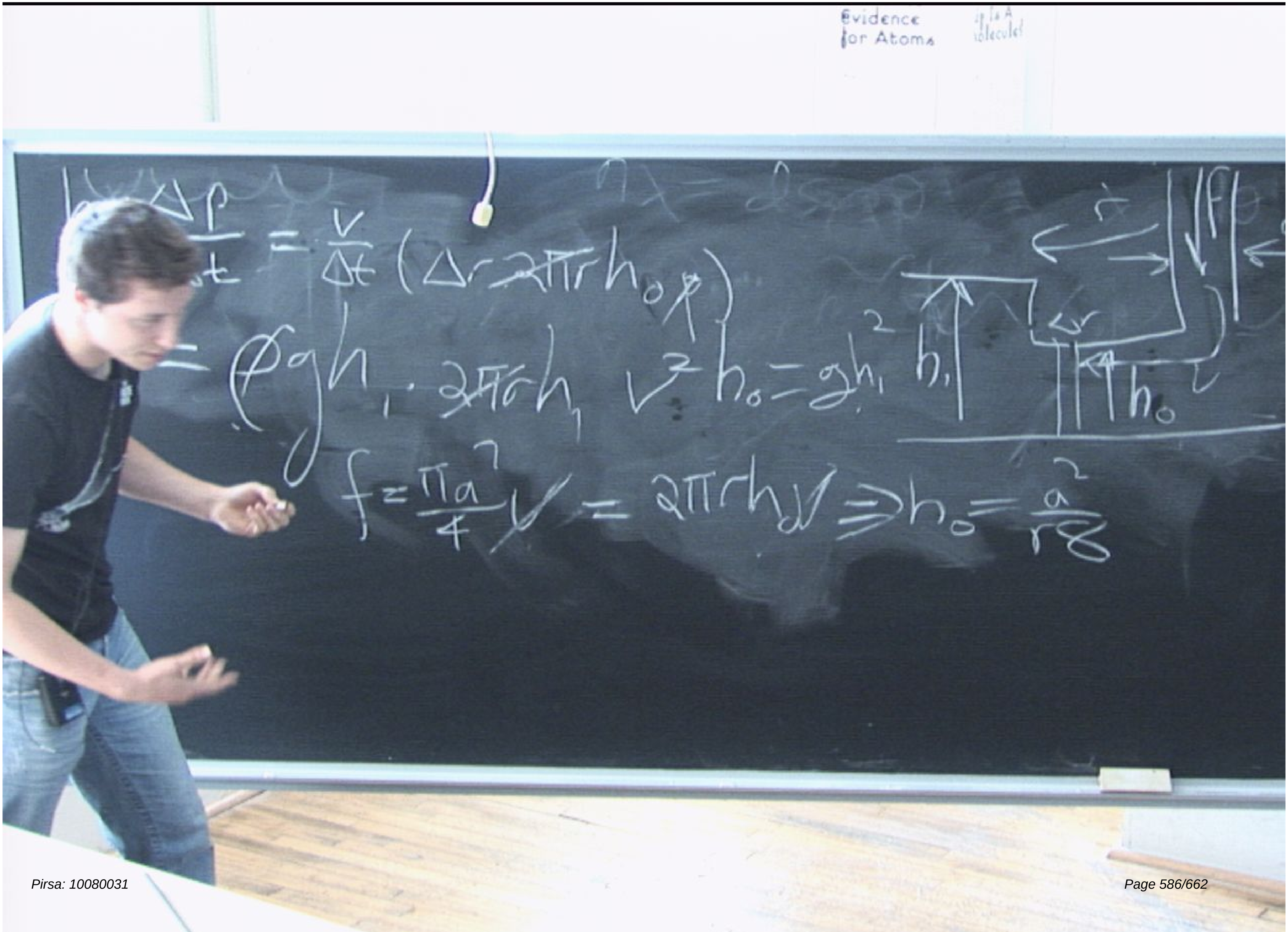
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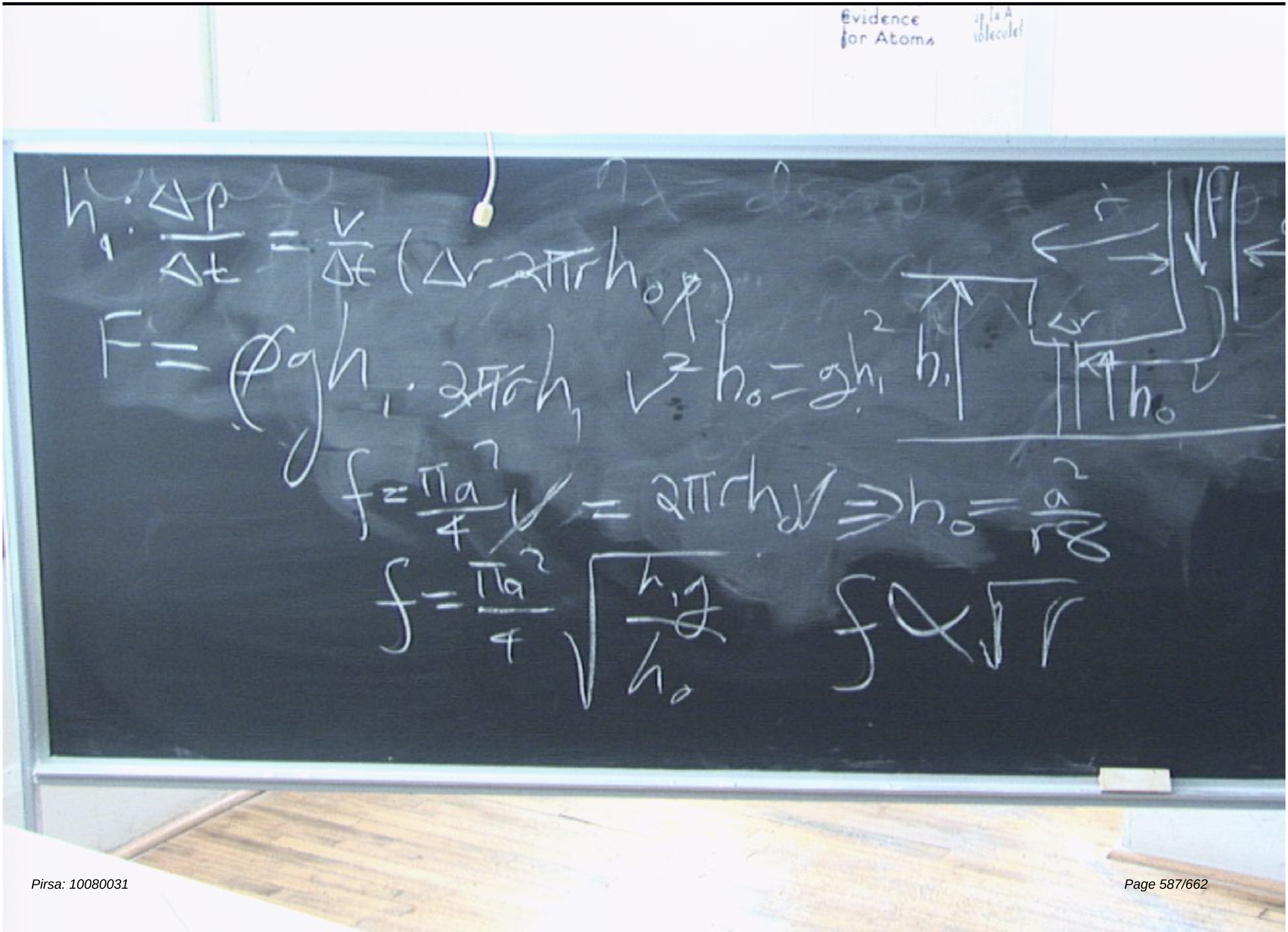
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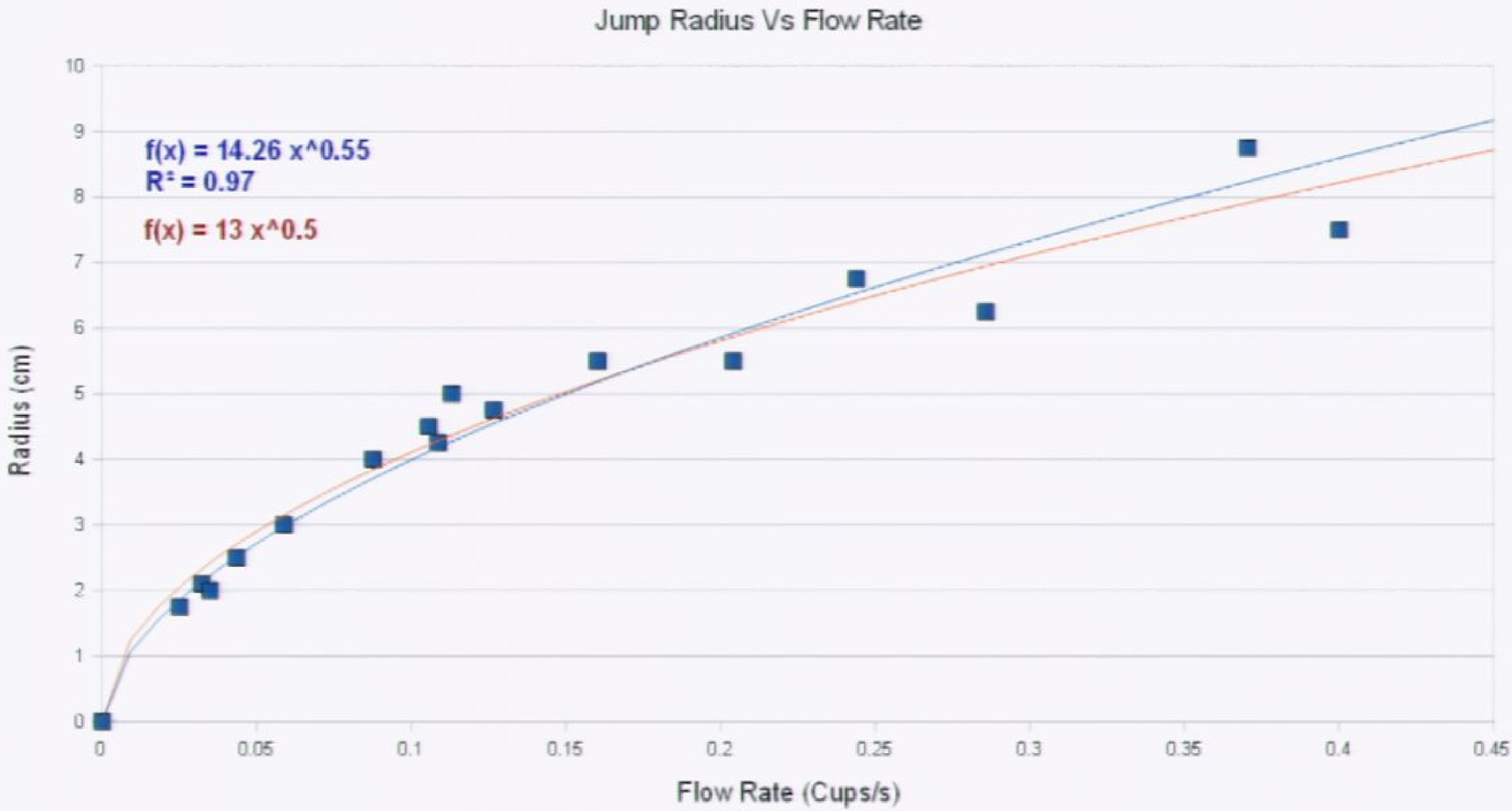
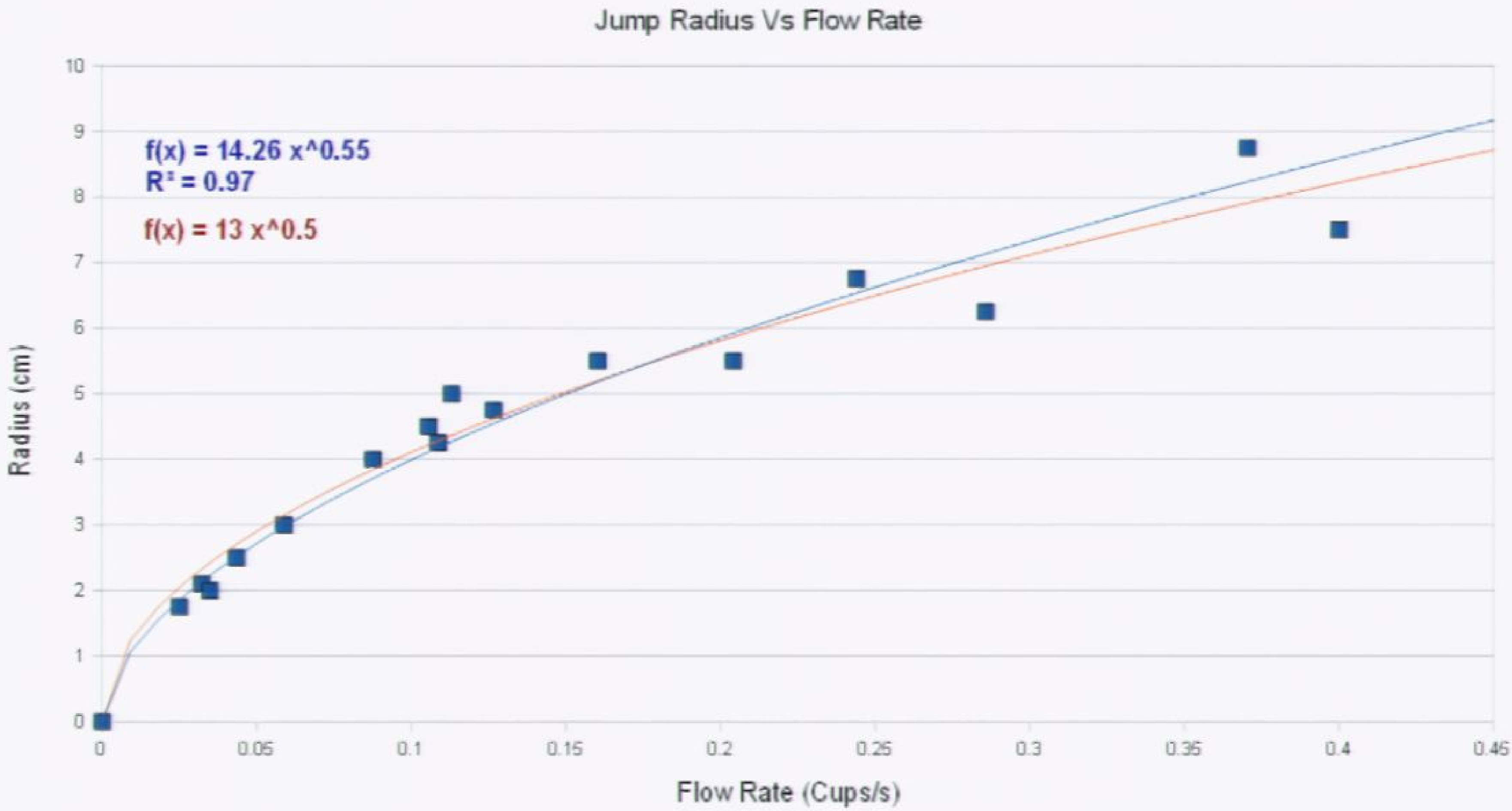


Jump Radius Vs Flow Rate
f(x) = 14.26 x^0.55
R² = 0.97
f(x) = 13 x^0.5
Radius (cm)
Flow Rate (Cups/s)
10
9
8
7
6
5
4
3
2
1
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45



Jump Radius Vs Flow Rate
f(x) = 14.26 x^0.55
R² = 0.97
f(x) = 13 x^0.5
10
9
8
7
6
5
4
3
2
1
0
Radius (cm)
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
Flow Rate (Cups/s)

Using Navier-Stockes and the no slip condition at stagnation

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Integration gives

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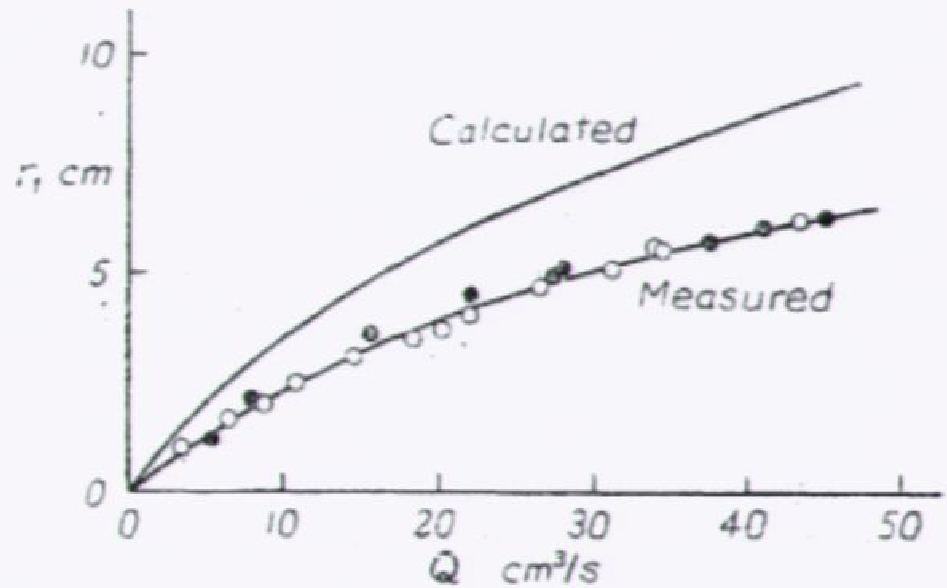

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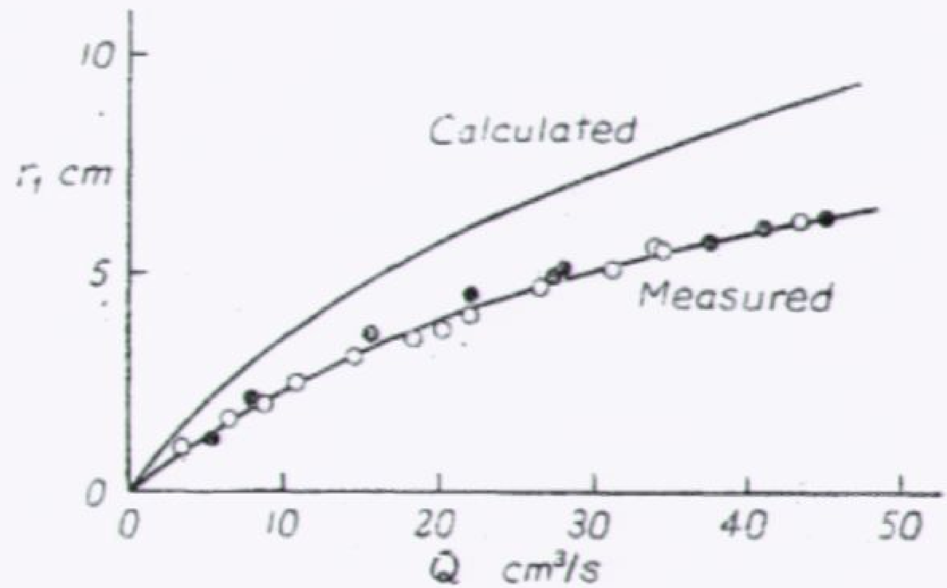

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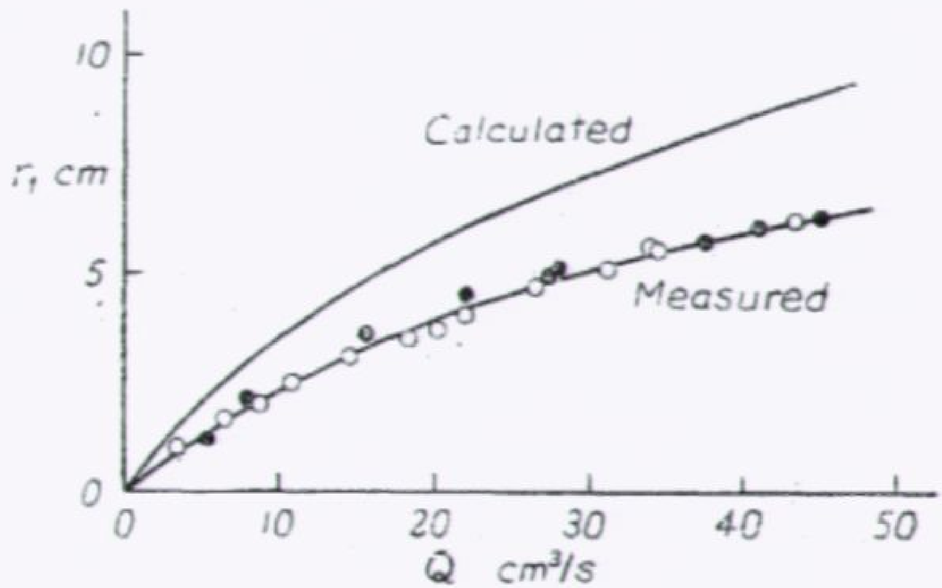

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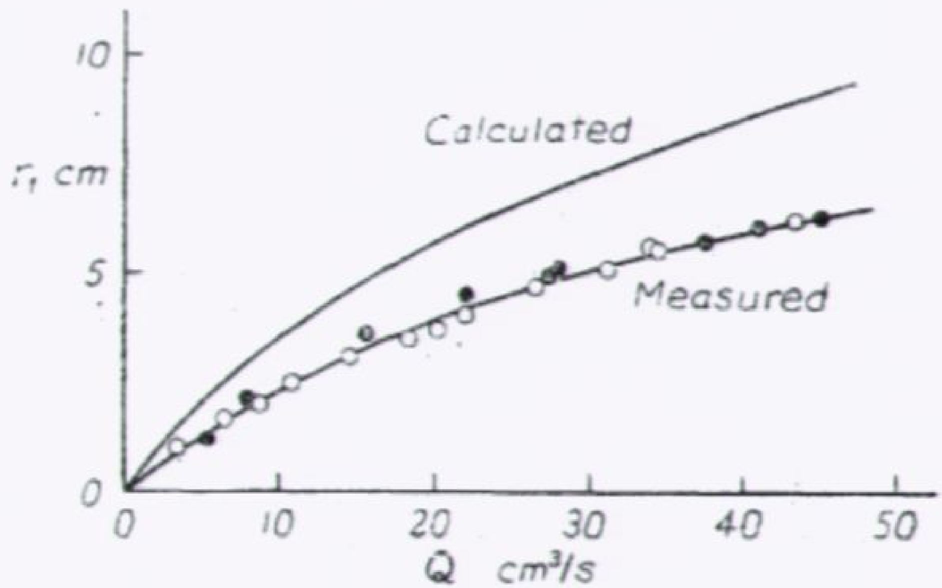

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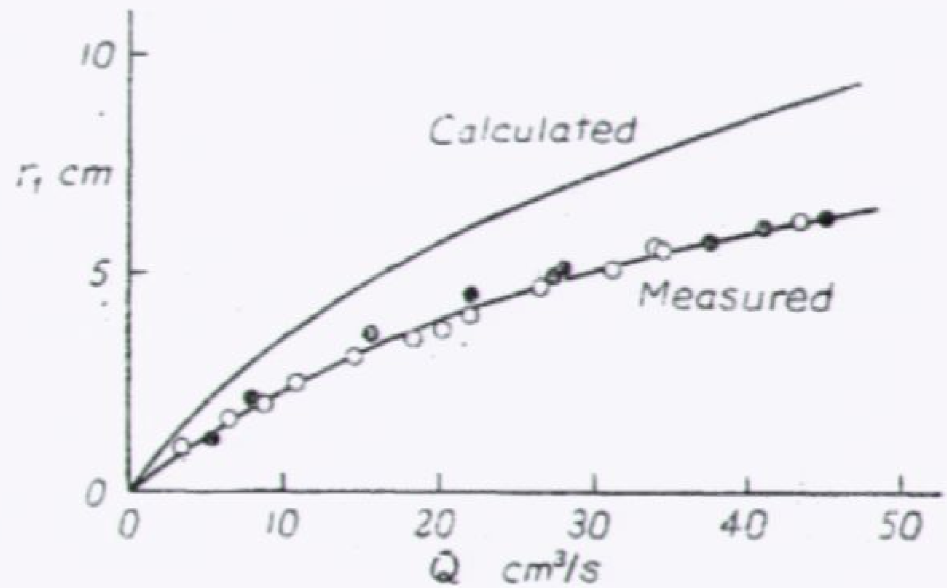

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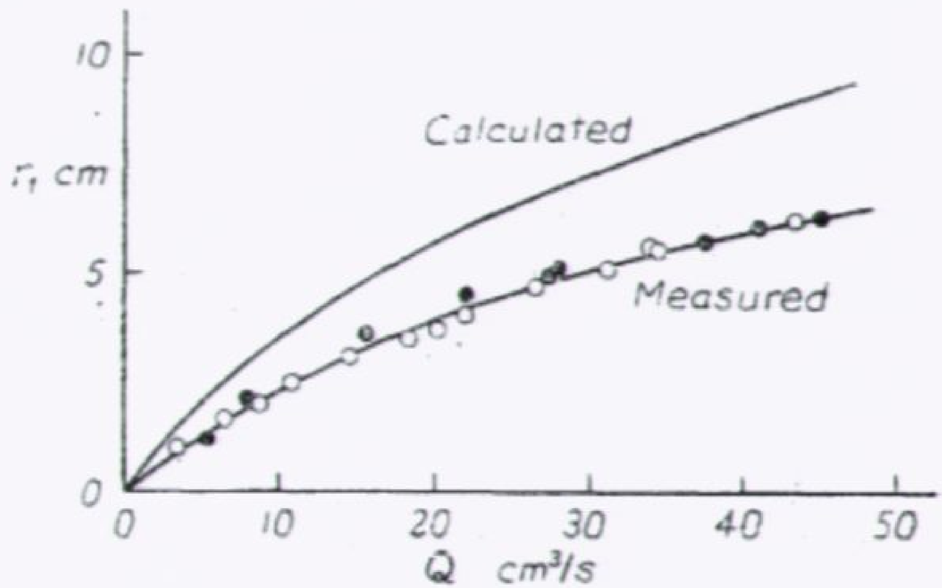

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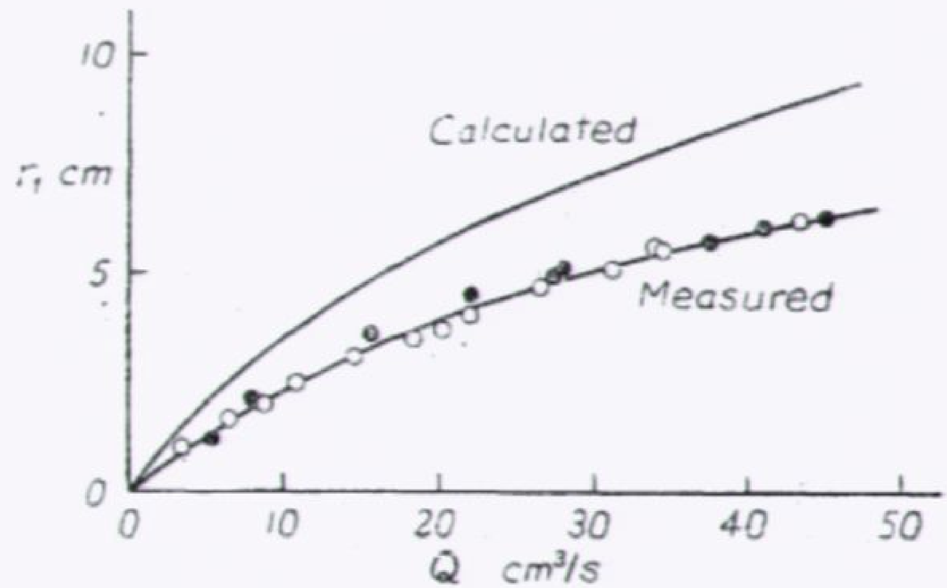

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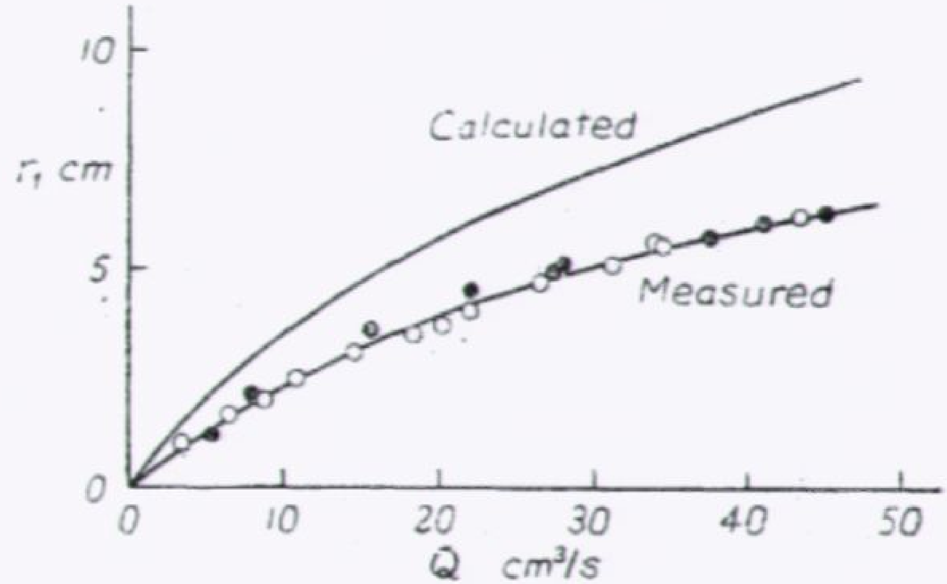

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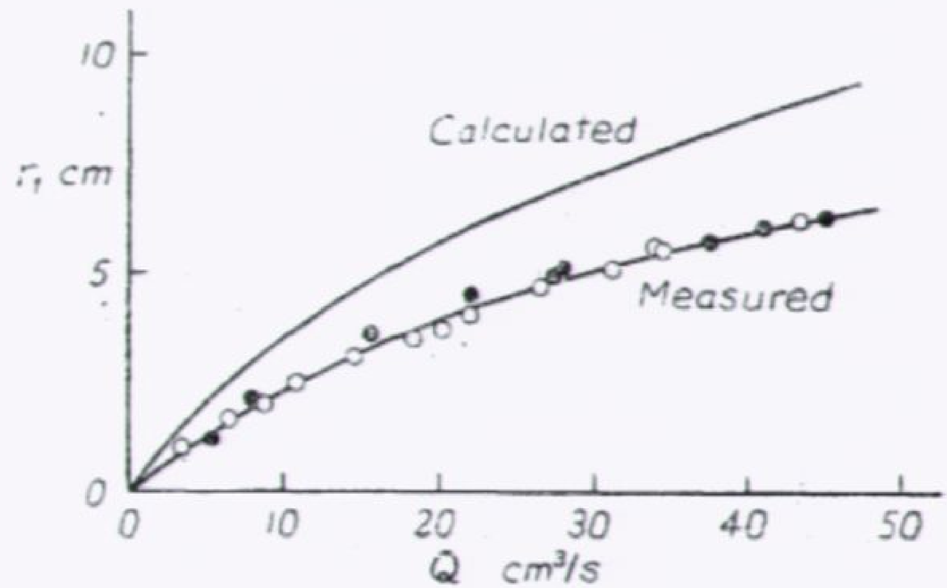

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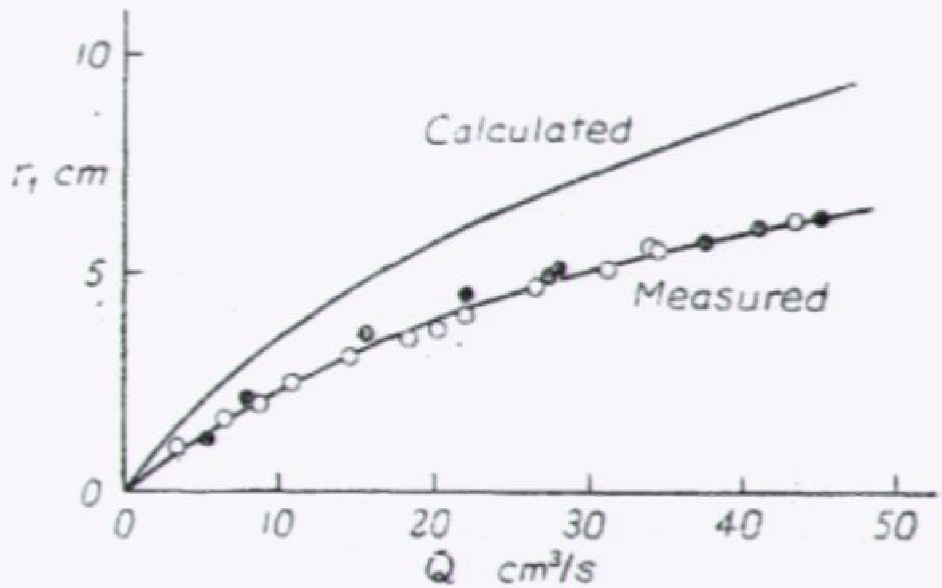

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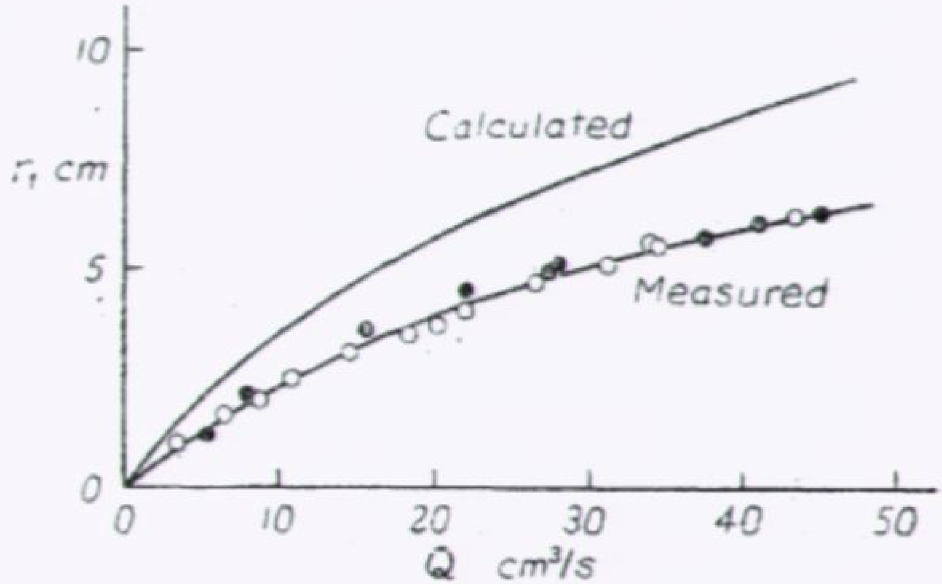

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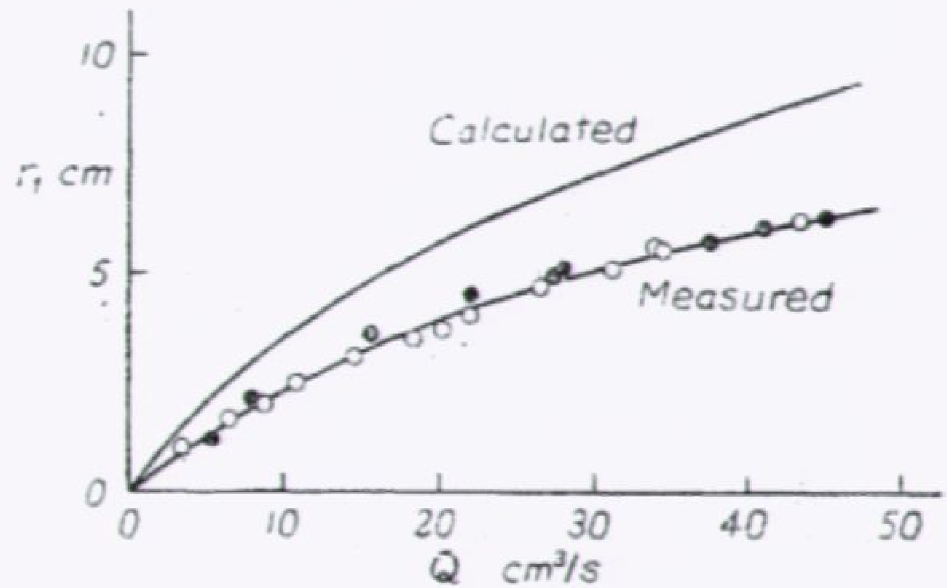

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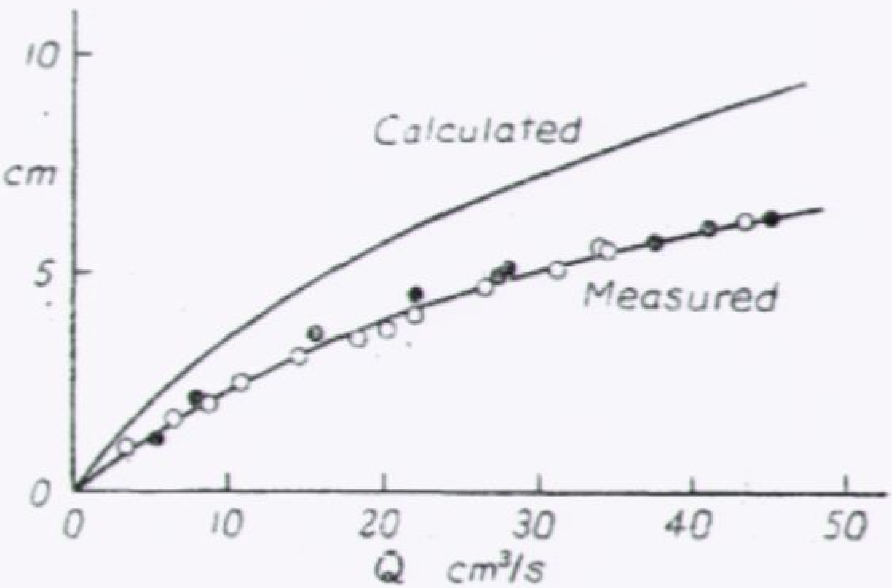

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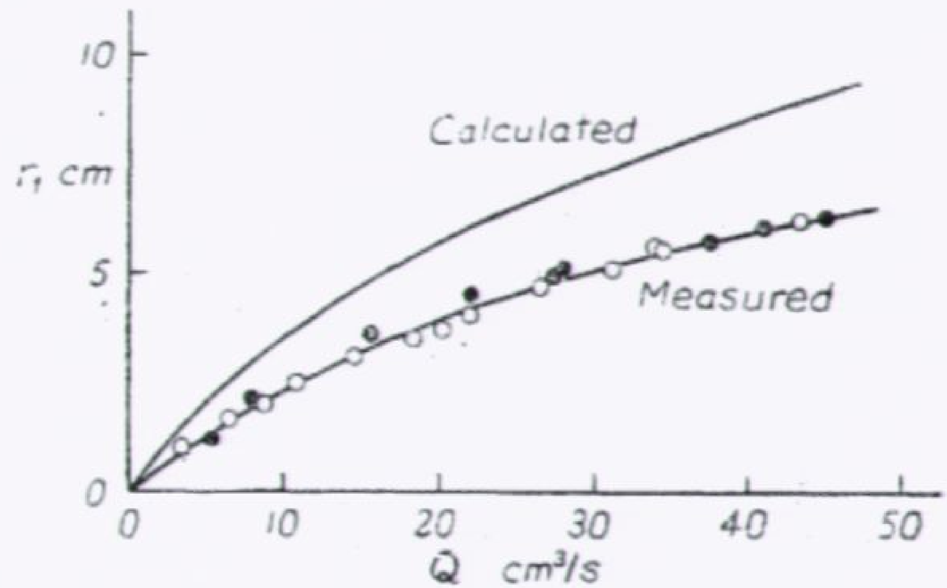

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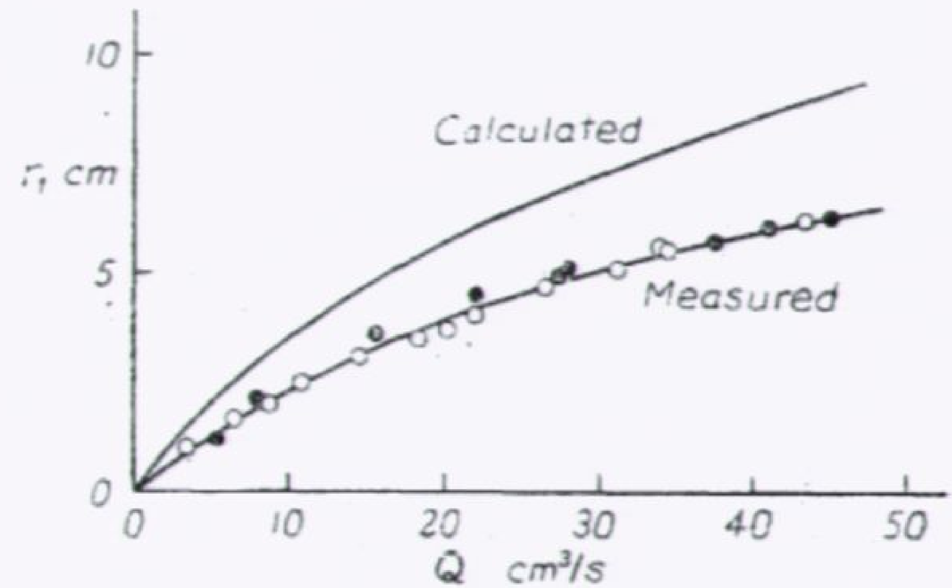

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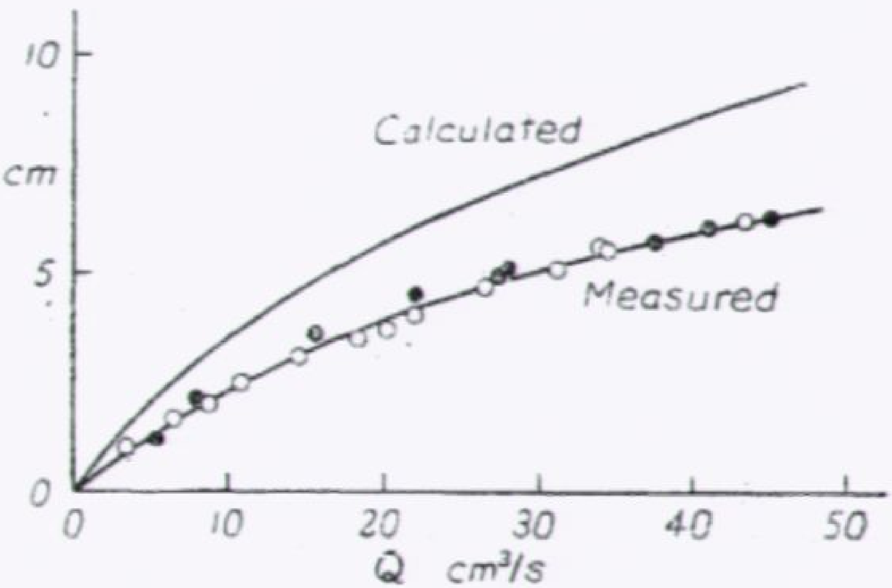

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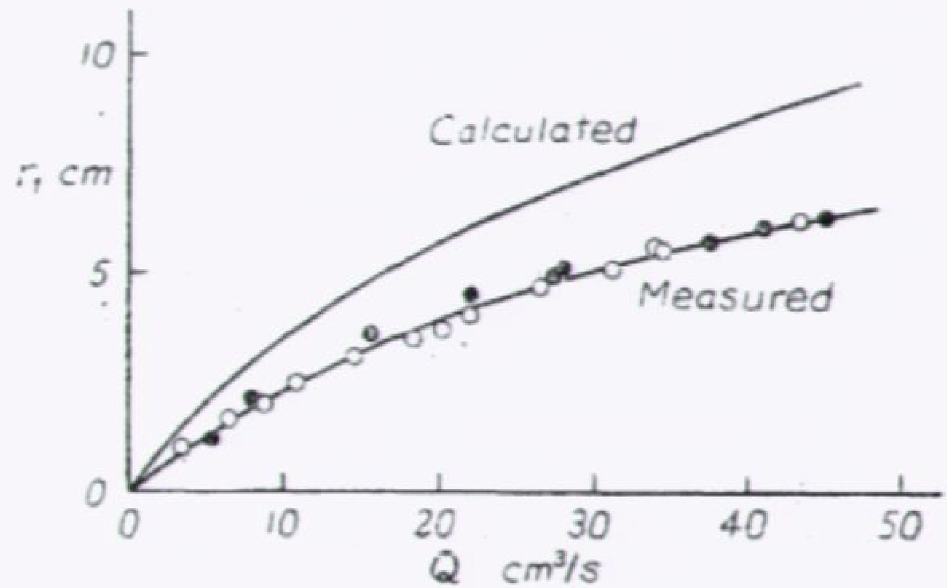

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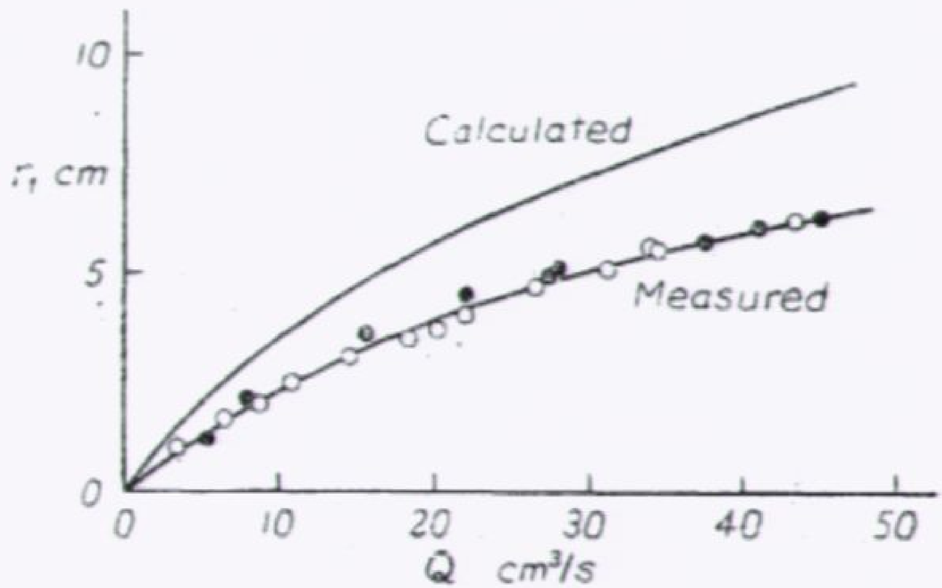

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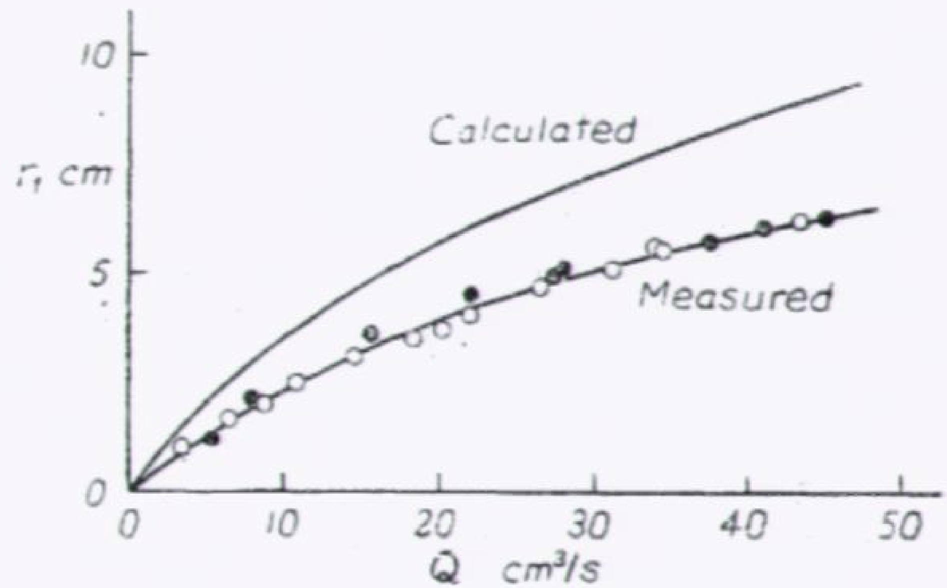

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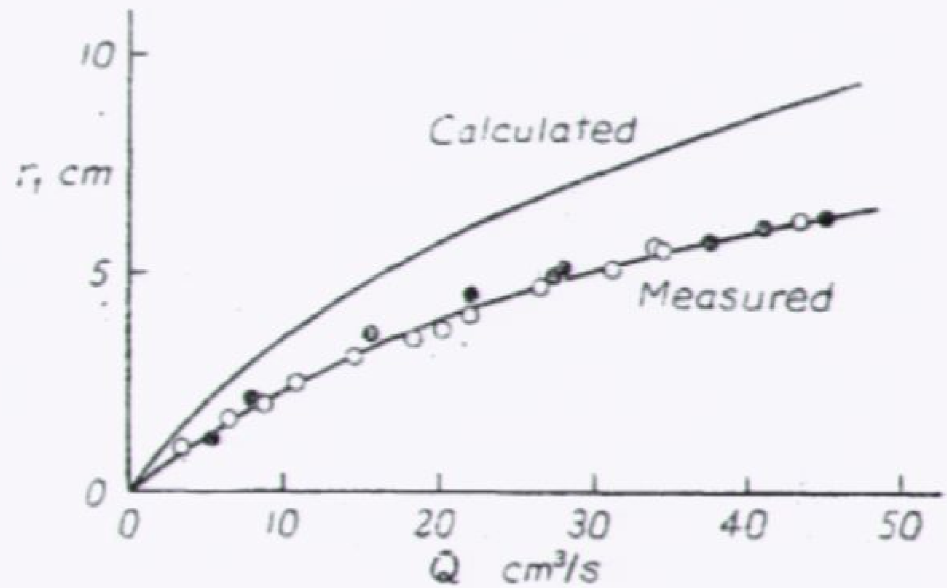

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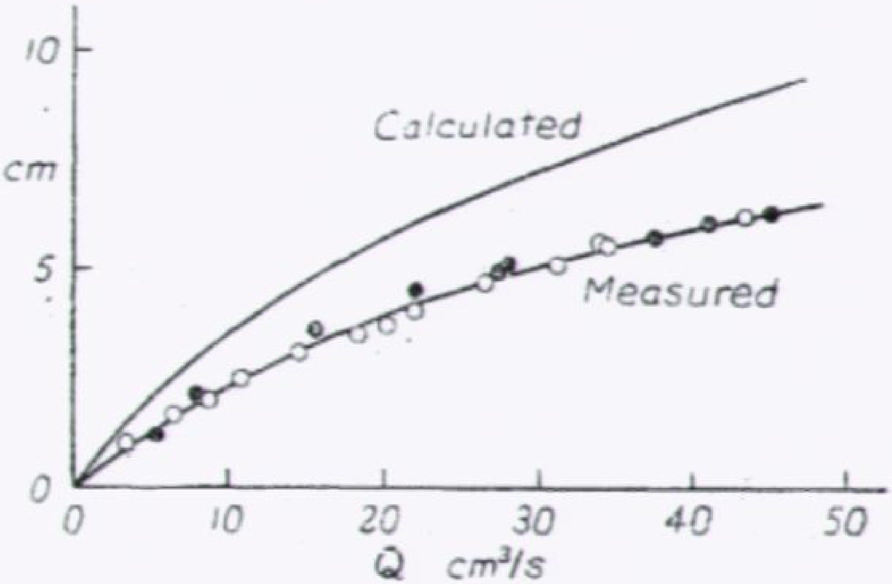

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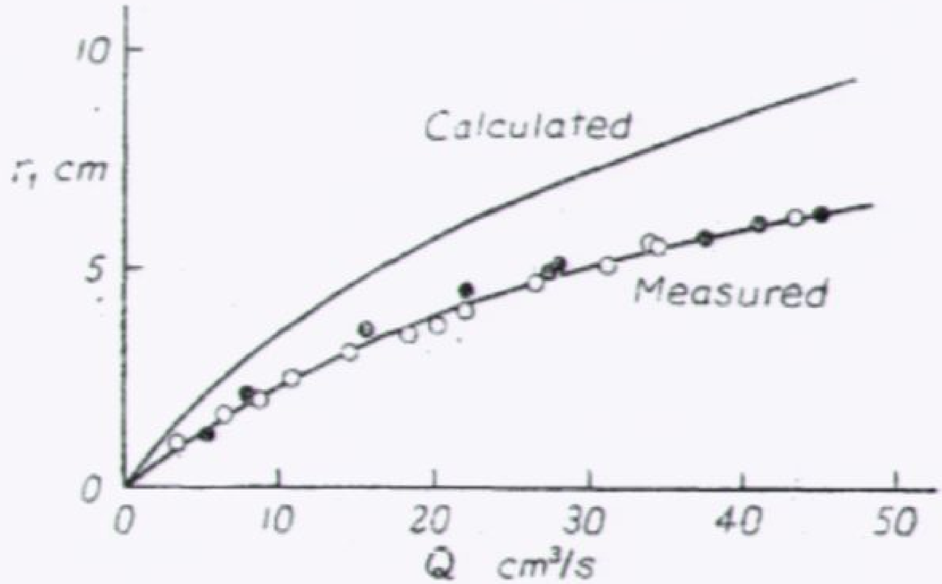

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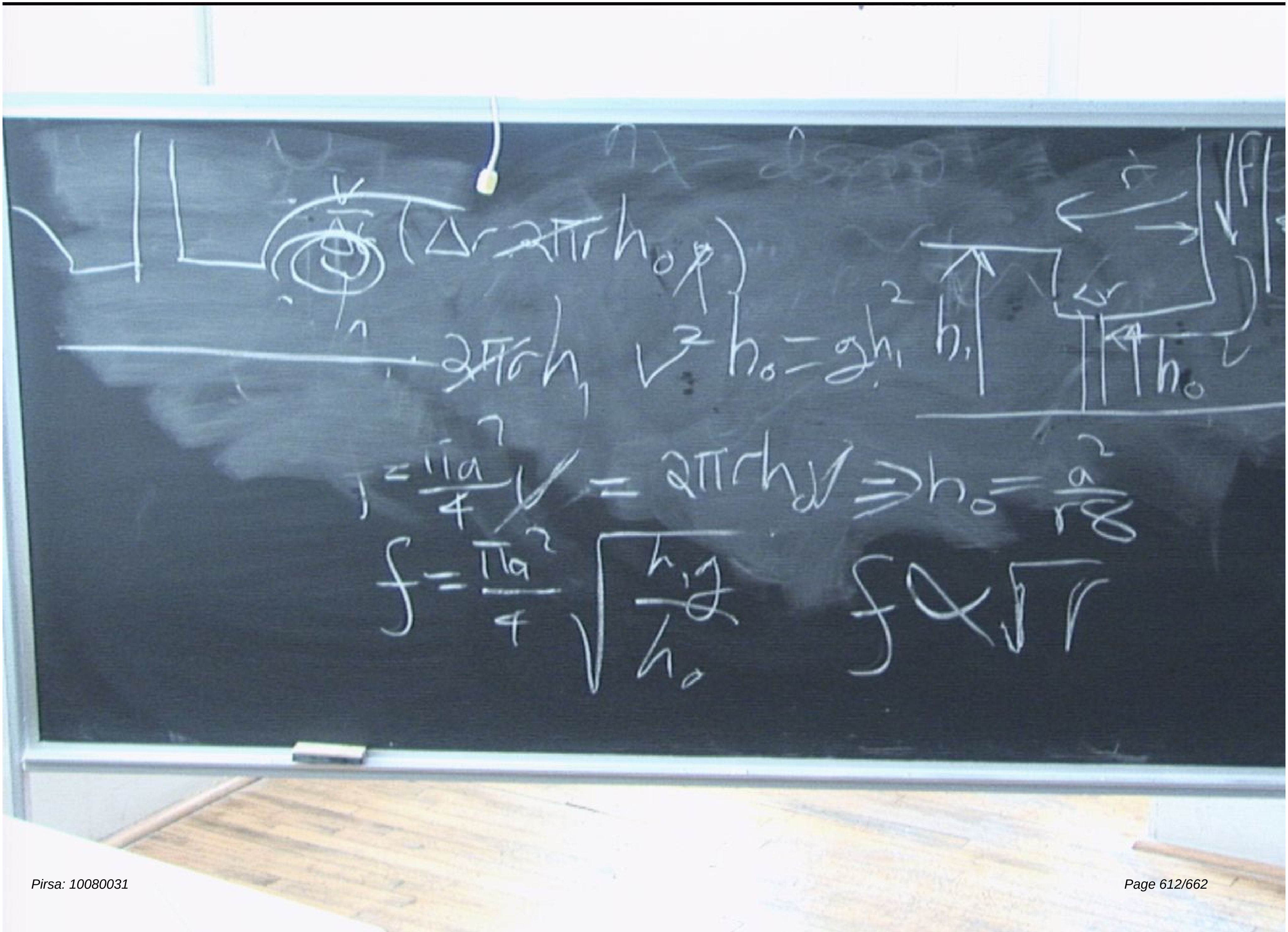
f ∝ √r

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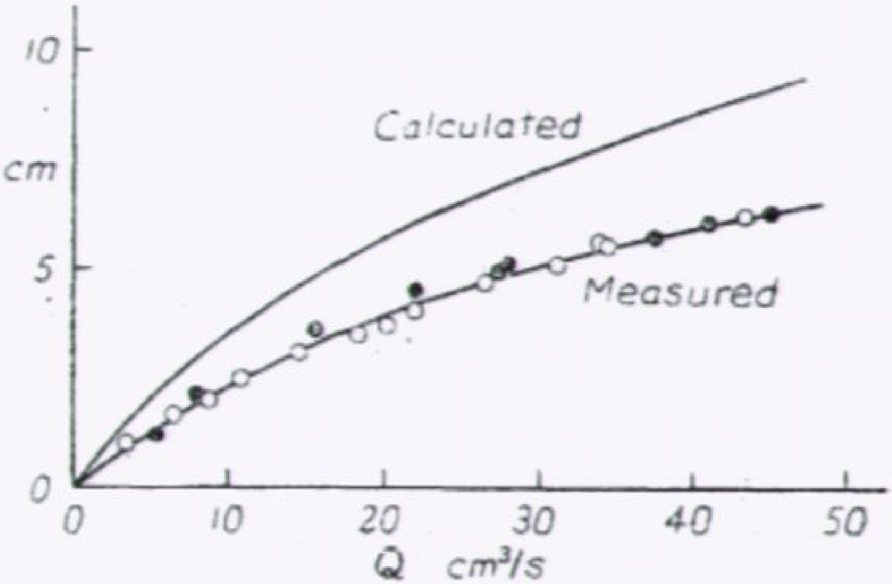

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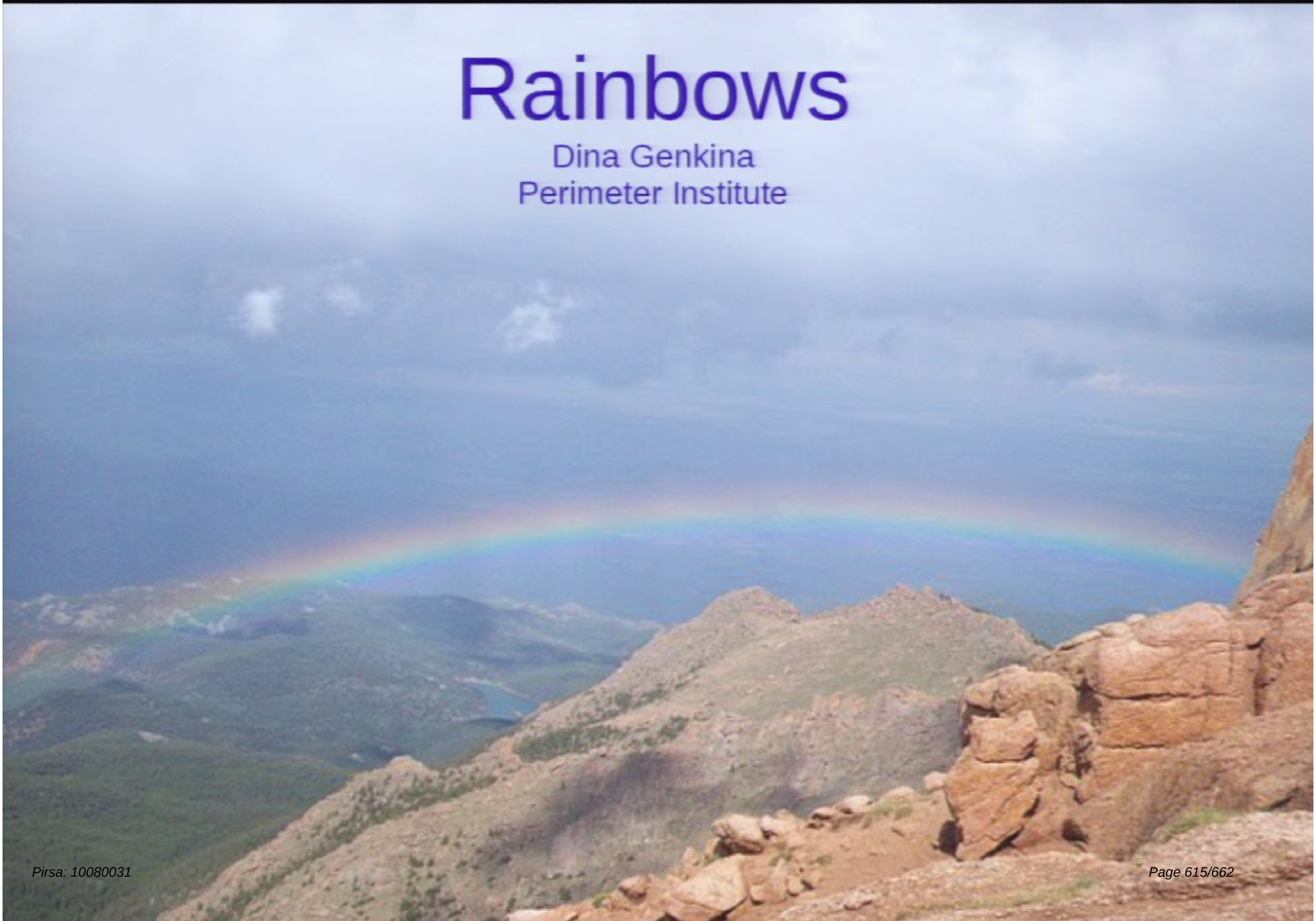
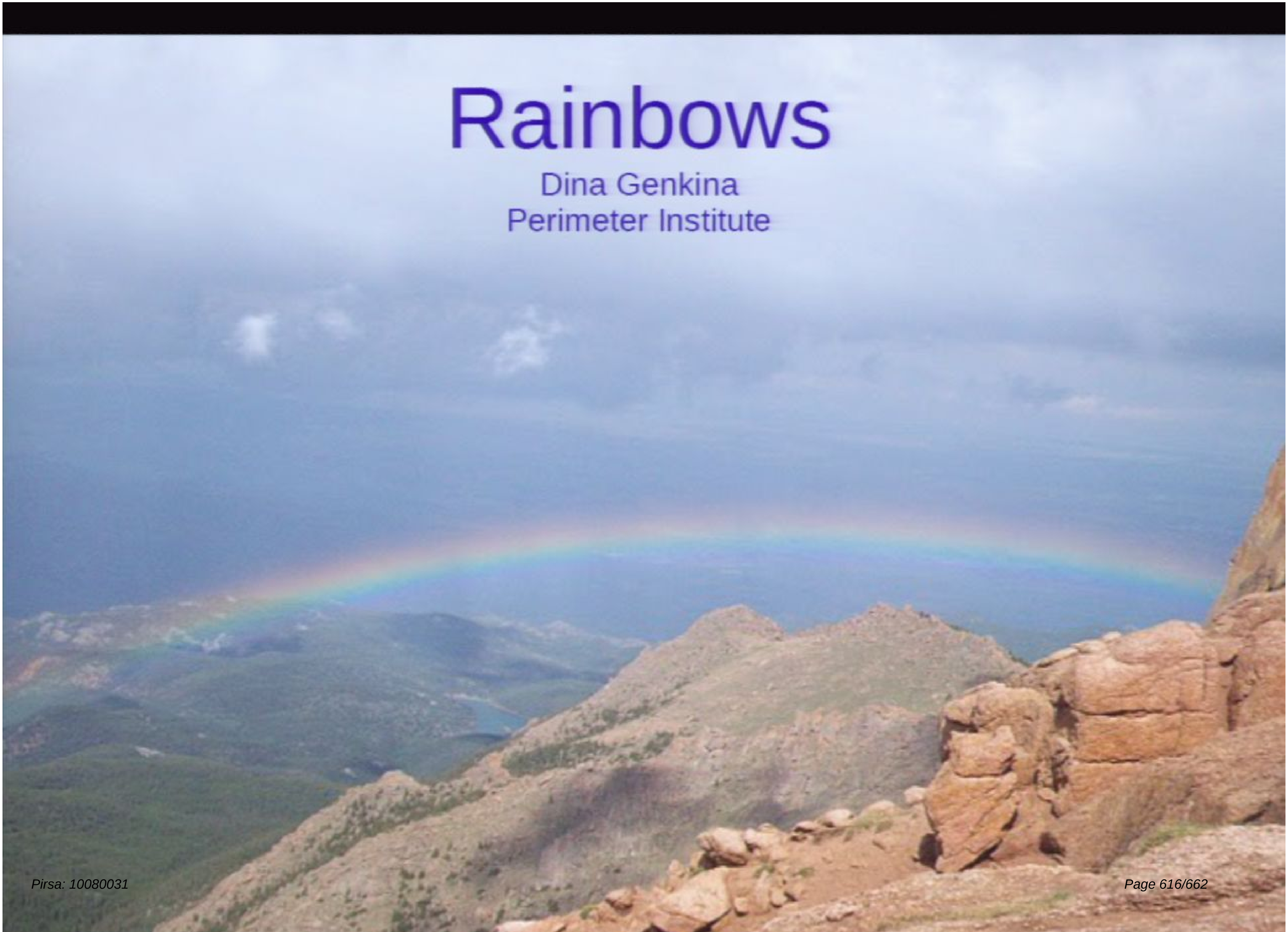
Rainbows

Dina Genkina
Perimeter Institute




Rainbows
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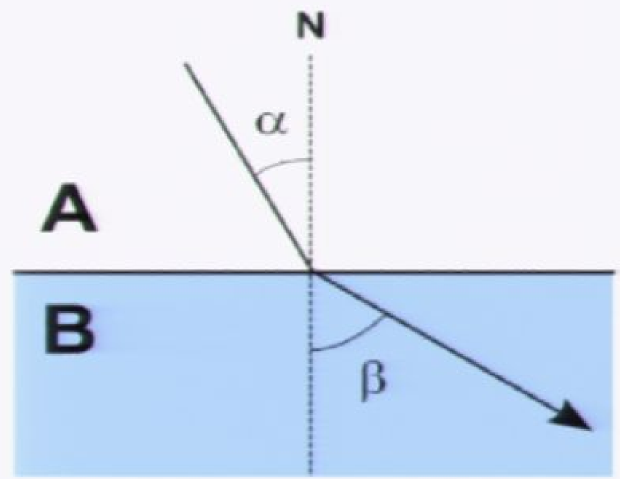
Perimeter Institute

Overview

- Where do rainbows come from?
- Why Roy G. Biv?
- Why is it an arc?
- Where do double rainbows come from?
- Pretty Pictures

Snell's Law – A review

$$n_1 \sin(\alpha) = n_2 \sin(\beta)$$

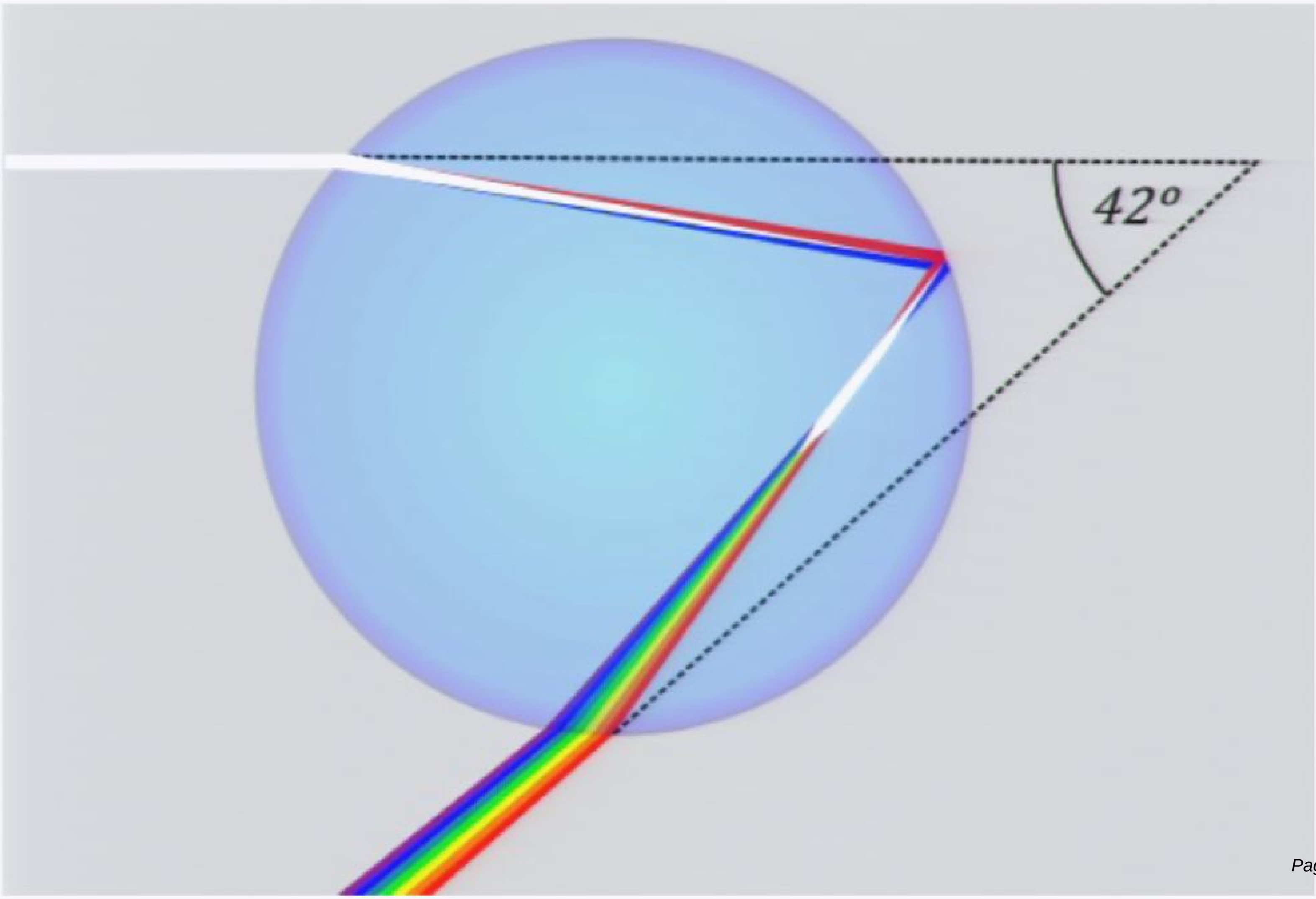


Index of refraction of water is a function of the light wavelength:

n(red) = 1.3312

n(blue) = 1.3404

Inside a rain drop



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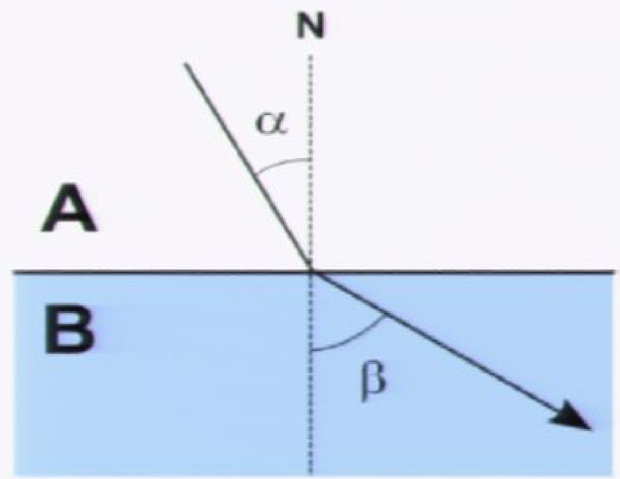

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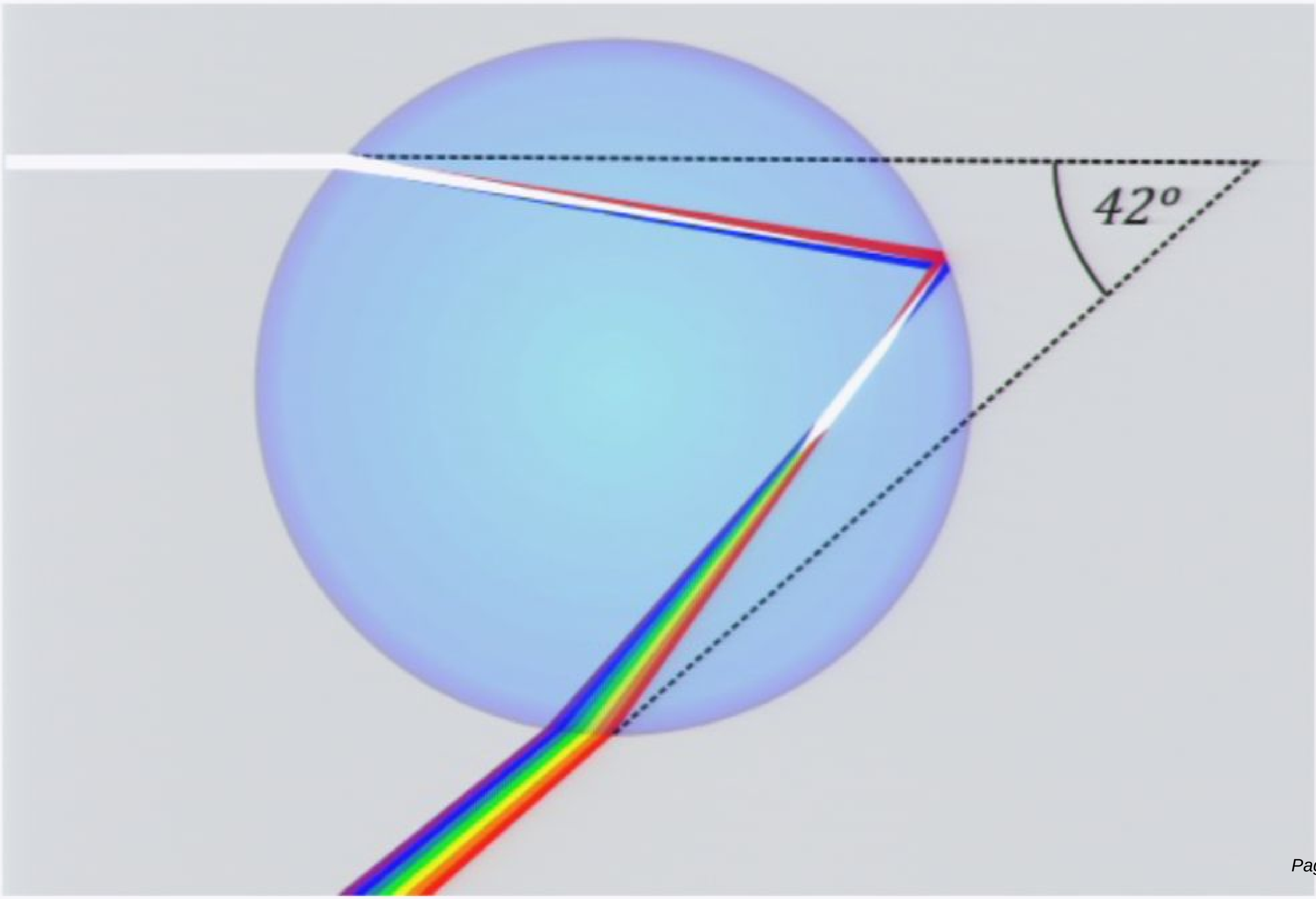
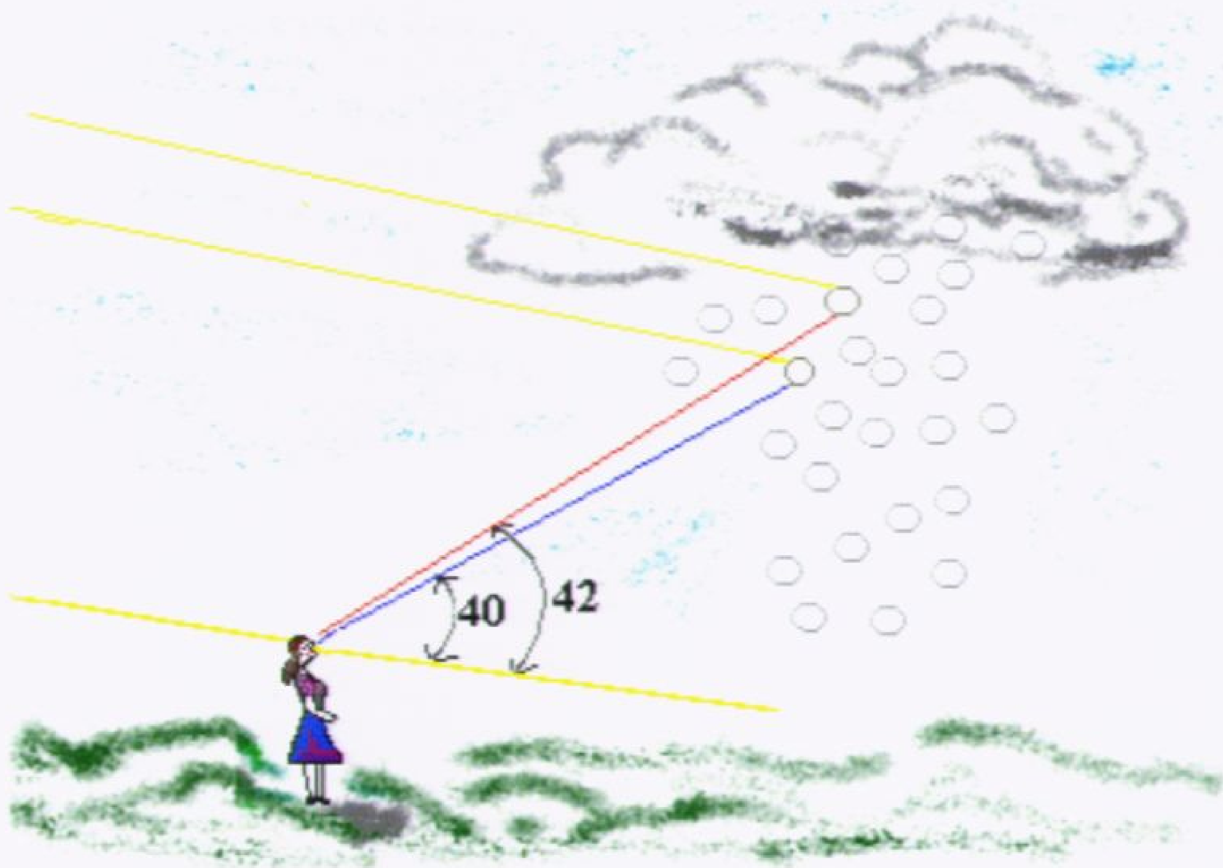
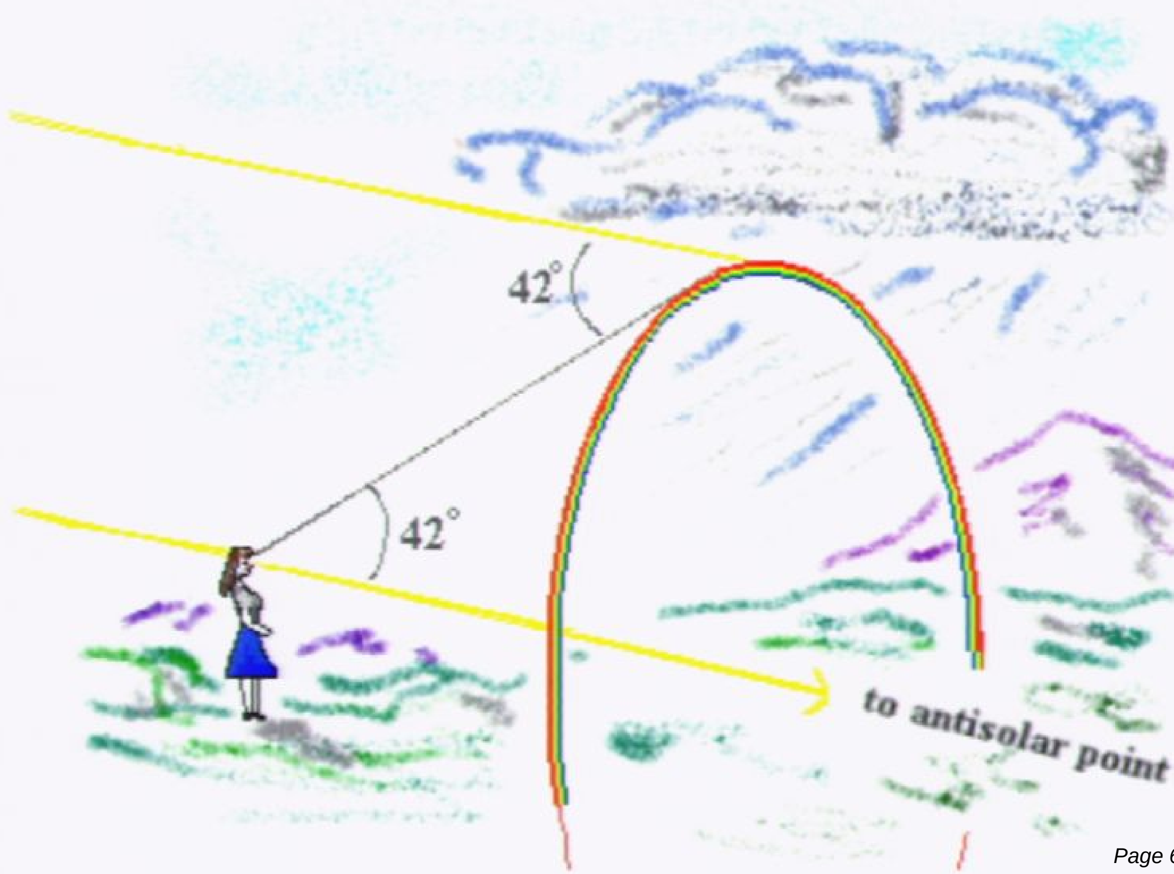




An observer sees different colors reflected from distinct raindrops, so that red appears on top.

An observer will see red light from all raindrops in a 42 degree cone around them, producing and arc above the horizon.

The sun must be less than 42 degrees above the horizon for a rainbow to be visible at sea level.



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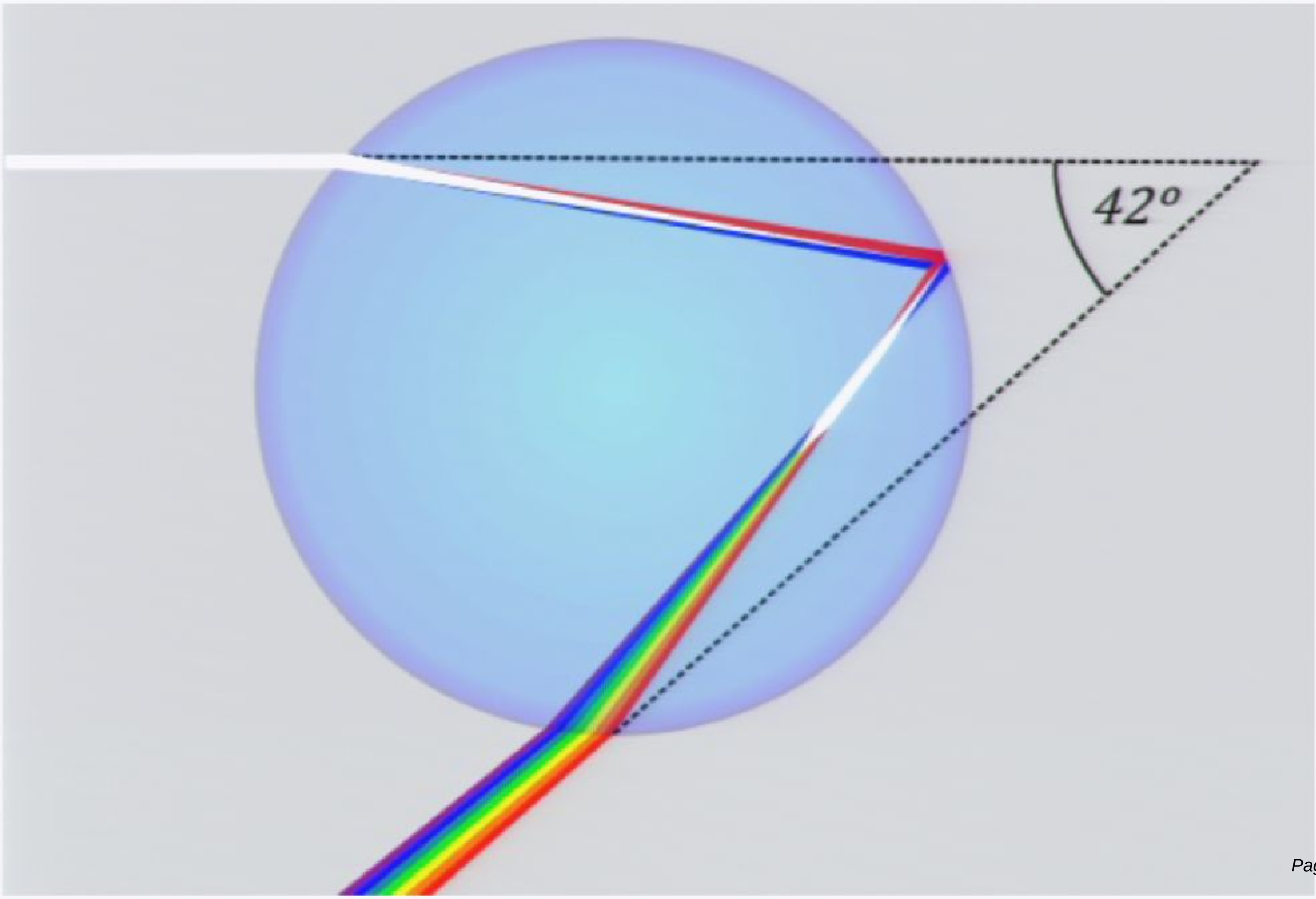

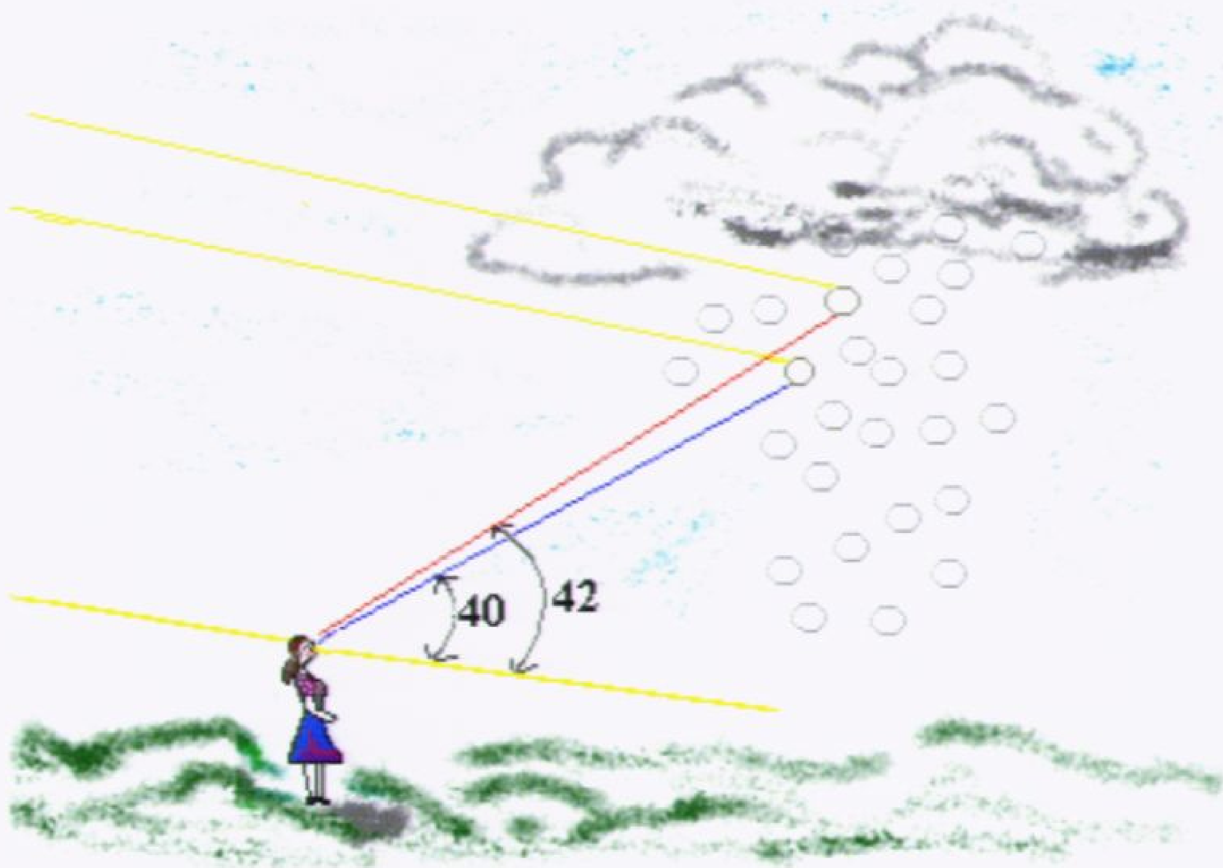

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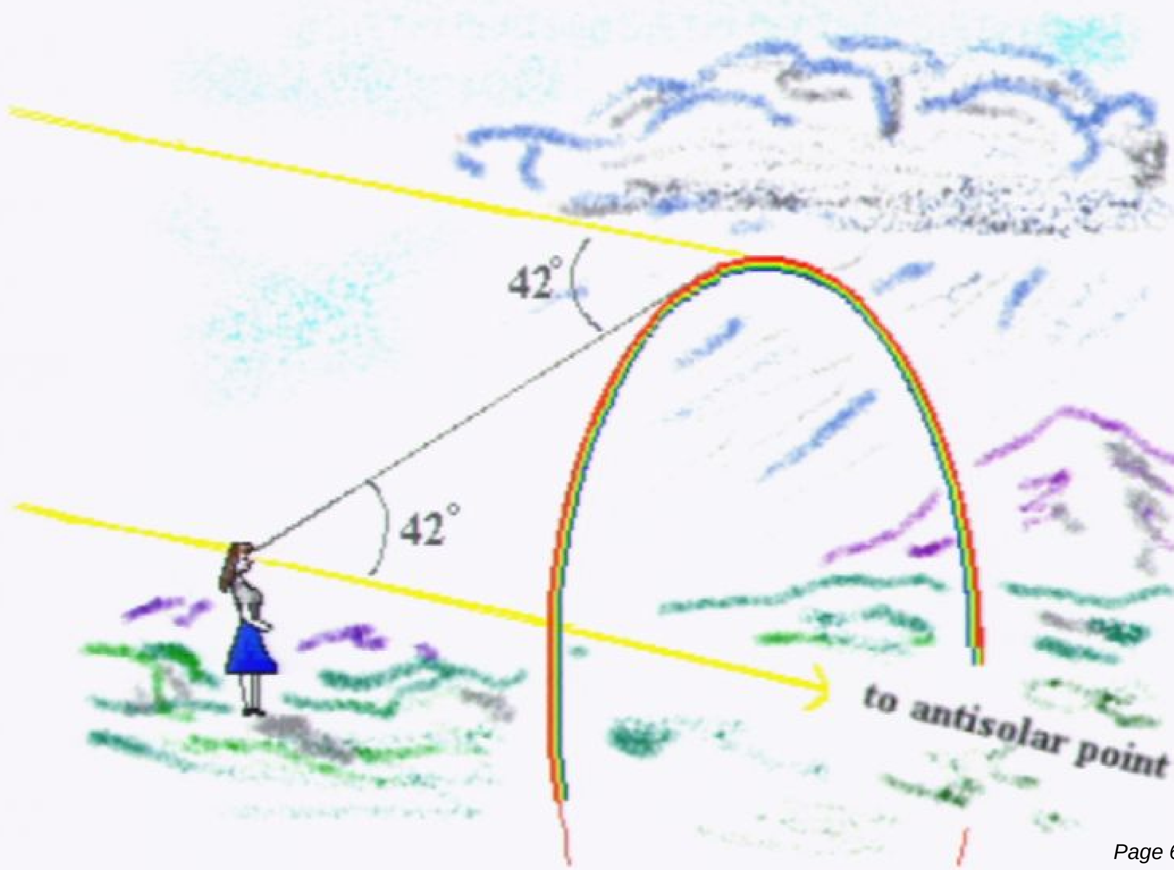
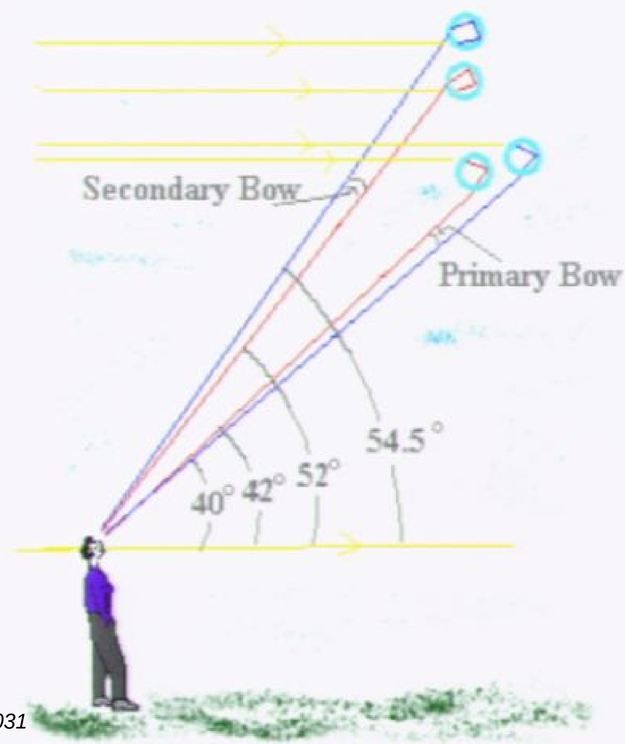
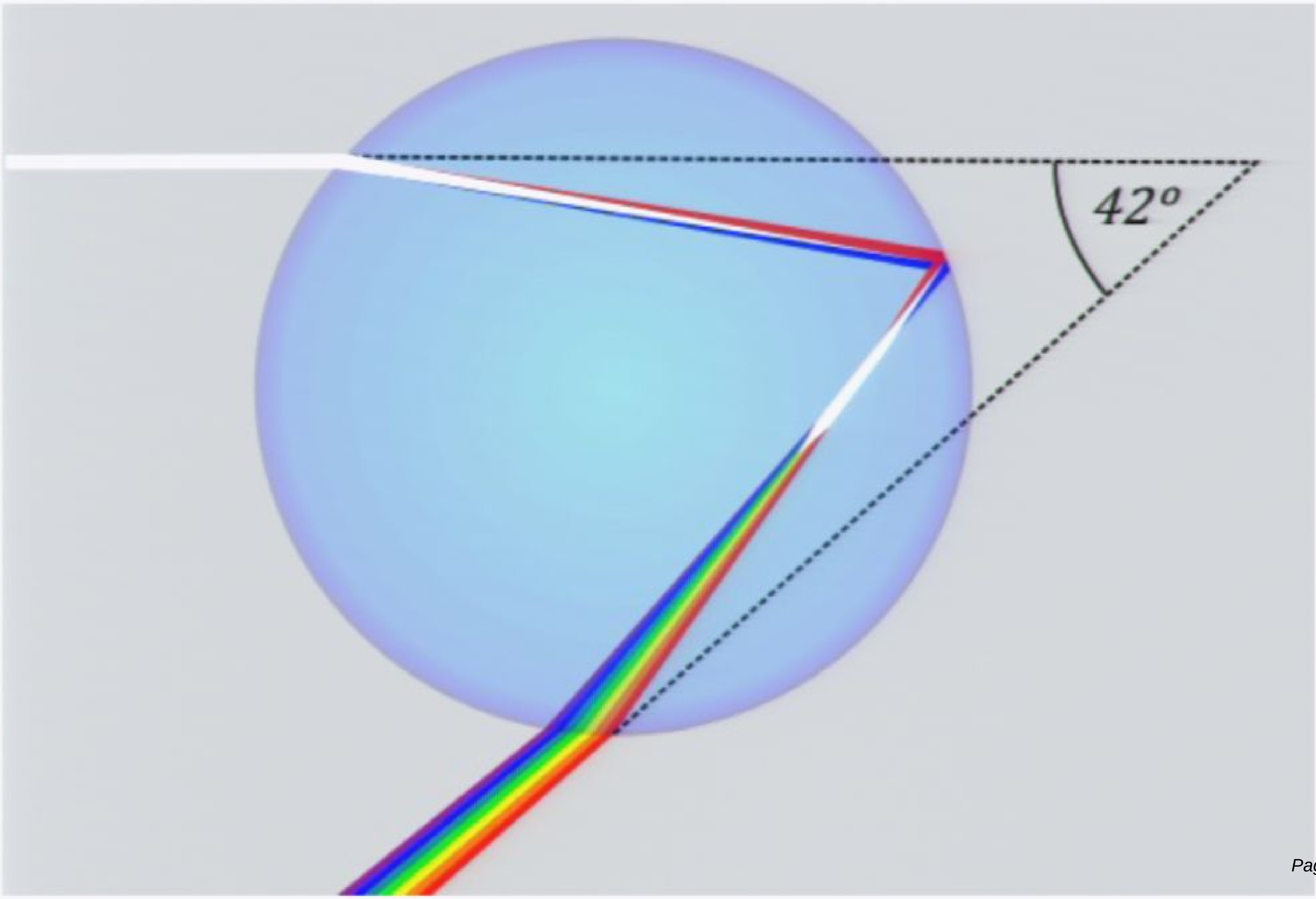


The double rainbow



The dark space between the rainbows is called Alexander's band and is caused by light reflected through larger angles than the maximum intensity

Inside a rain drop



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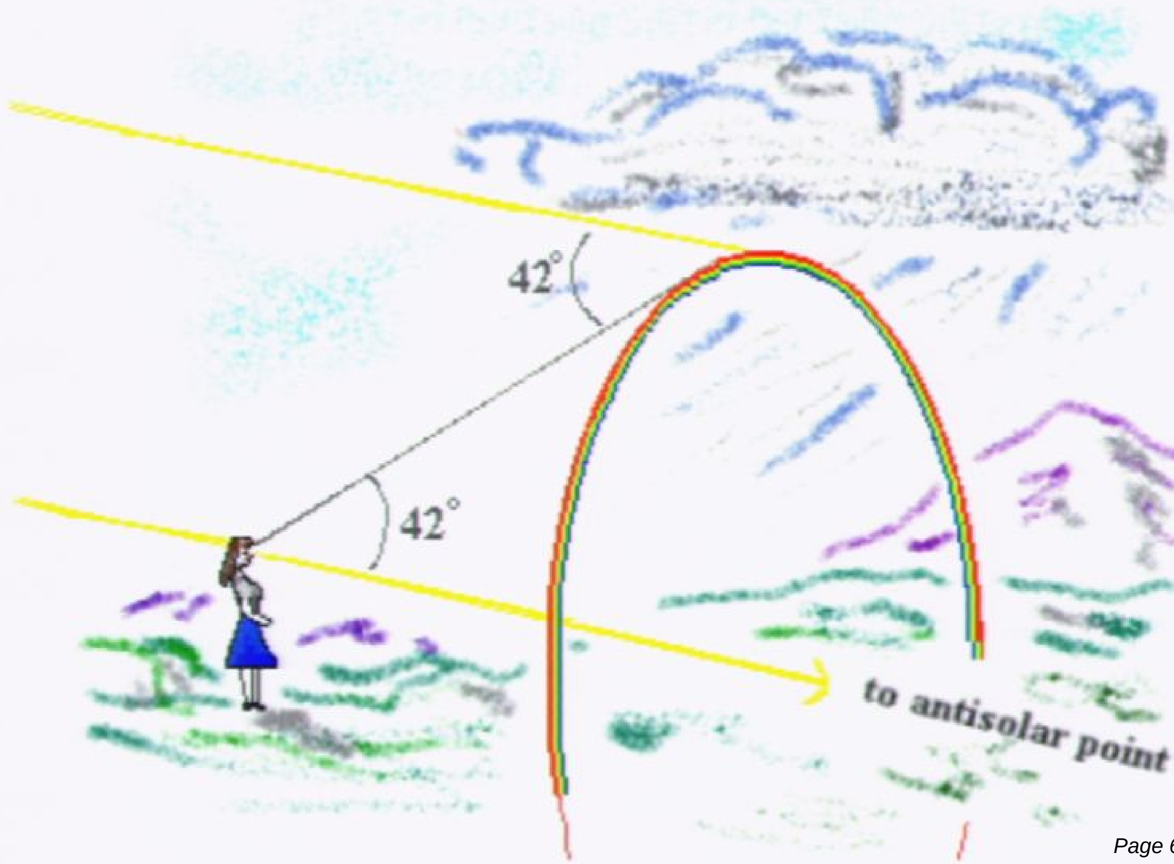

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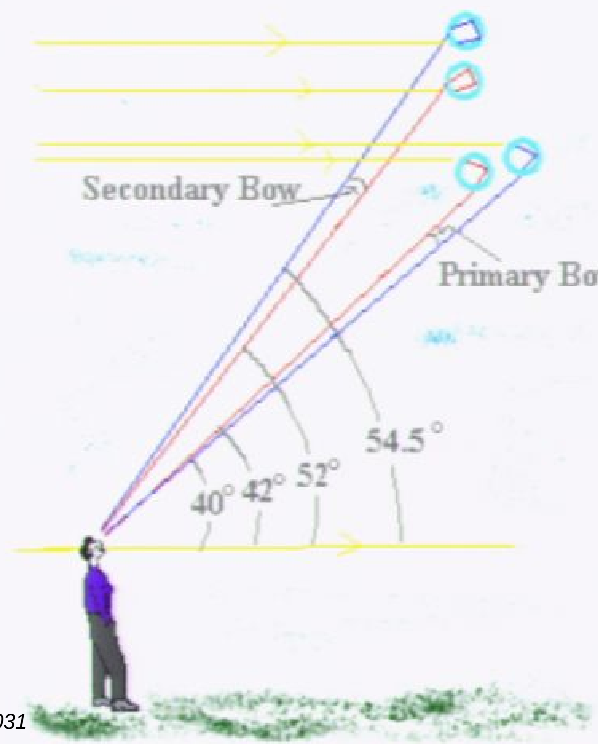

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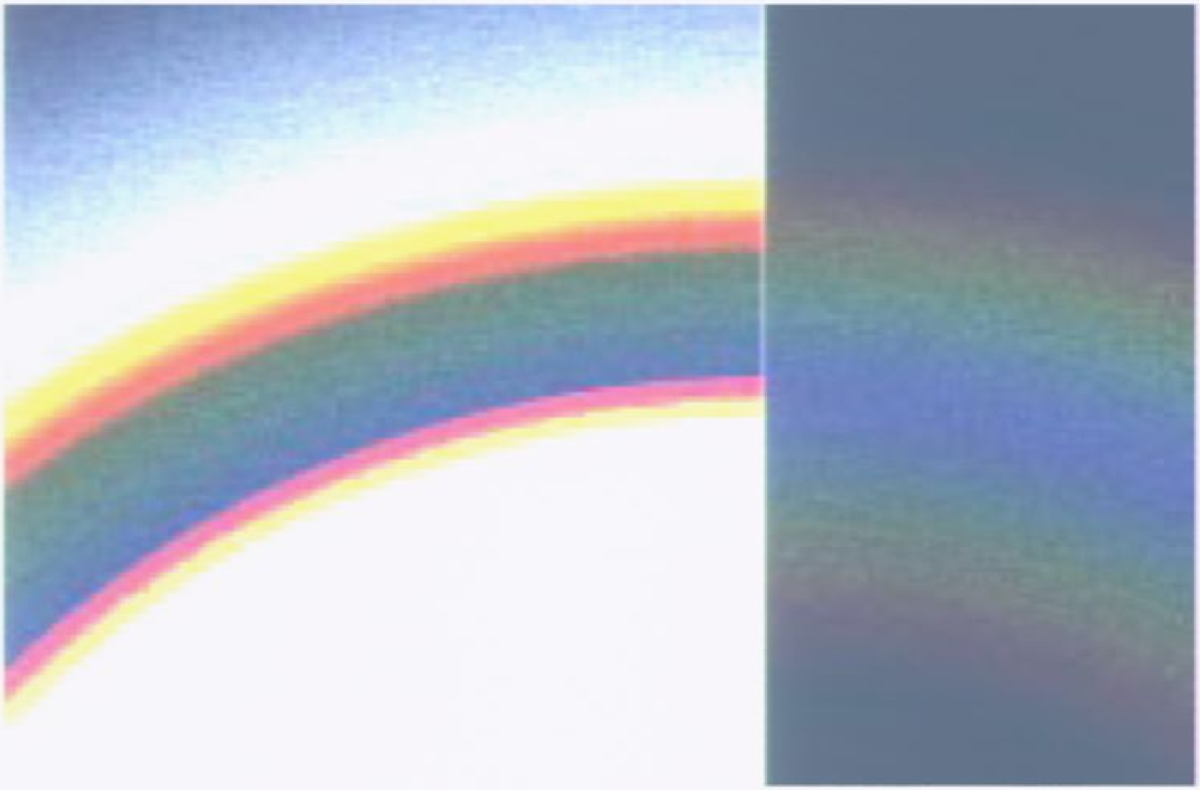
Higher Order Rainbows

A fifth order rainbow (right) falls within Alexander's band.



Using extremely strong laser light and suspended droplets, rainbows of order over 200 have been created in labs

Conclusion

Conclusion

Conclusion

Conclusion



Conclusion

Conclusion

Conclusion

Conclusion

Conclusion

Conclusion



Conclusion

Conclusion

Conclusion

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Conclusion

Conclusion

Conclusion

Conclusion

Conclusion

Conclusion

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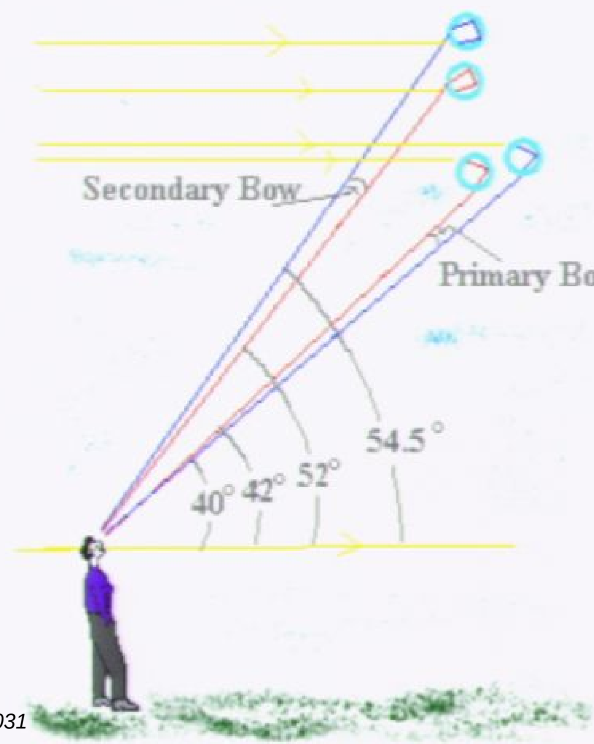
The double rainbow



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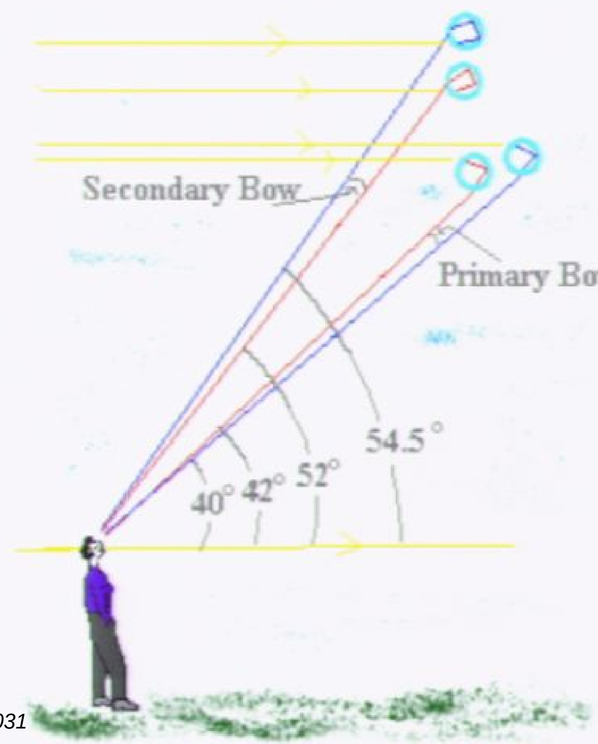

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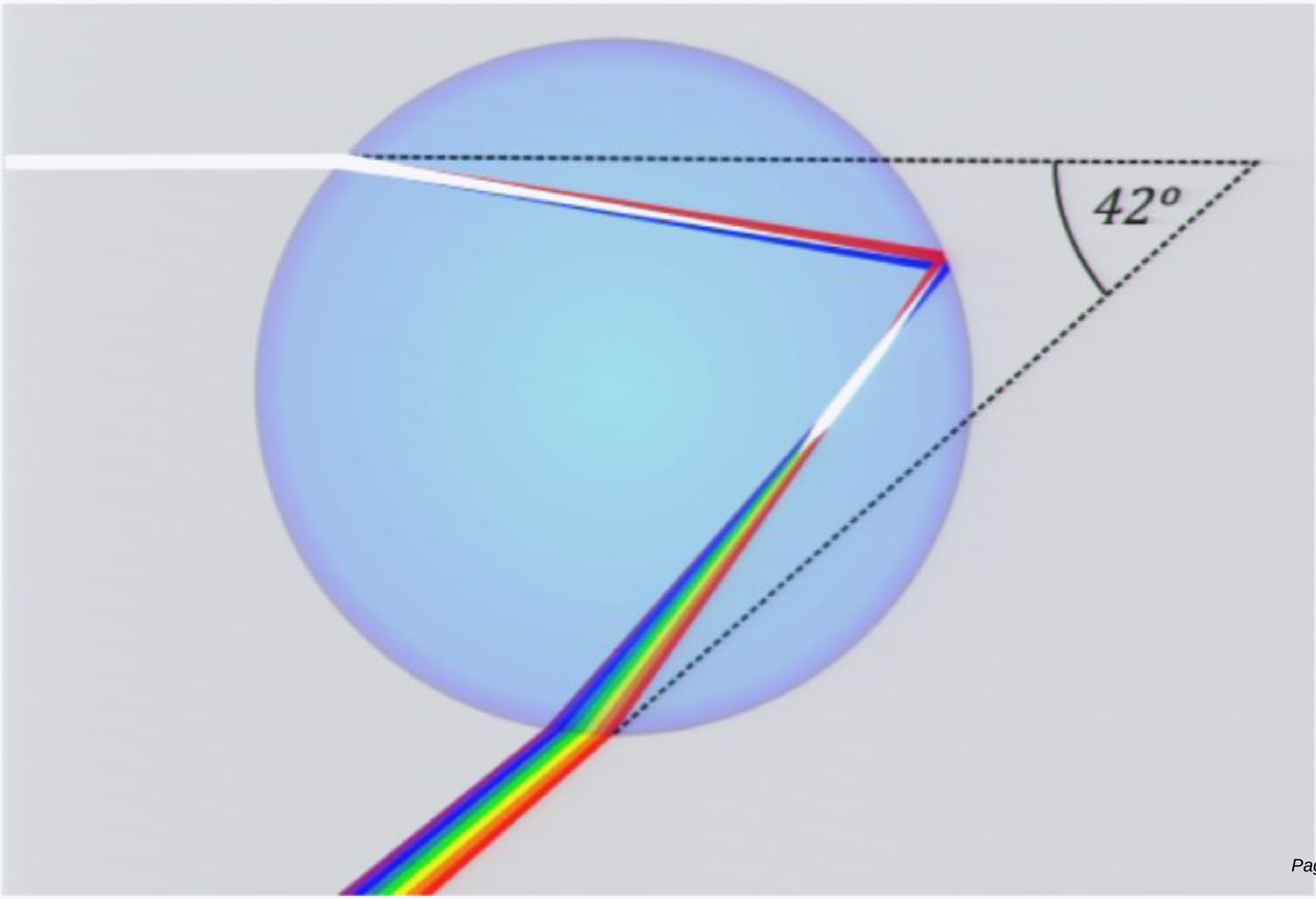
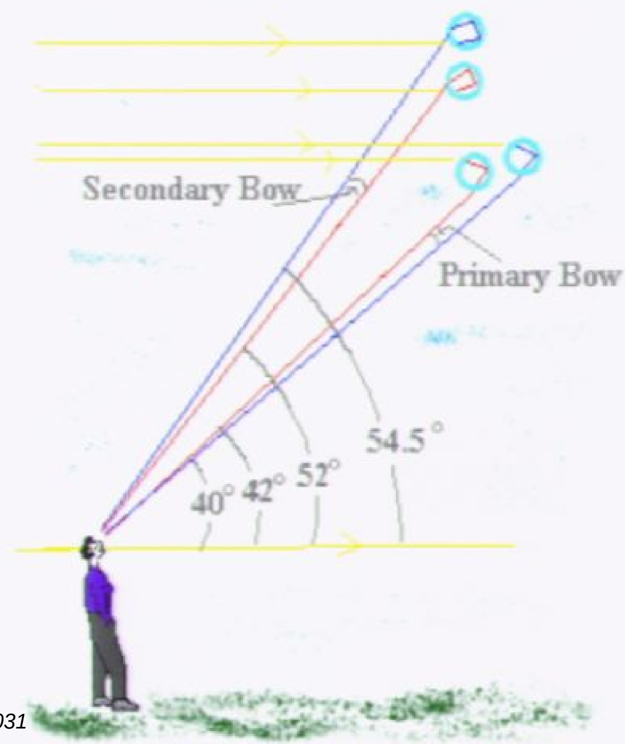
Inside a rain drop



The double rainbow



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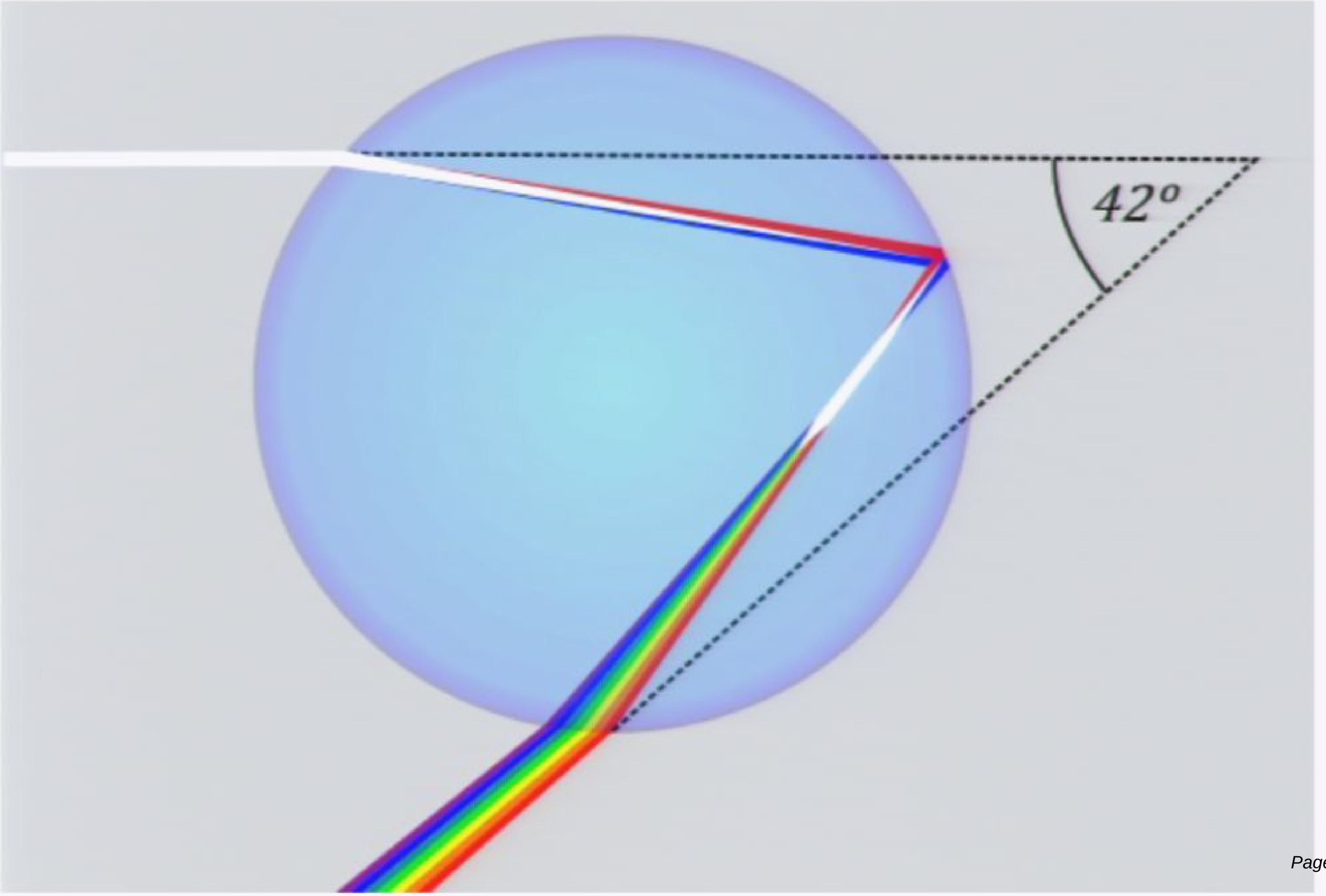
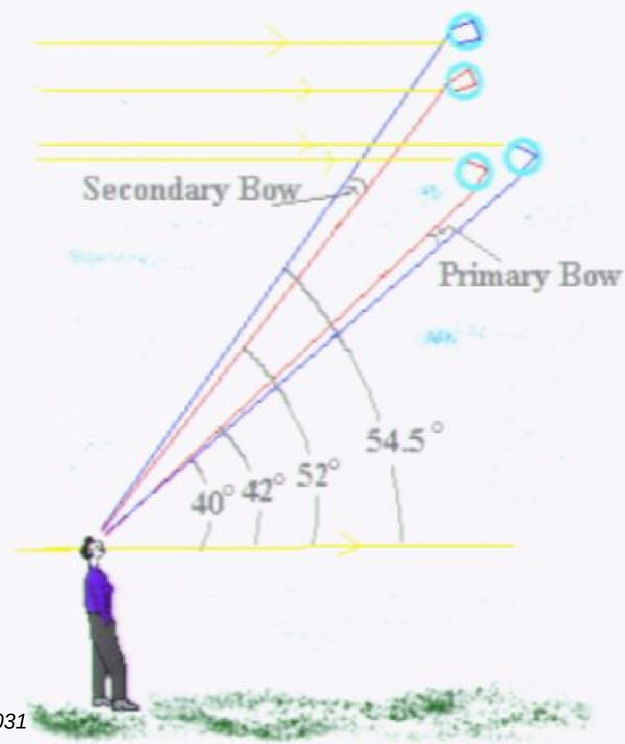


The double rainbow



The dark space between the rainbows is called Alexander's band and is caused by light reflected through larger angles than the maximum intensity

Conclusion

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