Title: 12/13 PSI - Student Presentations 2A

Date: Aug 17, 2012 01:30 PM

URL: http://www.pirsa.org/12080039

Abstract:

Arthur Lee.'Physics in Nature'. 17th Aug.

N_2 tyre filling - Brillant idea or scam?

What happens.

psedealerequipment.com


Why fill your tires with N_2?

Why fill your tires with N_2?

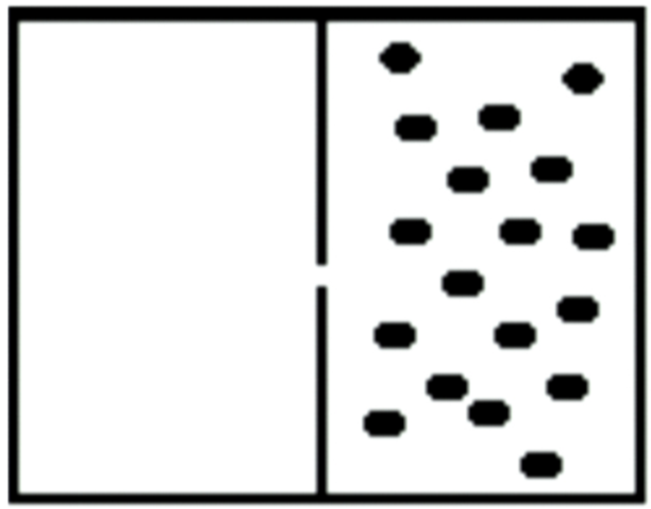
Benefits claimed:

1. Slower loss of pressure due to diffusion through the tyre,
2. decreased rate of corrosion of tyre frame, and
3. retarding the chemical degradation of rubber.

Decrease rate of frame corrosion

- frame corrosion produces aluminum oxide powder
- which can get stuck in air valves

Effusion



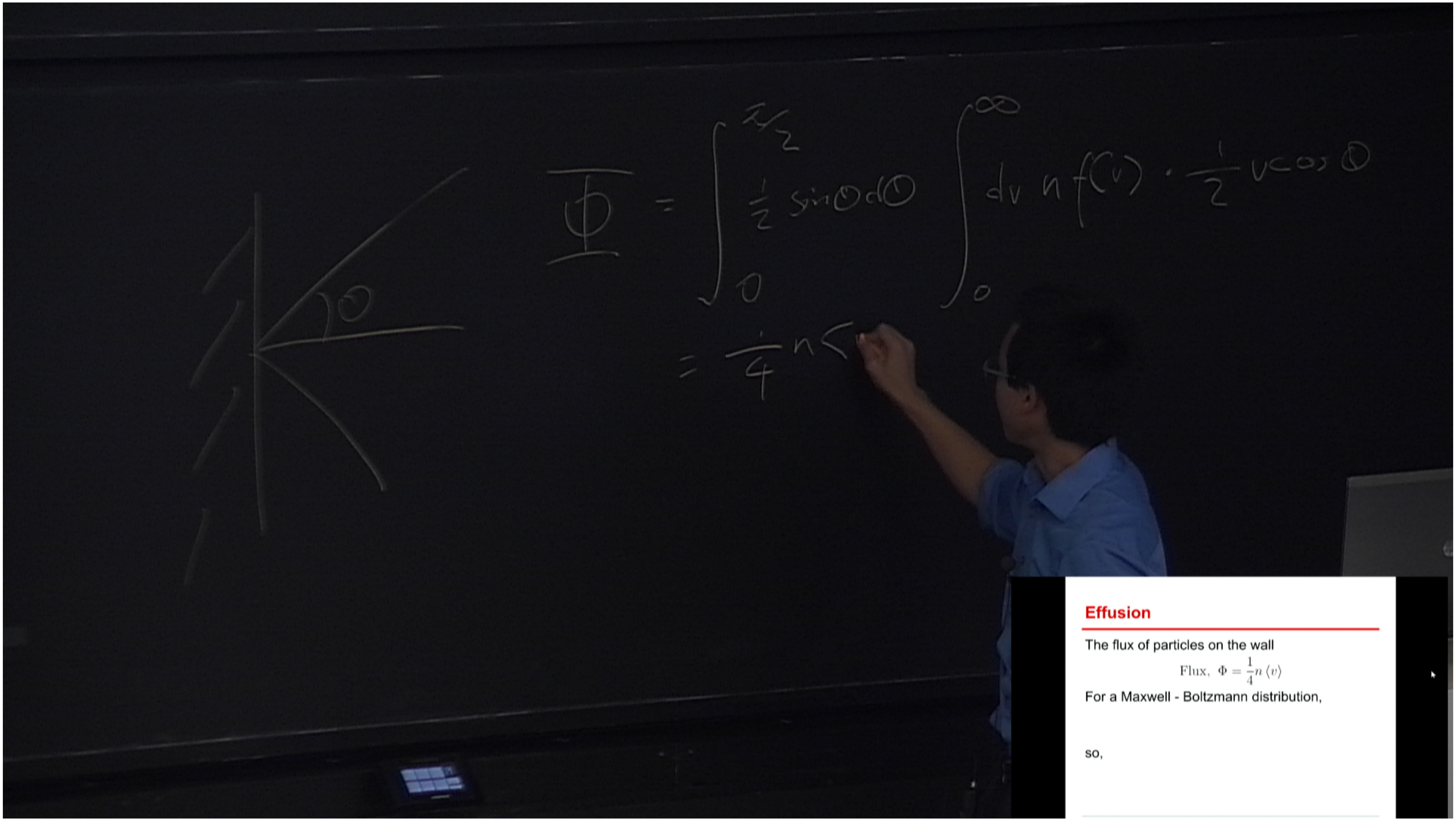
Effusion

The flux of particles on the wall

$$\text{Flux, } \Phi = \frac{1}{4} n \langle v \rangle$$

For a Maxwell - Boltzmann distribution,

so,


Effusion
The flux of particles on the wall
Flux, $\Phi = \frac{1}{4} n \langle v \rangle$
For a Maxwell - Boltzmann distribution,
so,

Effusion

The flux of particles on the wall

$$\text{Flux,}\ \ \Phi = \frac{1}{4} n \langle v \rangle$$

For a Maxwell - Boltzmann distribution,

$$\langle v \rangle = \sqrt{\frac{8 k_B T}{\pi m}} \propto \frac{1}{\sqrt{m}}$$

so,

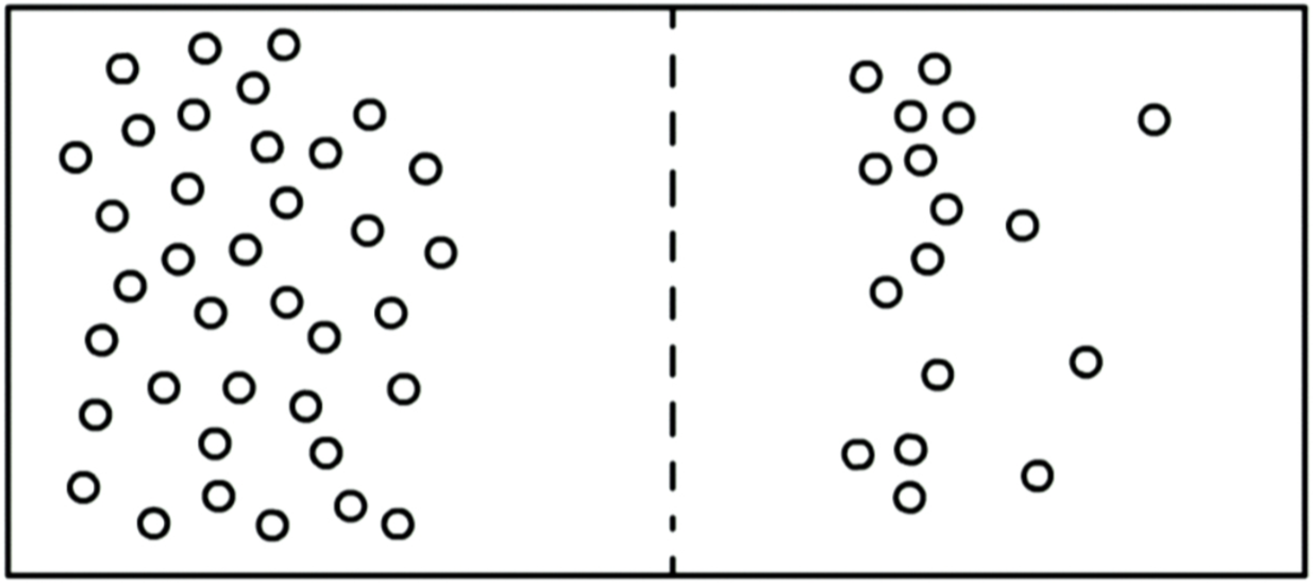
$$\Phi \propto \langle v \rangle \propto \frac{1}{\sqrt{m}}$$

Effusion

Hence,

$$\frac{\Phi_{O_2}}{\Phi_{N_2}} = \sqrt{\frac{m_{N_2}}{m_{O_2}}} = 0.935$$

Diffusion



Diffusion

Flux of particles

$$\text{Flux, } \vec{\Phi} = -\frac{1}{3}\lambda \langle v \rangle \nabla n$$

For a Maxwell - Boltzmann distribution,

Also,

Diffusion

So,

$$\Phi \propto \frac{1}{d^2\sqrt{m}}$$

Using the data

$$d_{O_2} = 0.358\,nm, \quad d_{N_2} = 0.370\,nm$$

Thus,

Diffusion

So,

$$\Phi \propto \frac{1}{d^2\sqrt{m}}$$

Using the data

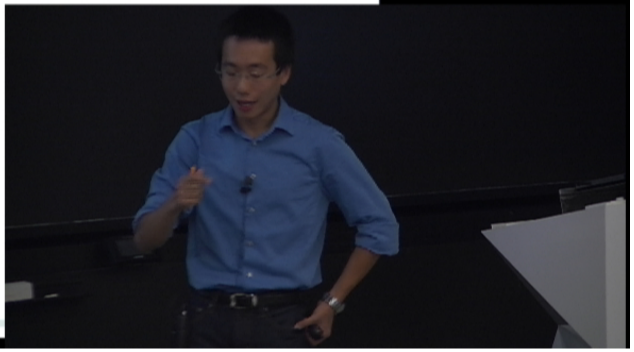
$$d_{O_2} = 0.358\, nm, \quad d_{N_2} = 0.370\, nm$$

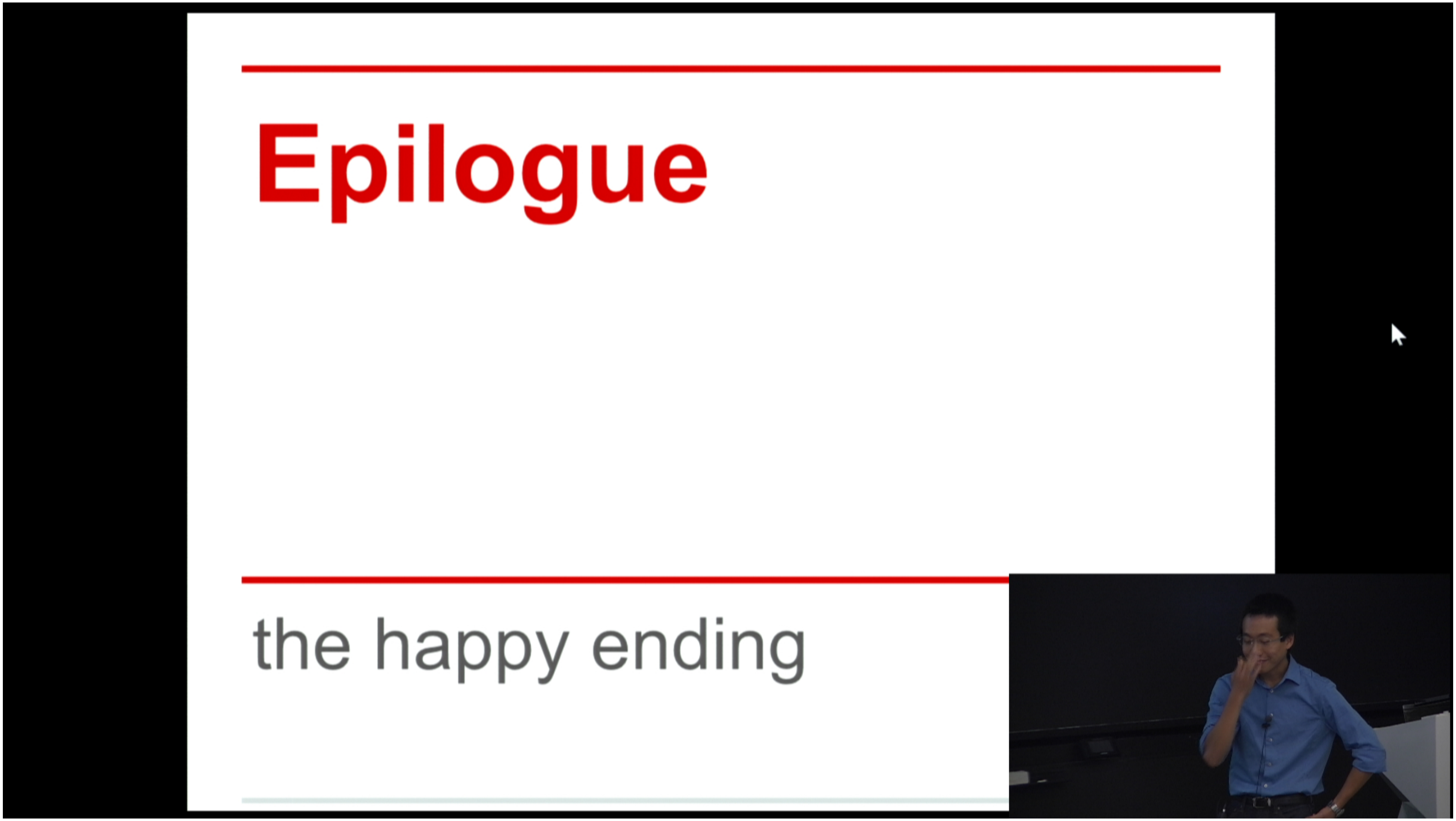
Thus,

$$\frac{\Phi_{O_2}}{\Phi_{N_2}} = \left(\frac{d_{N_2}}{d_{O_2}}\right)^2 \sqrt{\frac{m_{N_2}}{m_{O_2}}} = 0.9992$$

Conclusion

?

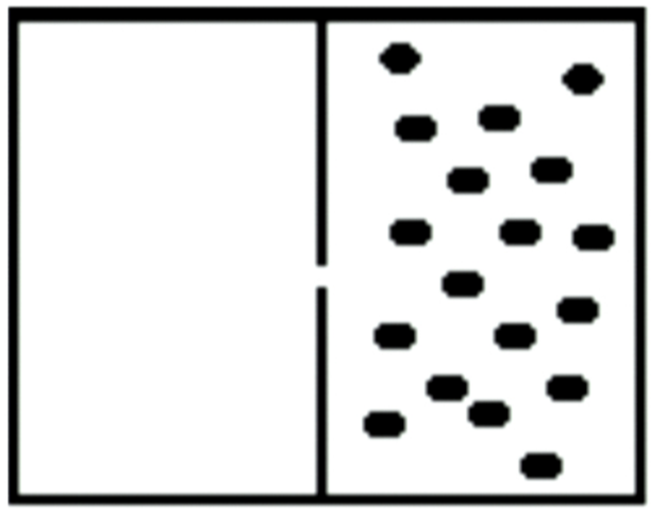



Epilogue
the happy ending

The end


BEVERLY TIRE & AUTO
GOODYEAR
DUNLOP
KELLY TIRES
LOF $24 95
WE DO AIR COND
E TESTS BRAKES
WE ACCEPT FLEET CARDS
MAXIMUM
60
COMPLETE AUTOMOTIVE SERVICE

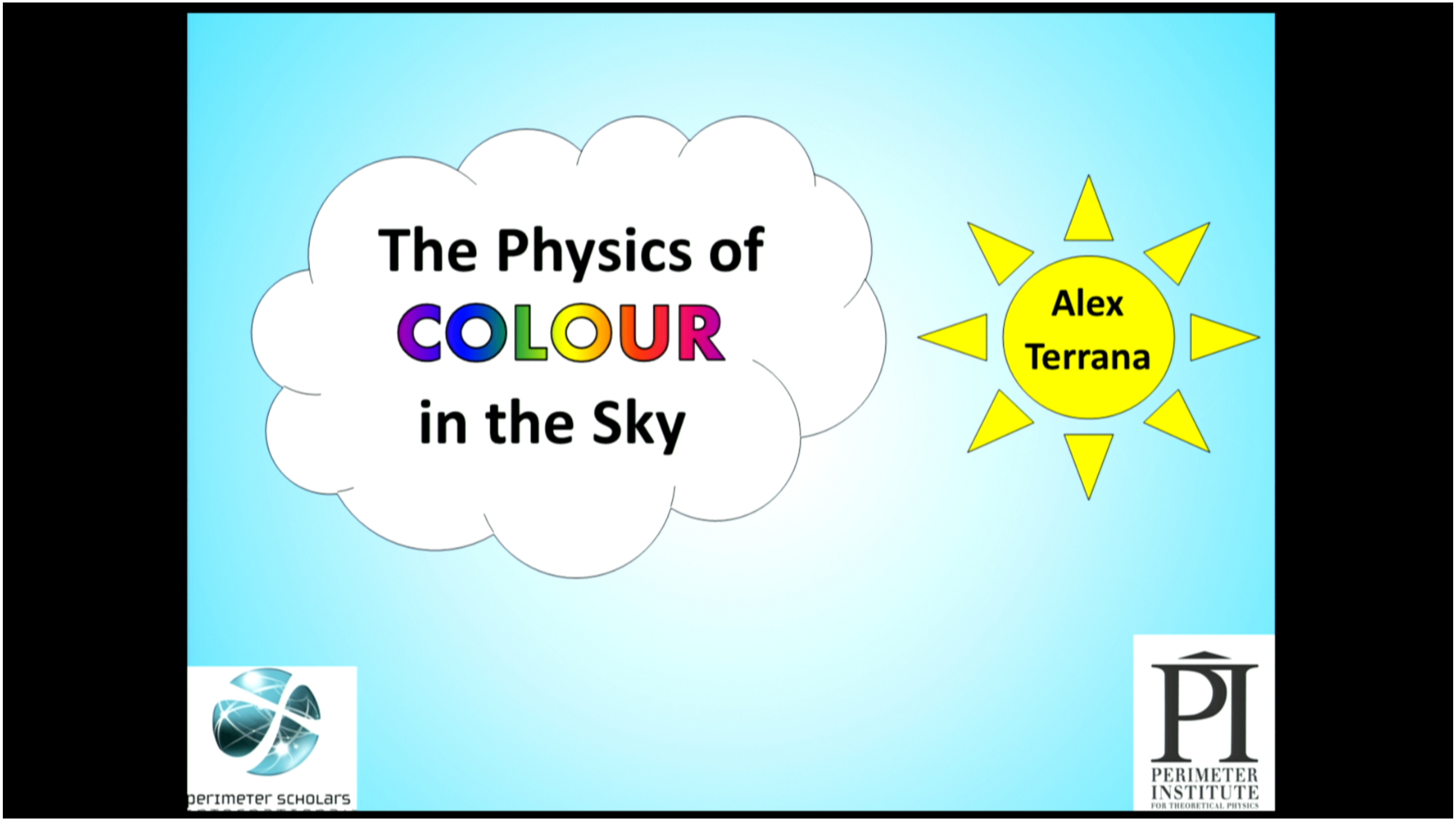
Effusion



Why fill your tires with N_2?

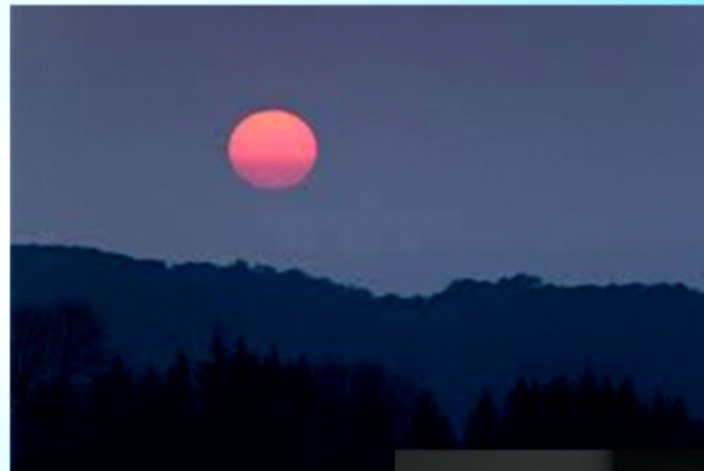
Benefits claimed:

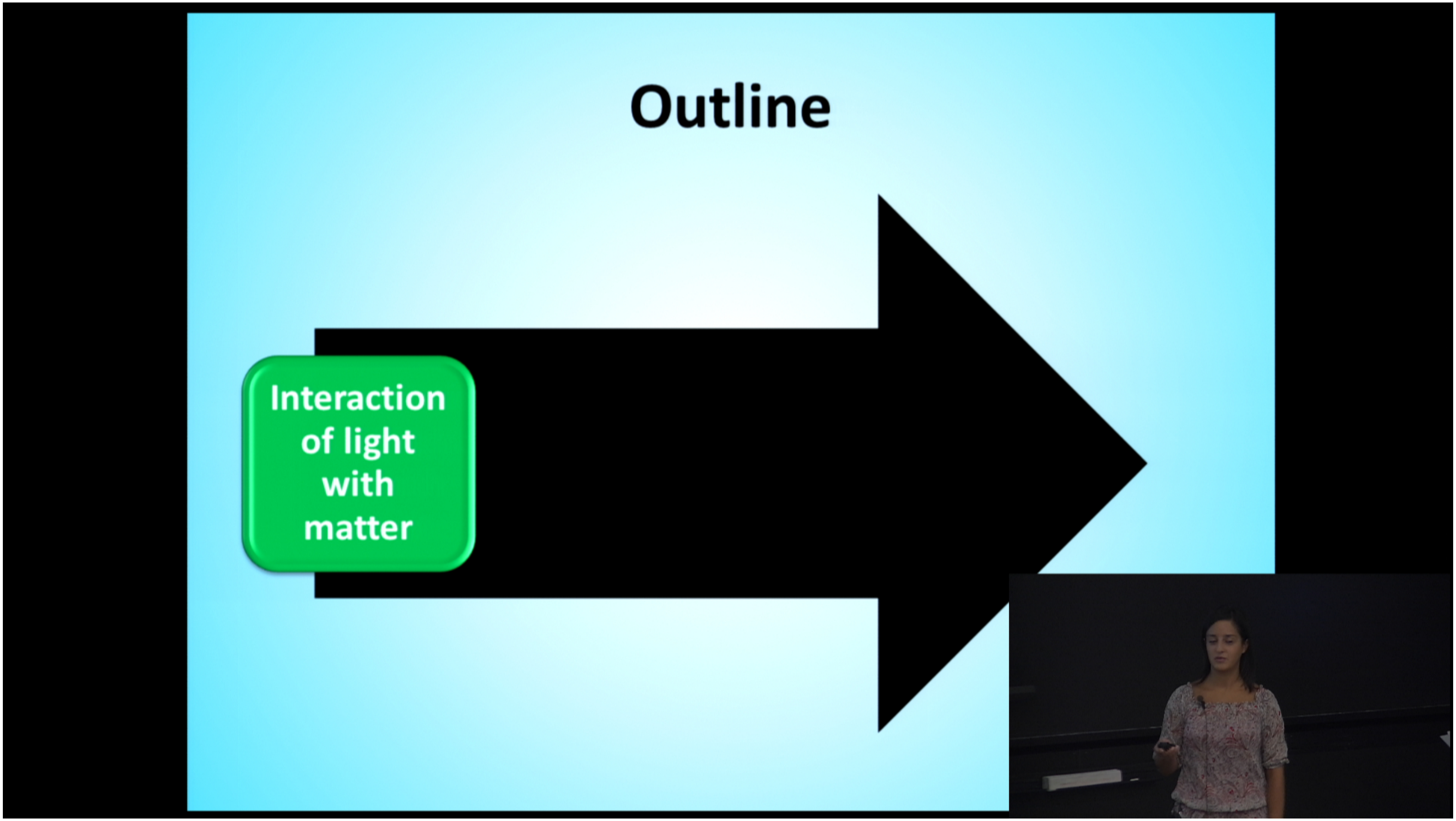
1. Slower loss of pressure due to diffusion through the tyre,
2. decreased rate of corrosion of tyre frame, and
3. retarding the chemical degradation of rubber.

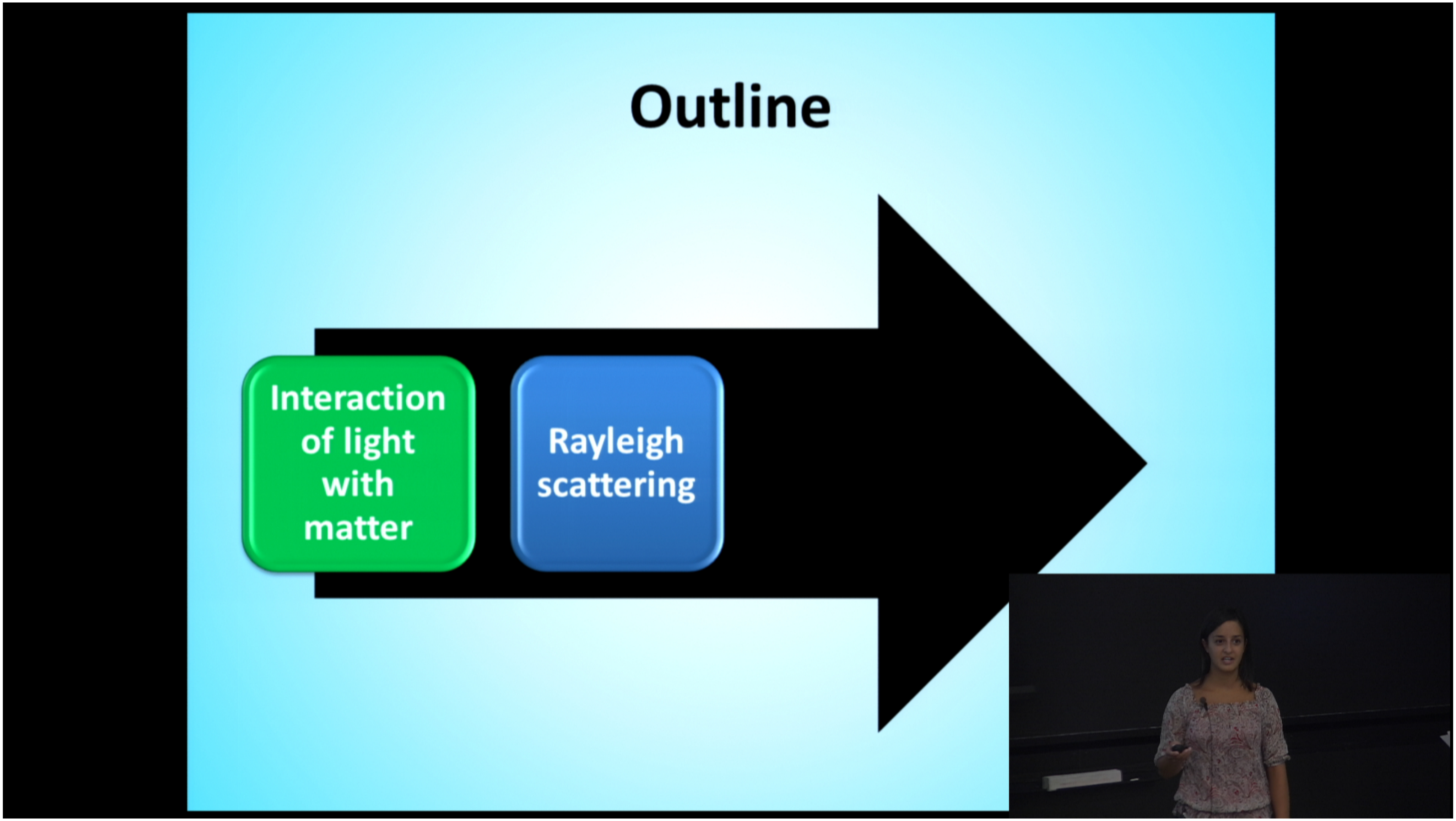

The Physics of
COLOUR
in the Sky
Alex
Terrana
perimeter scholars
PERIMETER
INSTITUTE
FOR THEORETICAL PHYSICS

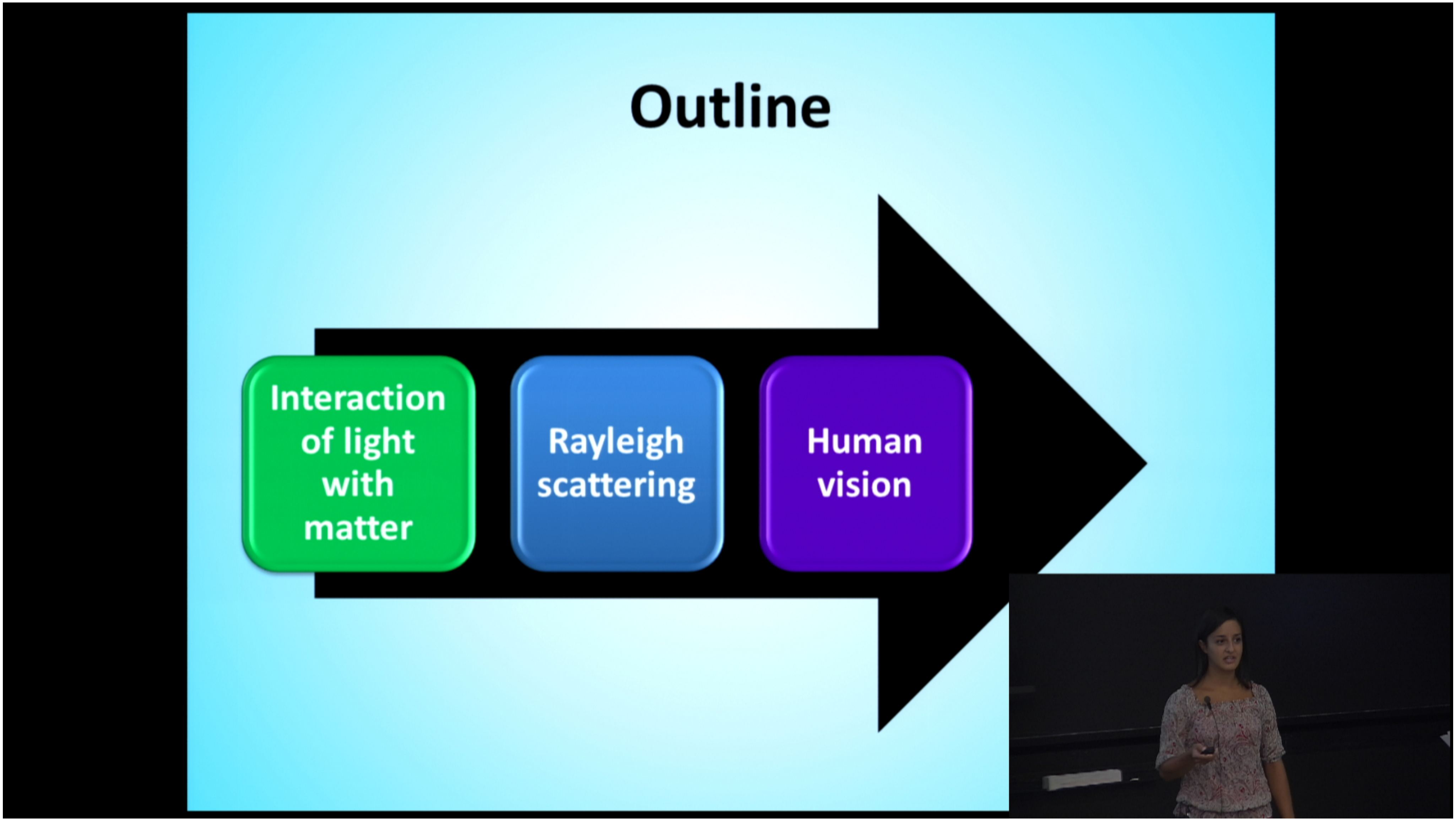
Why is the sky blue?

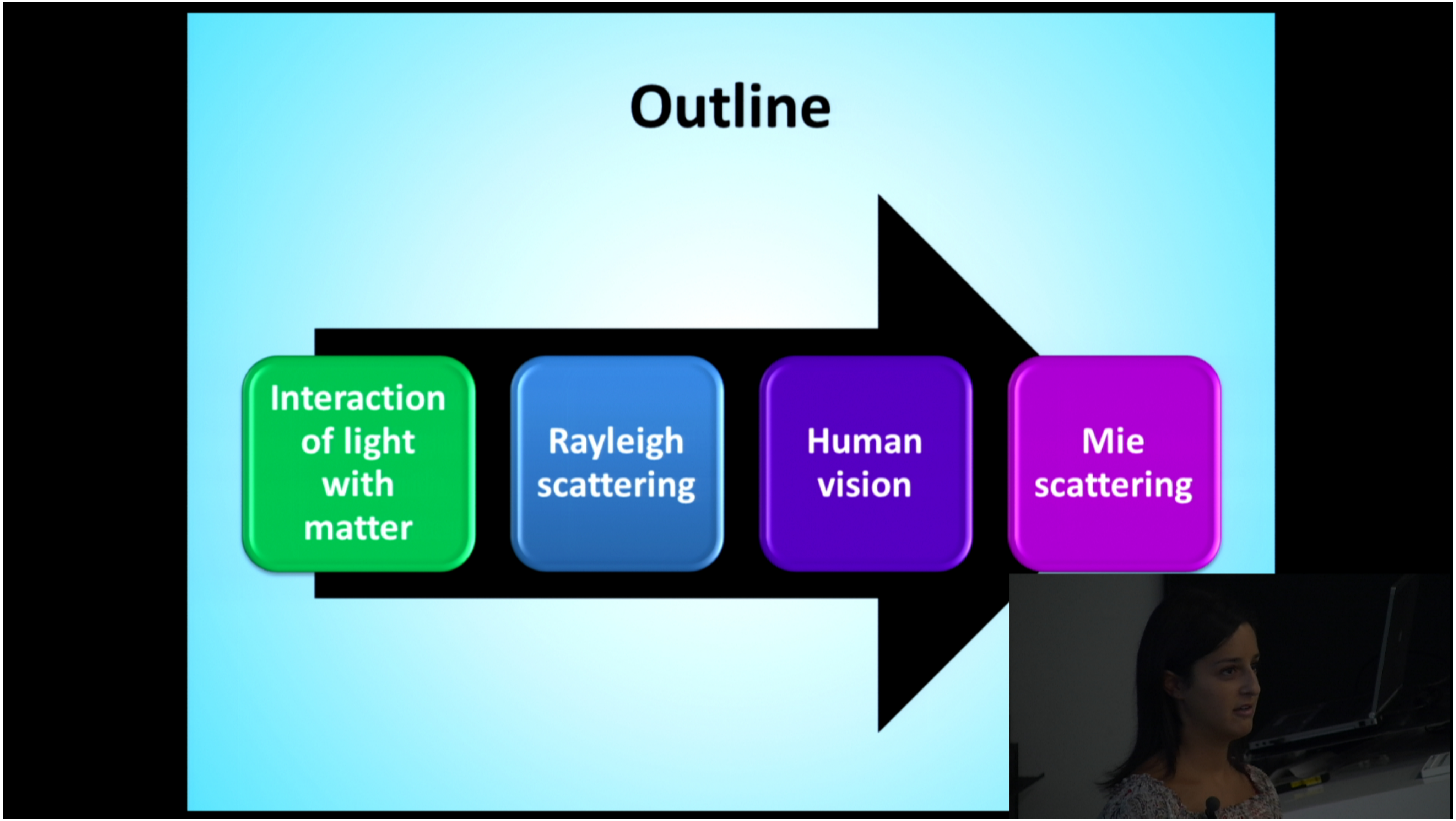
Why is the sun white/yellow at midday, but redder during sunset and sunrise?



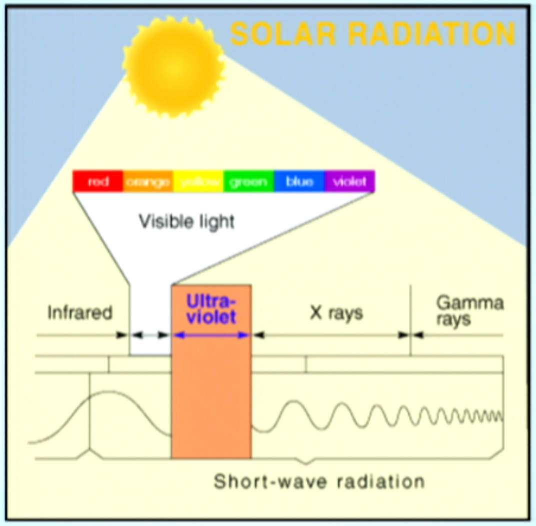

Outline
Interaction of light with matter


Outline
Interaction of light with matter
Rayleigh scattering

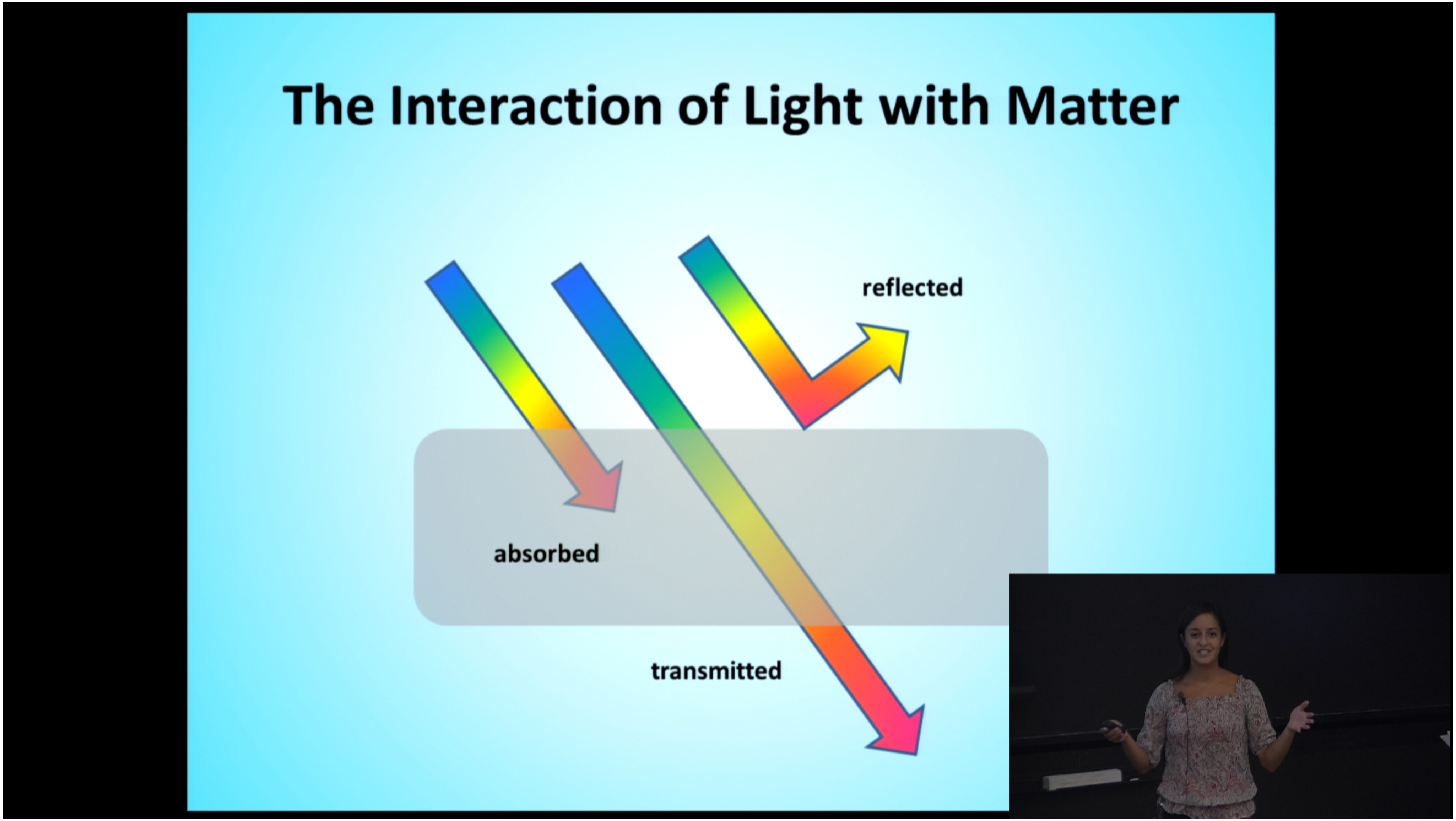

Outline
Interaction of light with matter
Rayleigh scattering
Human vision


Outline
Interaction of light with matter
Rayleigh scattering
Human vision
Mie scattering

Light From the Sun

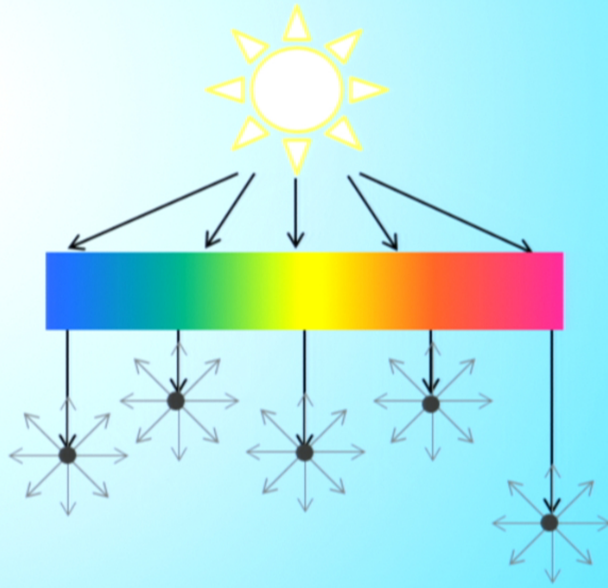


Picture source:
http://serc.carleton.edu/usingdata/nasaimages/index4.html


The Interaction of Light with Matter
reflected
absorbed
transmitted

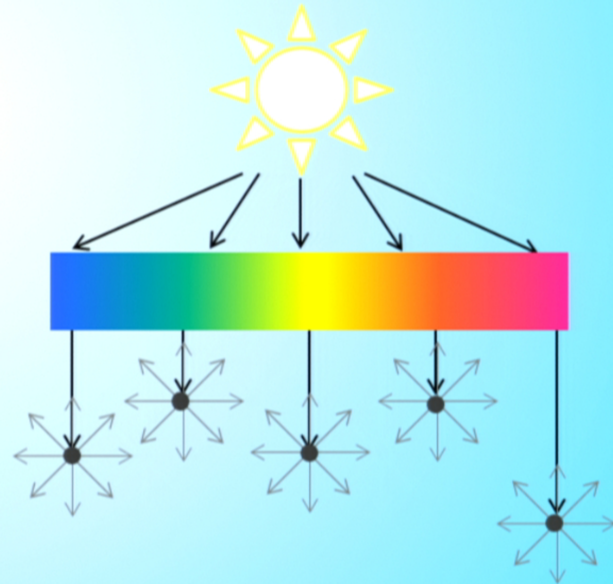
The Interaction of Light with Matter

The Interaction of Solar Light with the Atmosphere



The Interaction of Solar Light with the Atmosphere

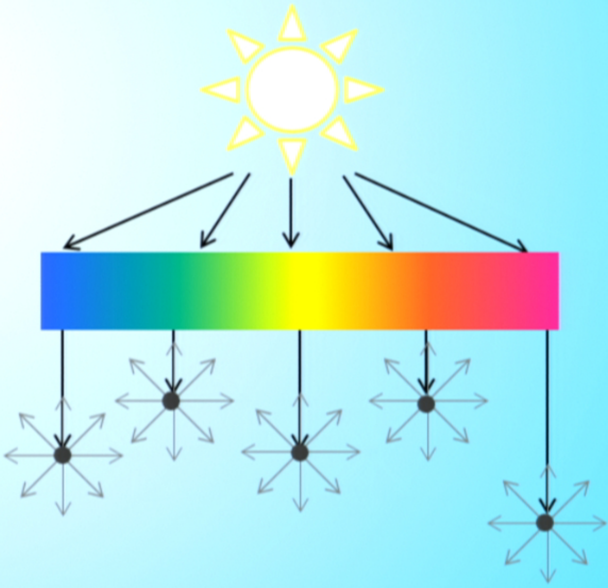
- Solar radiation is scattered by particles in the atmosphere



The Interaction of Solar Light with the Atmosphere

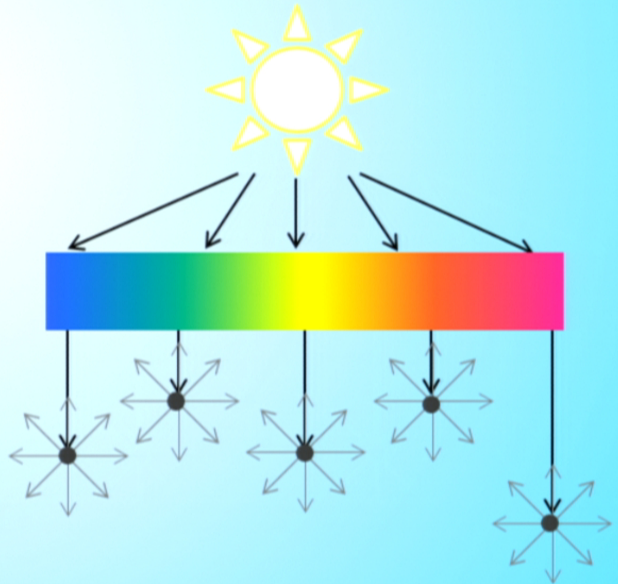
- Solar radiation is scattered by particles in the atmosphere

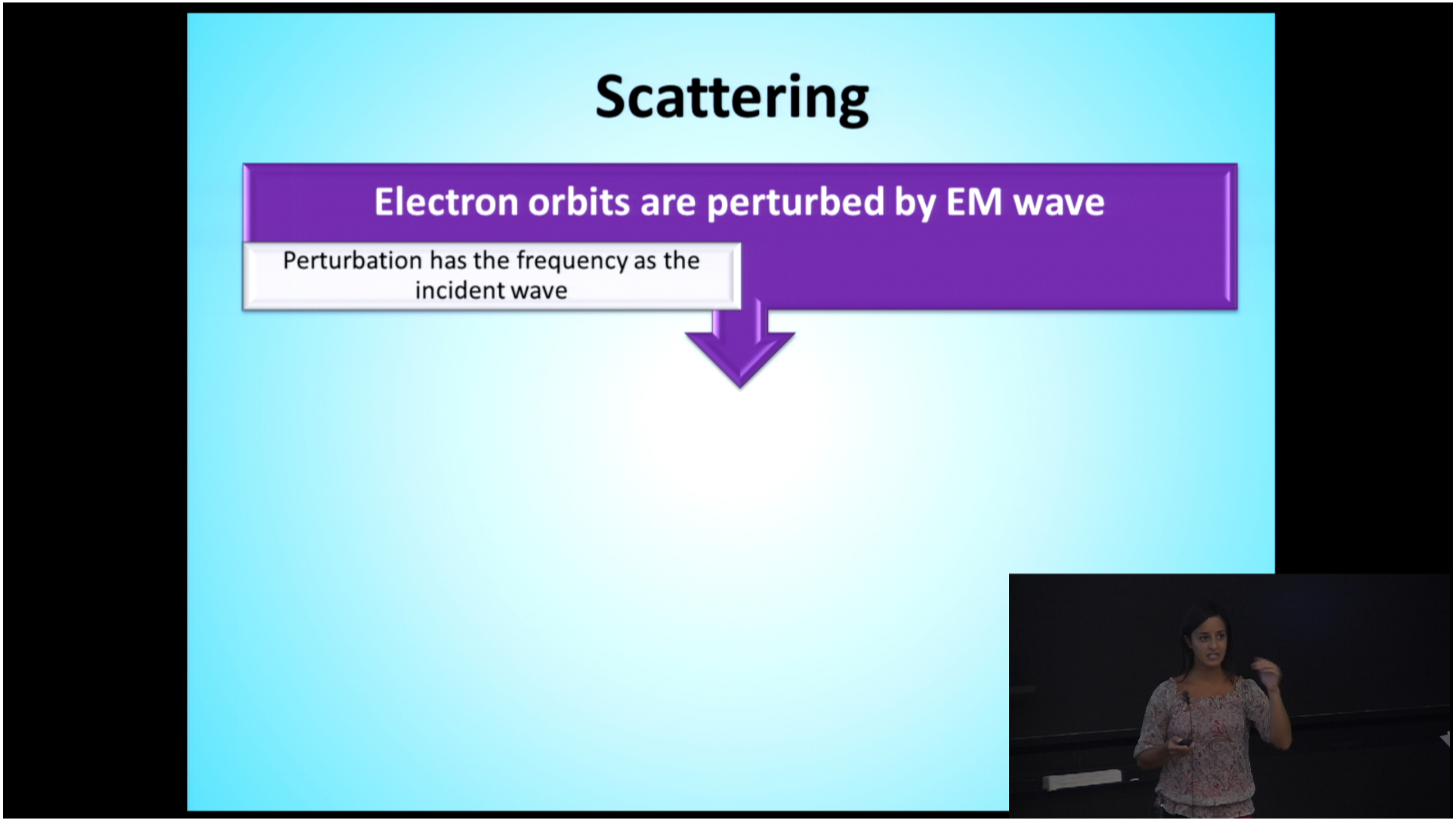
- Two types:
  - Rayleigh scattering
  - Mie scattering



The Interaction of Solar Light with the Atmosphere

- Solar radiation is scattered by particles in the atmosphere
- Two types:
  - Rayleigh scattering
  - Mie scattering
- These are elastic processes

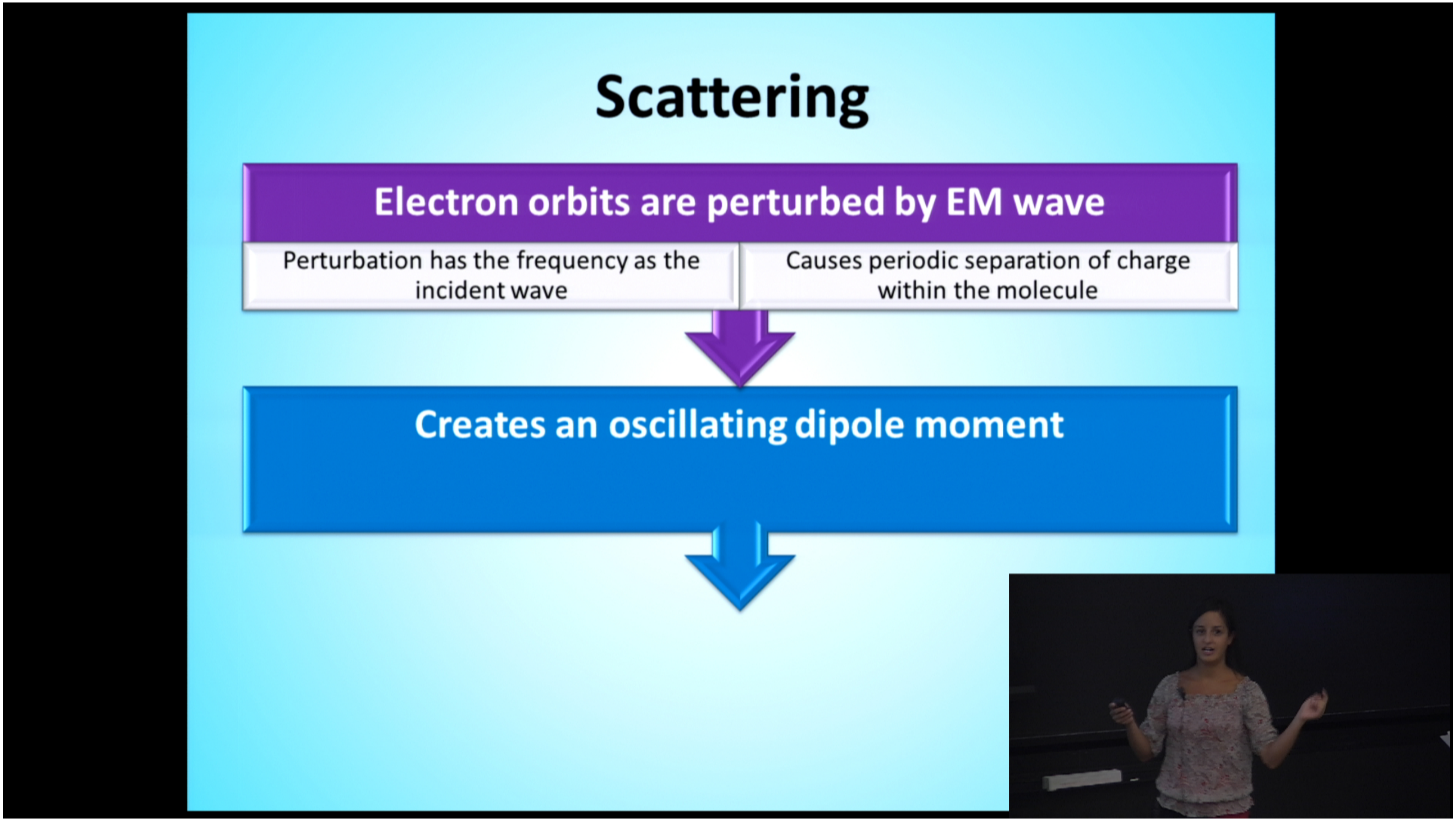


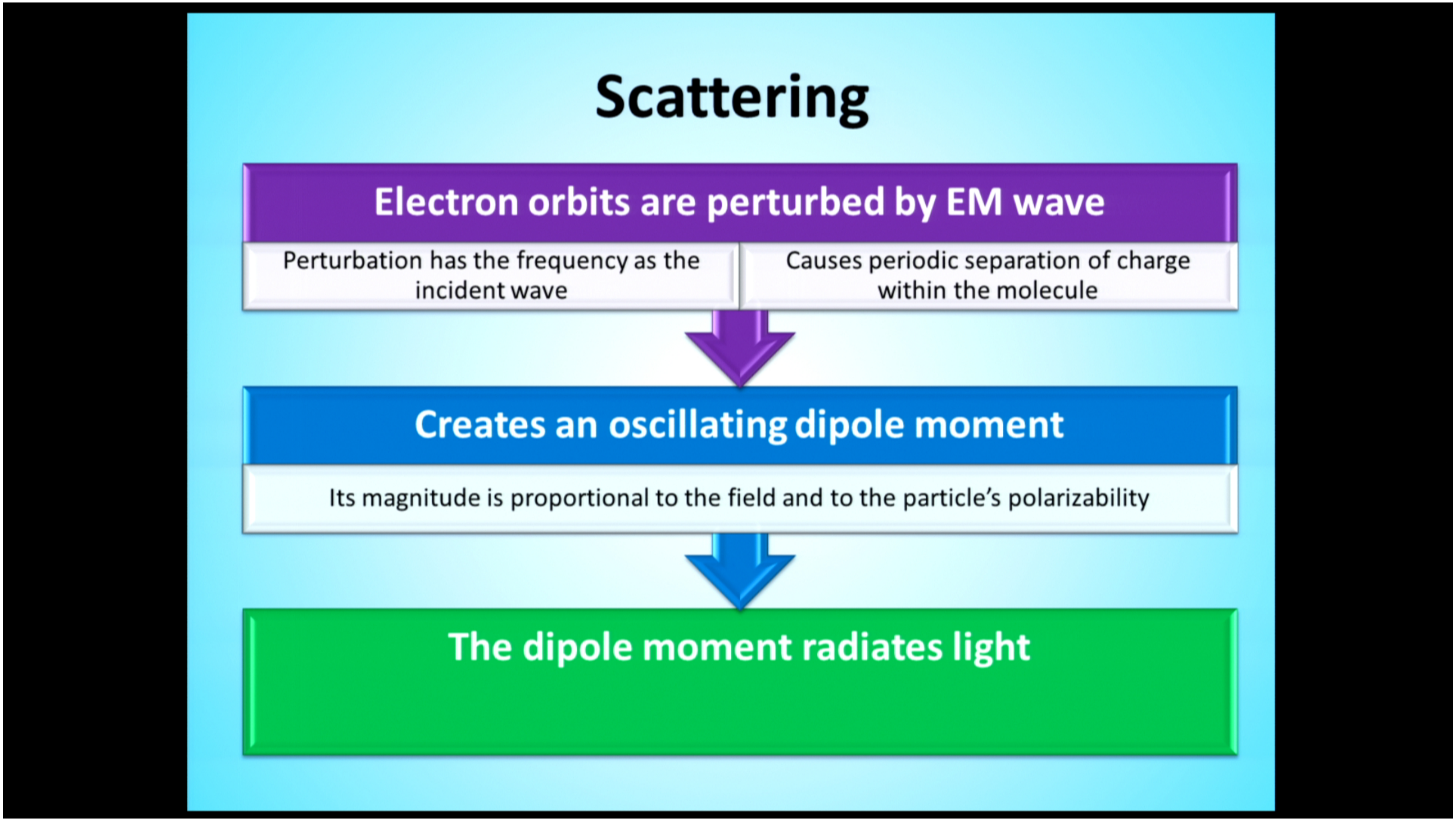

Scattering
Electron orbits are perturbed by EM wave
Perturbation has the frequency as the incident wave

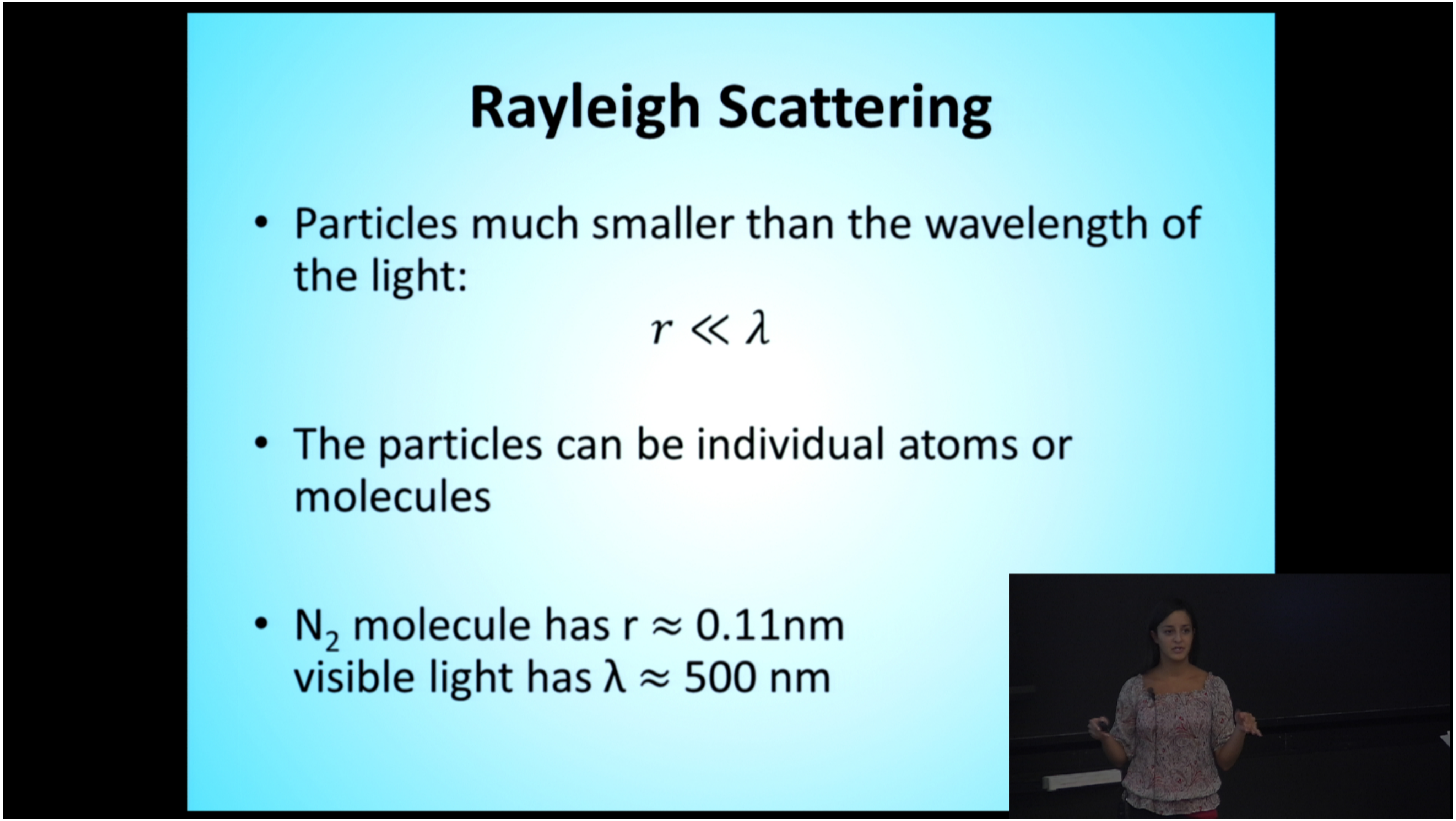
Scattering

Electron orbits are perturbed by EM wave

Perturbation has the frequency as the incident wave	Causes periodic separation of charge within the molecule


Scattering
Electron orbits are perturbed by EM wave
Perturbation has the frequency as the incident wave
Causes periodic separation of charge within the molecule
Creates an oscillating dipole moment


Scattering
Electron orbits are perturbed by EM wave
Perturbation has the frequency as the incident wave
Causes periodic separation of charge within the molecule
Creates an oscillating dipole moment
Its magnitude is proportional to the field and to the particle's polarizability
The dipole moment radiates light


Rayleigh Scattering
• Particles much smaller than the wavelength of the light:
$r \ll \lambda$
• The particles can be individual atoms or molecules
• N_2 molecule has $r \approx 0.11$nm
visible light has $\lambda \approx 500$ nm

Rayleigh Scattering

- The Intensity of light scattered by a single molecule is given by

$$I = I_0 \frac{8\pi^4 \alpha^2}{\lambda^4 R^2} (1 + \cos^2 \theta)$$

I_0 is the light's intensity   α is the molecular polarizability
λ is the wavelength R is the distance to the particle
θ is the scattering angle

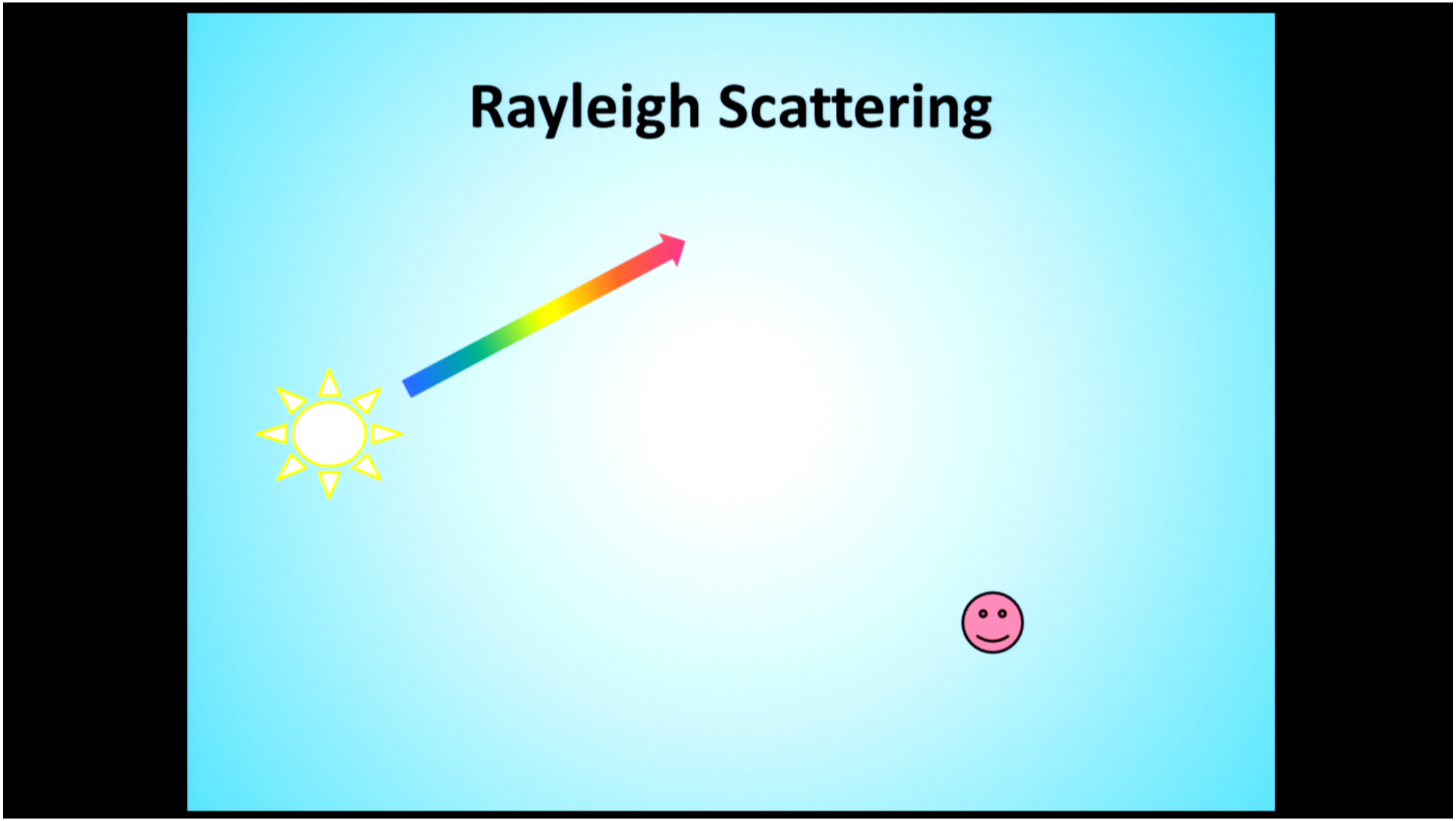
Seinfeld and Pandis, *Atmospheric Chemistry and Physics, 2nd Edition*, John Wiley and Sons, New Jersey 2006, Chapter 15.1.1

Rayleigh Scattering

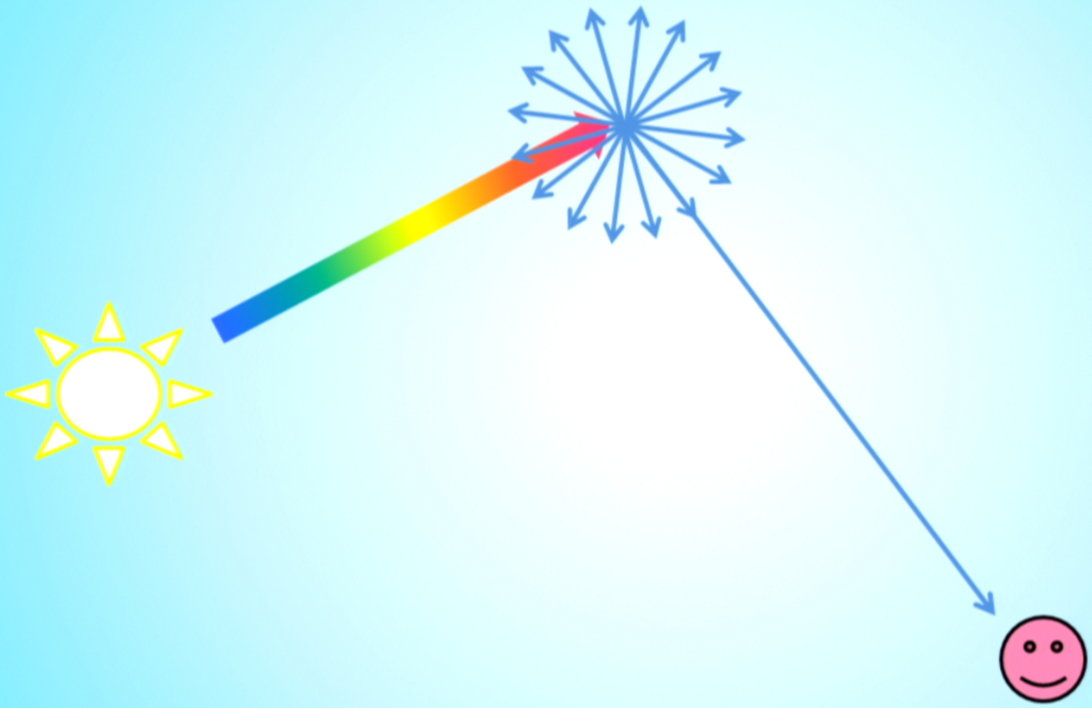
400nm 700nm

Scattered the most Scattered the least

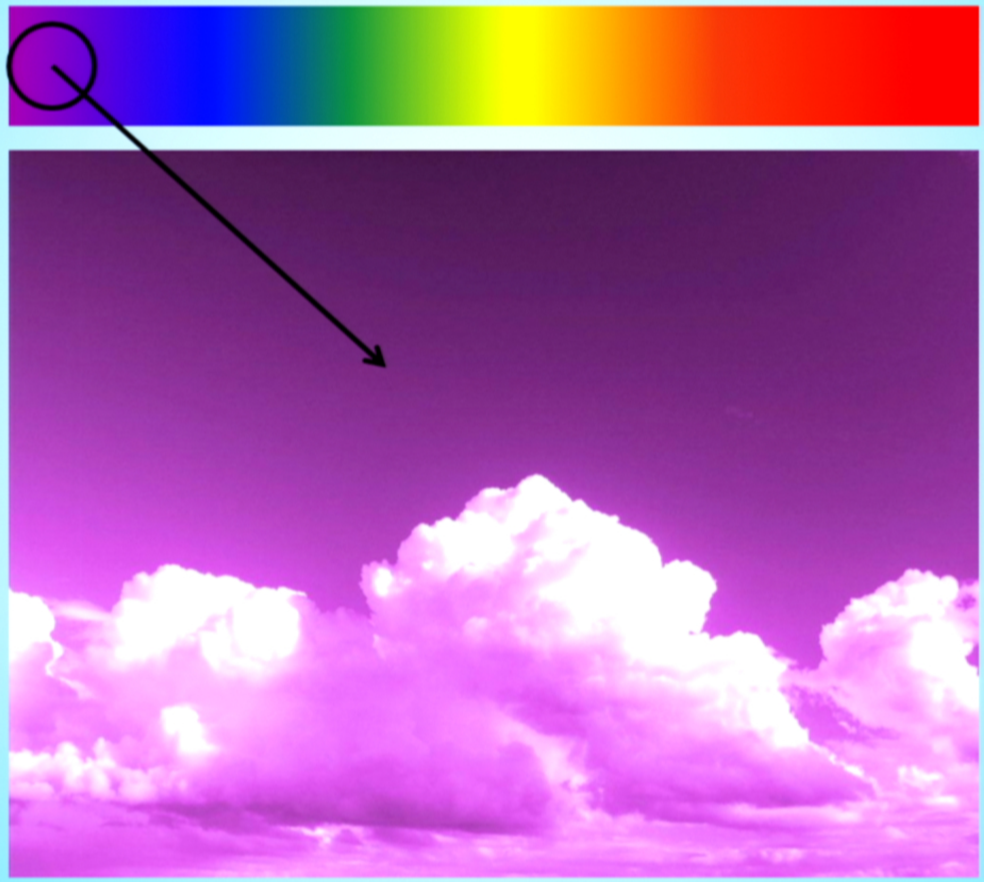
~9.4 x more scattering

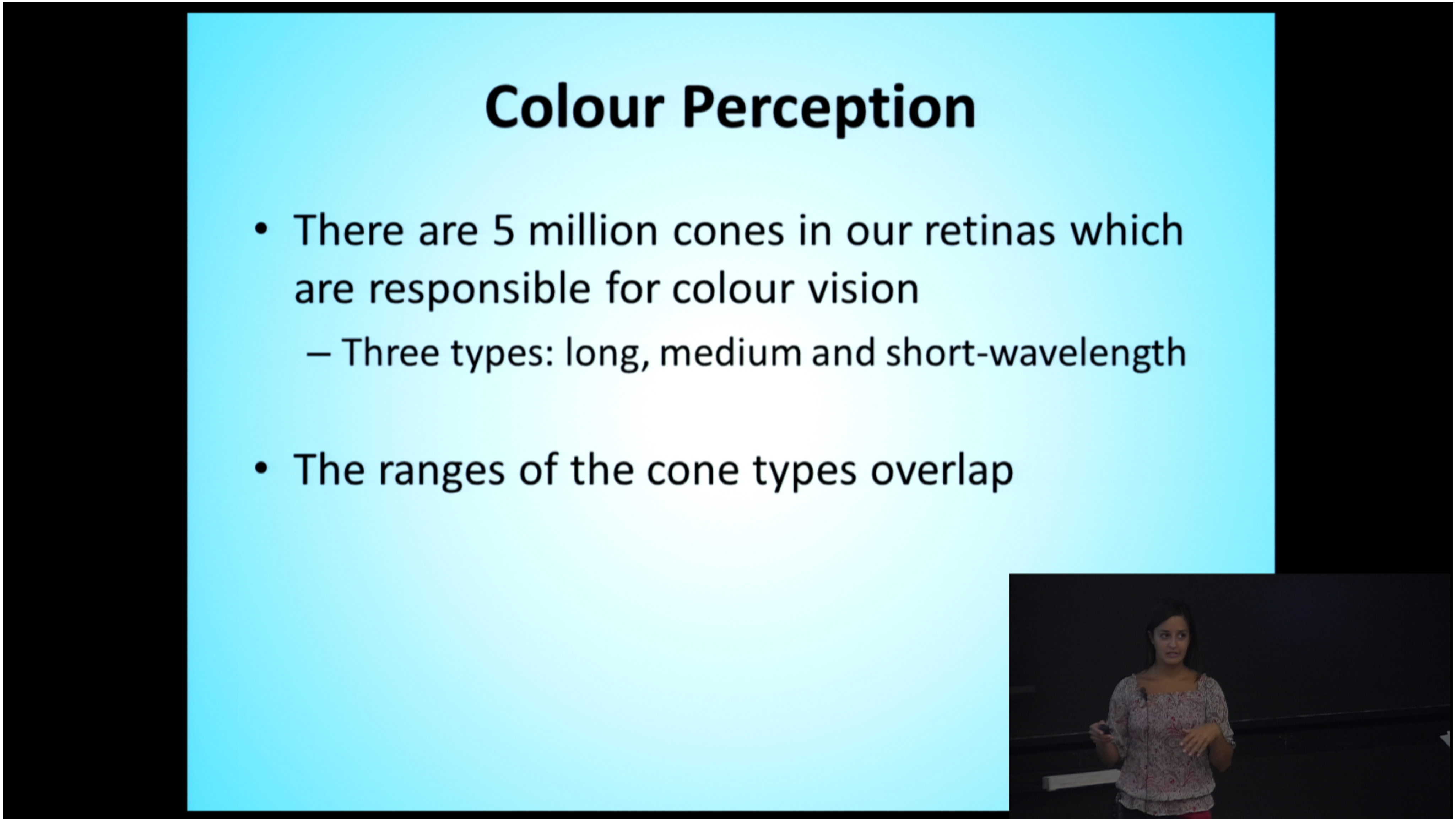

Rayleigh Scattering

Rayleigh Scattering



Why isn't the sky purple?

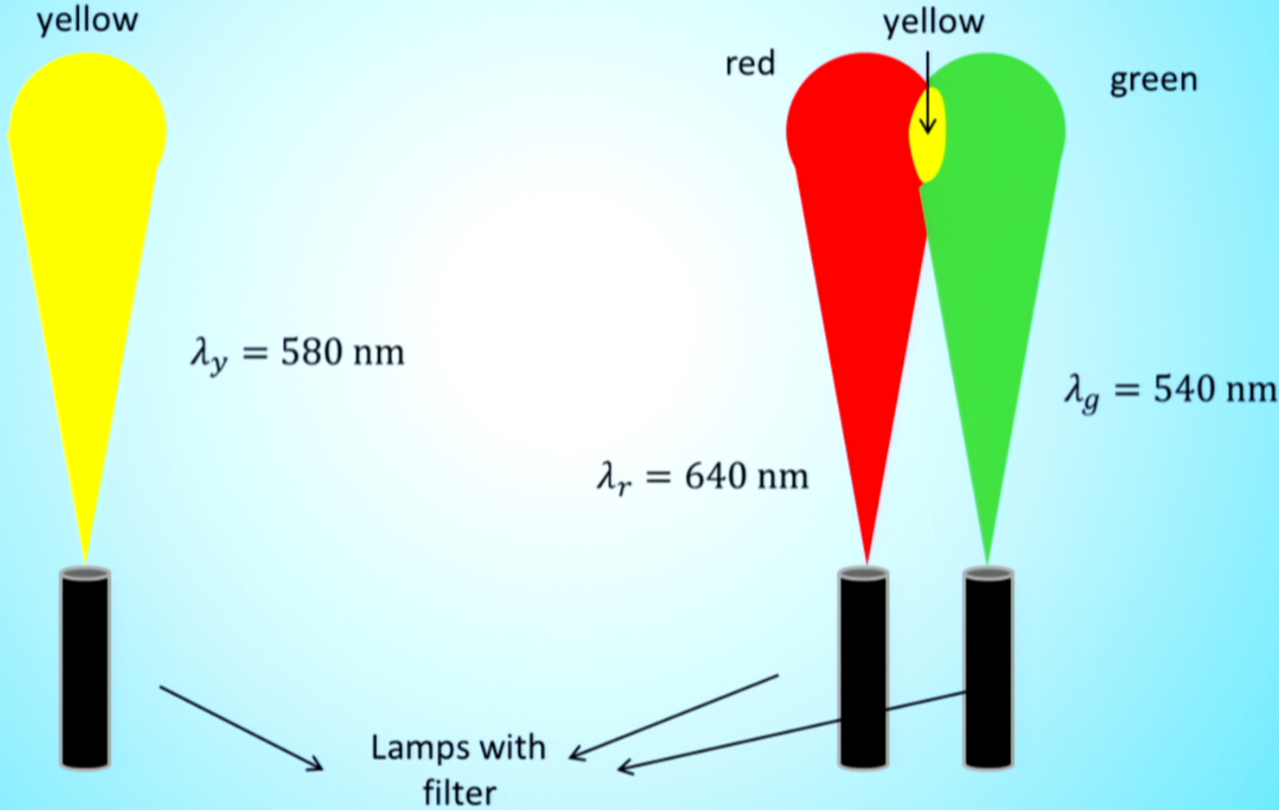



Colour Perception
• There are 5 million cones in our retinas which are responsible for colour vision
– Three types: long, medium and short-wavelength
• The ranges of the cone types overlap

Colour Perception

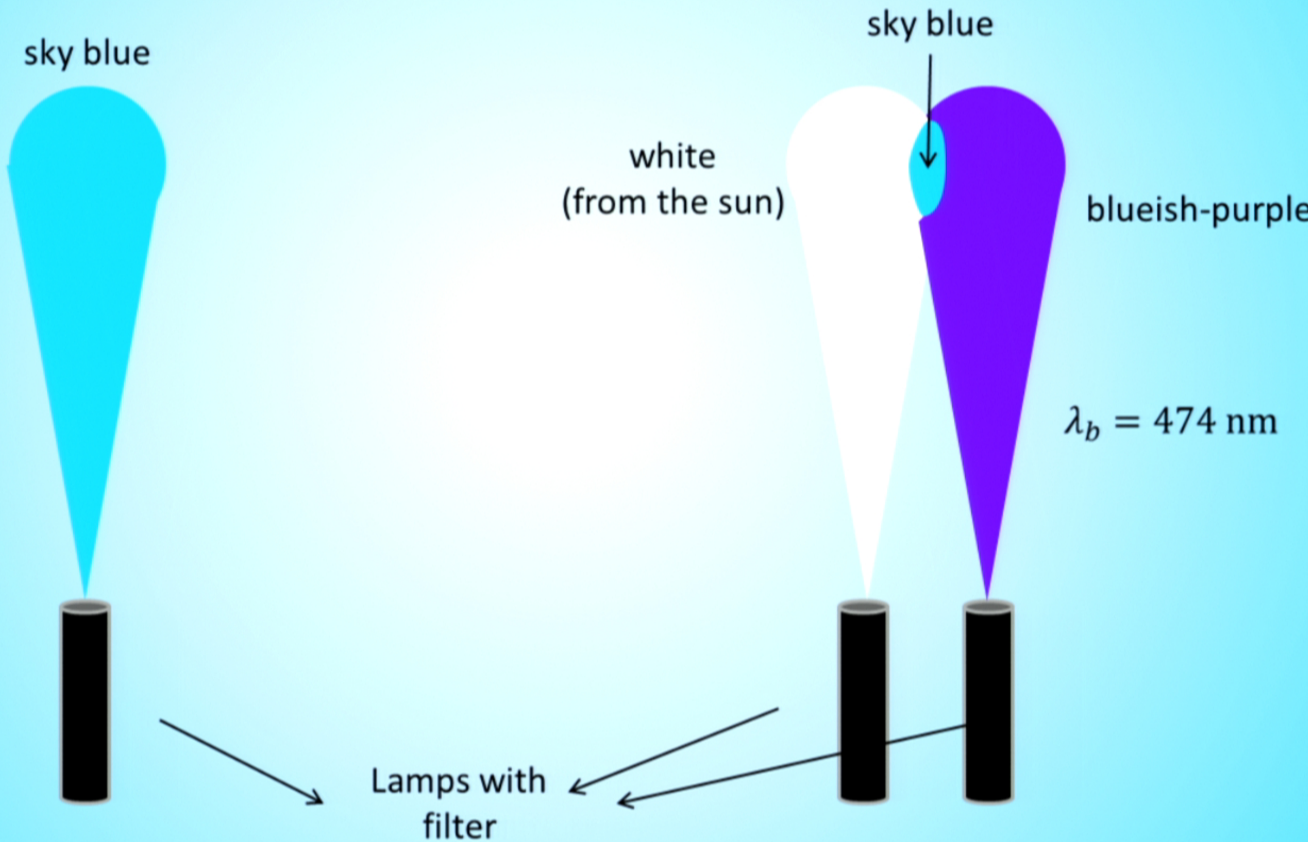
- There are 5 million cones in our retinas which are responsible for colour vision
  - Three types: long, medium and short-wavelength
- The ranges of the cone types overlap
- Different spectral combinations can be detected as the same colour

Colour Matching Experiment

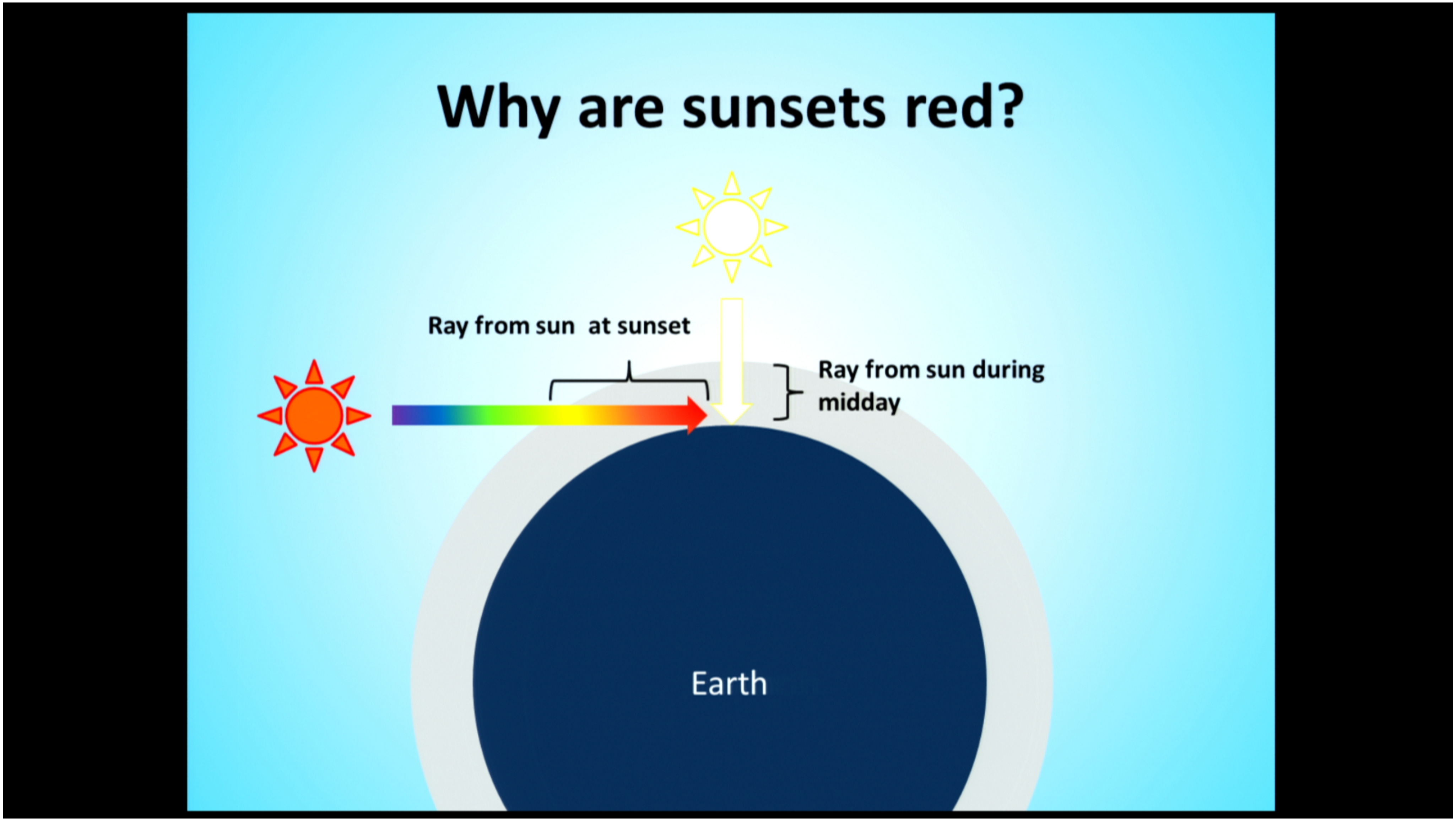


Smith, Glenn S. "Human Color Vision and the Unsaturated Blue Color of the Daytime Sky." *American Journal of Physics* 73.7 (2005): 590.

Colour Matching Experiment

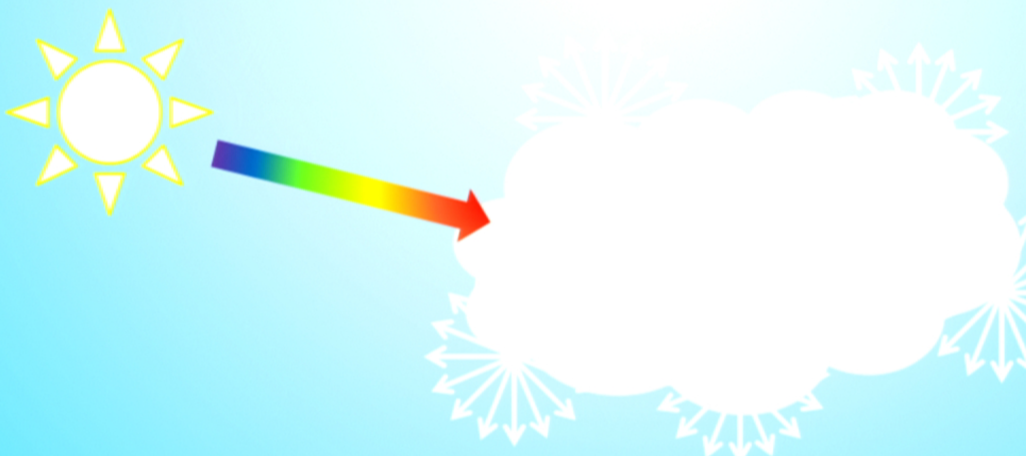


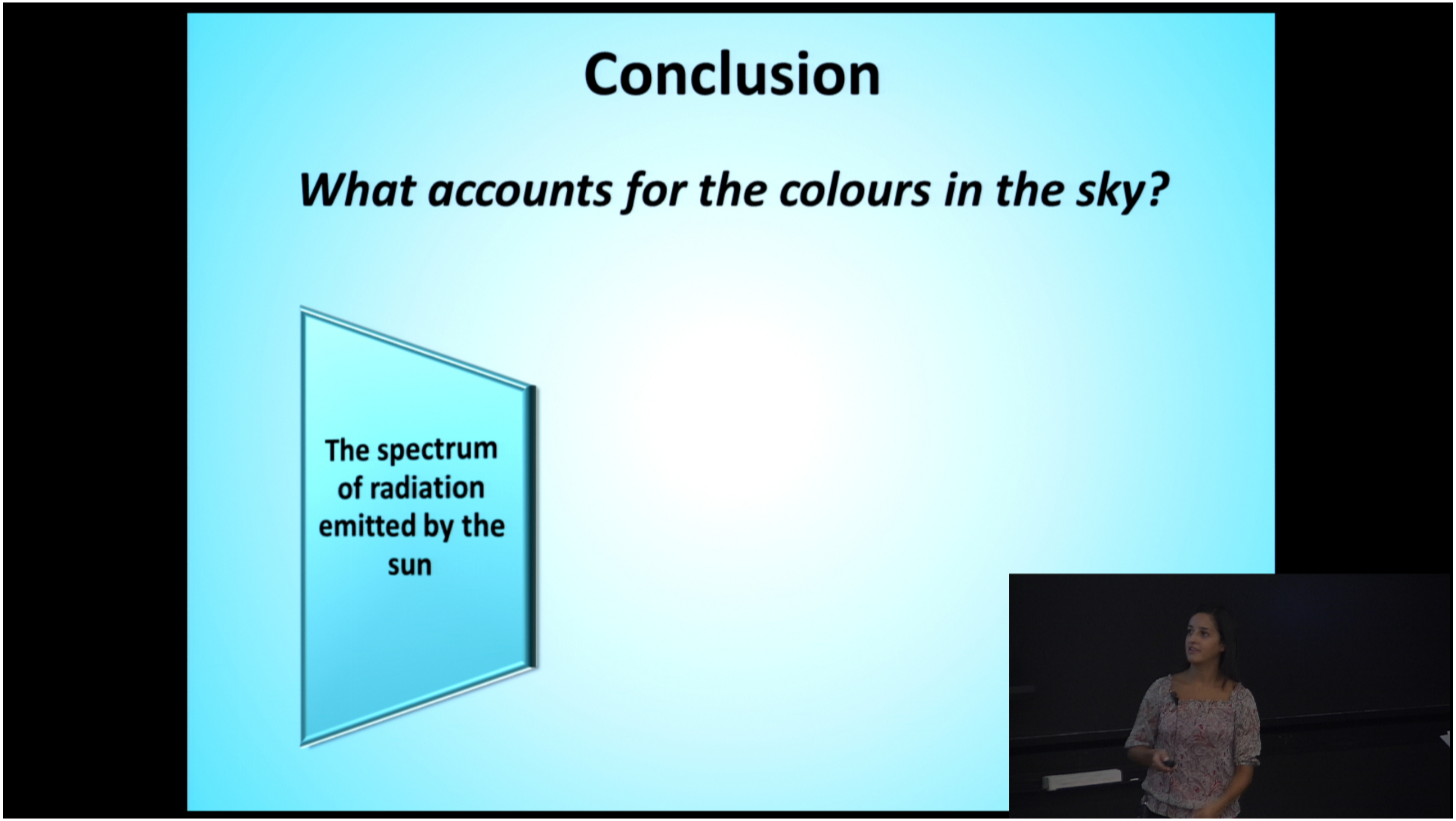
Smith, Glenn S. "Human Color Vision and the Unsaturated Blue Color of the Daytime Sky." *American Journal of Physics* 73.7 (2005): 590.

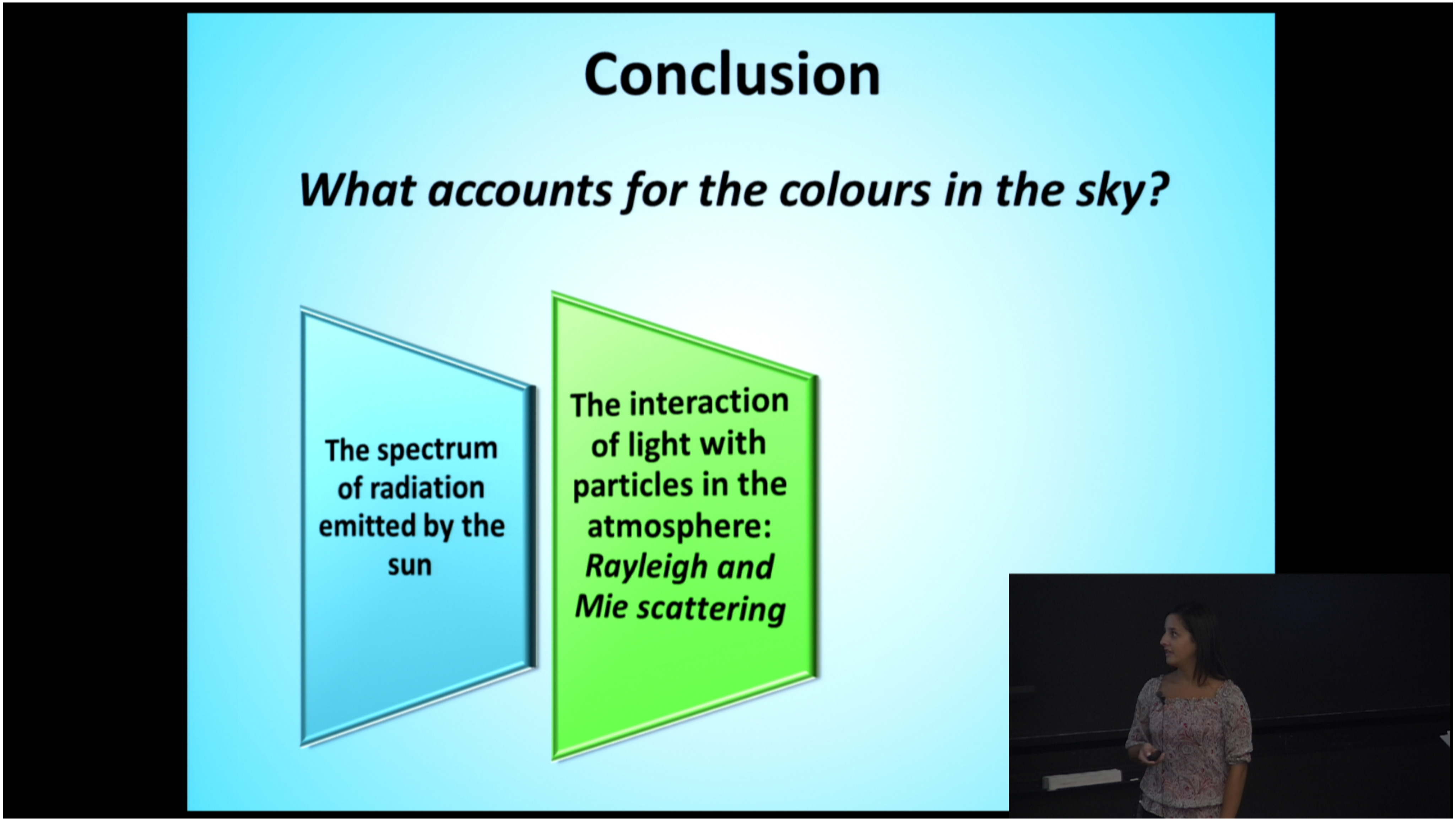

Why are sunsets red?
Ray from sun at sunset
Ray from sun during
midday
Earth

Mie Scattering

- size of the particle $\geq$ wavelength
- Not heavily wavelength dependent in the visible range
- Produces the white light from clouds, mist and fog
- Rayleigh scattering is just an approximation to Mie scattering in the limit of small particle size.




Conclusion
What accounts for the colours in the sky?
The spectrum of radiation emitted by the sun


Conclusion
What accounts for the colours in the sky?
The spectrum of radiation emitted by the sun
The interaction of light with particles in the atmosphere: Rayleigh and Mie scattering

Conclusion

What accounts for the colours in the sky?

The spectrum of radiation emitted by the sun

The interaction of light with particles in the atmosphere: *Rayleigh and Mie scattering*

Human colour vision


THE
END

Physics in Nature: A Birdseye View

Perimeter Scholars International 2012/2013
Daniel Xavier Ogburn

"To see a world in a grain of sand,
And a heaven in a wild flower,
Hold infinity in the palm of your hand,
And eternity in an hour."

- William Blake: Auguries of Innocence

perimeter scholars international

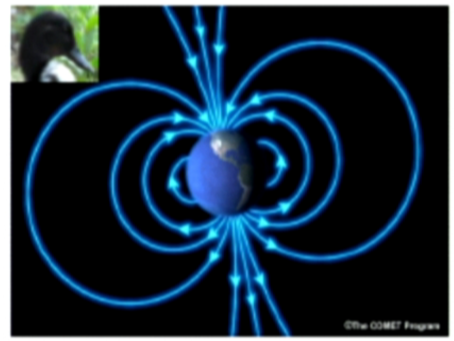
1:56 PM

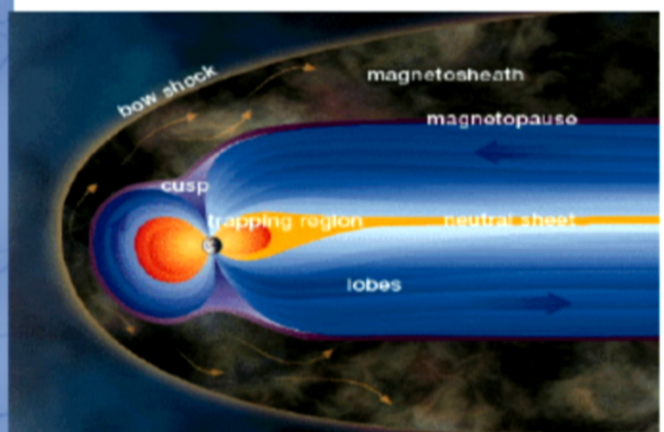
What are you looking at?

Or what are *they looking at* …?

Magnetic Navigation: Just Wing It

- Many bird species migrate
  - e.g. Ducks and Geese in Waterloo
  - Changing photoperiod
  - Weather, food, habitat
- ~ 50 known animal species use Earth's magnetic field to navigate.





- Earth's magnetic field:
  - Background dipole ~ 50μT (stable, long time scales).
  - Solar wind perturbation (dayside/nightside tail).
  - Plasma waves & resonances in magnetosphere and ionosphere: ~ short (s) nT pertbuation.

The Avian Compass: Nature's Magnetometer

- Humans:
  -Compass

  -Aeromagnetic survey:
  Fluxgate magnetometer (~0.2nT)

  Cesium vapor magnetometers (QM, Zeeman ~ 0.01nT)

- How do Migratory Birds navigate?
  - Klaus Schulten 1970s: geomagnetically sensitive biochemical reaction in eye
  - Cryptocrome protein molecule.
  - Photons → Cryptocrome energy boost → …

Fancy some entanglement?

- **“iMagnetometer”**

  Photons → Eye →
  Cryptocrome energy boost →
  Free Radical Pair →
  Entangled Electrons (separated, but spins linked) →
  Hypersensitivity to Magnetic Fields →
  Chemical Reactions →
  Magneto-reception and the Avian Compass.

- Nature: QM entanglement in warm, noisy environment!
  vs
- Humans: QM entanglement in isolated, cryogenic setting without noise.

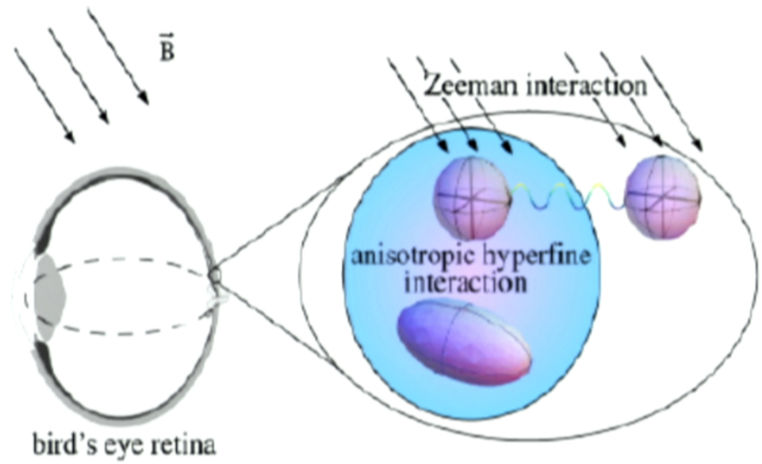
Fancy more entanglement?

- Sense variations < 0.3% of Earth's magnetic field strength ~ 150 nT! (Conservative model used by Gauger et al).
- Experiments of Ritz et al. sensitivity as low as ~ 15nT (European robin).

- Bird "sees" the magnetic field.
- Requires electrons to be entangled for ~ 100 μs.
- No cryogenics, outperforms NaC0^{60} by at least 20μs !
- Robust sensor (training, protected by noise).

A Radical Notion: The RP Mechanism

- Quantum Evolution of spatially separated pair of e^- spins after energized by photon.
- Two e^- spins and one nuclear spin.
- Spheroid - directionality



- Spatial separation: Nucleus interacts with one spin
  - Asymmetry for singlet-triplet oscillations.
  - RP formation at t=0, Hamiltonian for system after separation.
  - one e^- coupled to nucleus, one e^- ~'free (Gauger et al.)

$$H = \hat{I} \cdot \mathbf{A} \cdot \hat{S}_1 + \gamma \mathbf{B} \cdot (\hat{S}_1 + \hat{S}_2)$$

Radical Pair Mechanism (2)

- Gauger et al. also Investigated more detailed models:
  -e.g. add 2nd nuclear spin, replace nuclear asymmetry with anisotropic g-factor for e^- .

- All models give rise to same qualitative behavior and decoherence timescales as the simple RP model.

- **Underlying principle**: e^- spins of RP must be protected from decoherence to be susceptible to the experimentally applied RF magnetic field.

- External magnetic field: $\mathbf{B} = \mathbf{B}_0 + \cos(\omega t)\mathbf{B}_{rf}$

- At Frankfurt: $B_0 \sim 47\mu T$.
  Experiment and Simulation: B_{rf} =150nT.

2:02 PM
17-Aug-12

Radical Pair Mechanism (2)

- Gauger et al. also Investigated more detailed models: -e.g. add 2nd nuclear spin, replace nuclear asymmetry with anisotropic g-factor for e^- .
- All models give rise to same qualitative behavior and decoherence timescales as the simple RP model.
- **Underlying principle**: e^- spins of RP must be protected from decoherence to be susceptible to the experimentally applied RF magnetic field.
- External magnetic field: $\mathbf{B} = \mathbf{B}_0 + \cos(\omega t)\mathbf{B}_{rf}$
- At Frankfurt: $B_0 \sim 47\mu T$.
  Experiment and Simulation: B_{rf} =150nT.

Time Evolution: Master Equation

- Resonant excitation with uncoupled e^- spin: $\mathbf{B}_{rf}$ frequency 1.316MHz.
- 8-dimensional Hilbert space of 3 spins (entangled electrons + nucleus)
  - 2 singlet projectors and 3 triplet projectors P_i
- Model dynamics with Linblad Master Equation (density matrix):

$$\dot{\rho} = -\frac{i}{\hbar}[H, \rho] + k\sum_{i=1}^{8} P_i \rho P_i^\dagger - \frac{1}{2}(P_i^\dagger P_i \rho + \rho P_i^\dagger P_i).$$

- Decay rate *k* for projectors.
- Solve for density matrix ρ.

Entanglement + Background Noise = Good Times

- Choosing constants:

  - Resonance frequency of the 'free' electron = 1.316MHz.

  - Experiments show a 1.316MHz perturbing magnetic field can disorient the bird.

  - No disruption if B_{rf} is parallel to B_0.

- Resulting bound on decay rate: $k \leq 10^4\ s^{-1}$.
- Consistent with long RP lifetimes for cryptochrome molecules in migratory birds.
- Q: How robust is this mechanism against environmental noise?
  A: Random noise actually *protects against* decohorence!
- Anti-intuitive: Human experiments achieve entanglement by using cryogenic temperatures and minimizing noise.

EN 2:03 PM 17-Aug-12

Entanglement + Background Noise = Good Times

- Choosing constants:

  - Resonance frequency of the 'free' electron = 1.316MHz.

  - Experiments show a 1.316MHz perturbing magnetic field can disorient the bird.

  - No disruption if B_{rf} is parallel to B_0.

- Resulting bound on decay rate: $k \leq 10^4 \, s^{-1}$.
- Consistent with long RP lifetimes for cryptochrome molecules in migratory birds.
- Q: How robust is this mechanism against environmental noise?
  A: Random noise actually *protects against* decohorence!
- Anti-intuitive: Human experiments achieve entanglement by using cryogenic temperatures and minimizing noise.

Modeling Noise

- Add Linblad dissipator to Linblad Master Equation:

$$\dot{\rho} = -\frac{i}{\hbar}[H,\rho] + k\sum_{i=1}^{8} P_i \rho P_i^{\dagger} - \frac{1}{2}(P_i^{\dagger} P_i \rho + \rho P_i^{\dagger} P_i) \text{ + Noise}$$

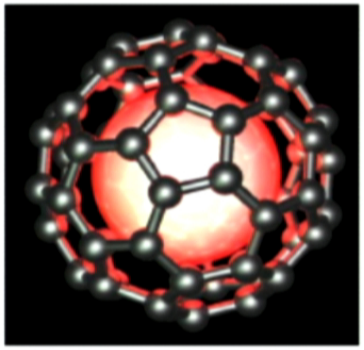
$$\text{Noise} = \sum_i \Gamma_i \left(L_i \rho L_i^{\dagger} - \frac{1}{2}(L_i^{\dagger} L_i \rho + \rho L_i^{\dagger} L_i) \right)$$

- Noise Operators L_i and their decoherence rate Γ_i .
- Conservative estimate: when $\Gamma \geq k$ angular sensitivity degrades.
- Implies that the decoherence time for the two-electron avian compass is of the order of 100µS or more.

Bird vs Scientists

- Avian compass decoherence time (at room temp.) ≥ ~ 100μS.
- Best decoherence time achieved in a laboratory at room temp for preservation of a molecular electron spin state: 80μS for NaC^{60}.

>



- Compass mechanism is almost immune to phase noise.
- If strong phase is present t the level of Gamma ~ >= 10k it would actually render the bird immune to weak RF magnetic perburations!

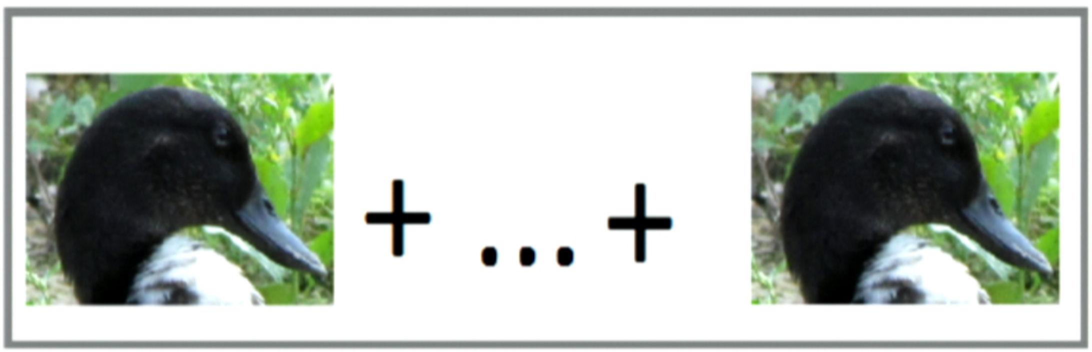
Applications: Quantum Computing

- Imitate nature:

  - Entangled states with long lifetimes at room temp.

Intel Pentium X

=



Quantum Biology: More Examples

- Photosynthesis:
  - Classically invalid pathways
  - Photoelectric effect
  - Photoelectron entanglement, Hamiltonian least path calculation in Chlorophyll to reach target molecule.

- Sunlight: Fusion, QM tunneling through Coulomb barrier.

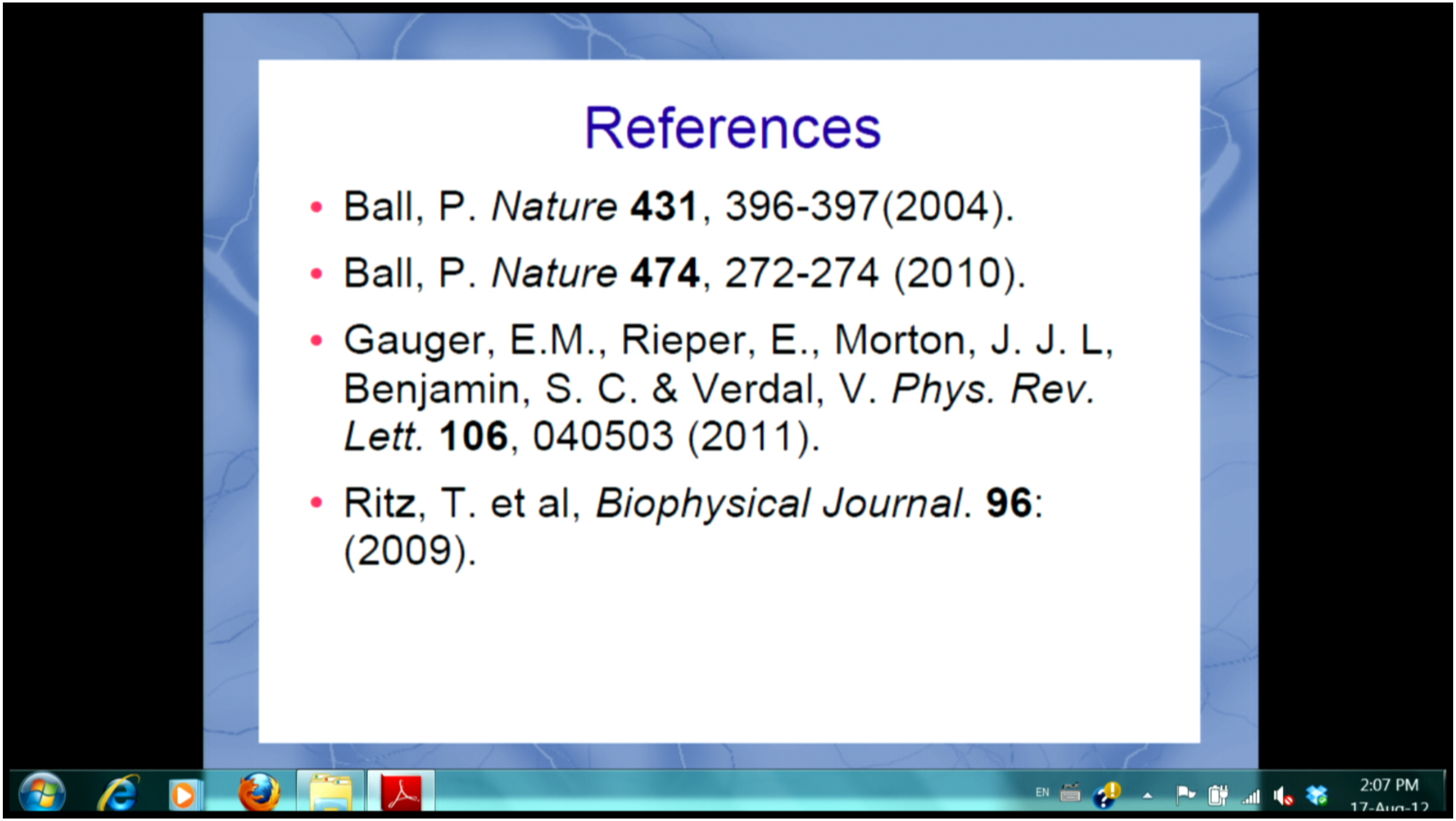
- Sense of Smell: entanglement (debated).

- Cats in boxes.

Thanks for Listening[1]!

perimeter scholars
international™

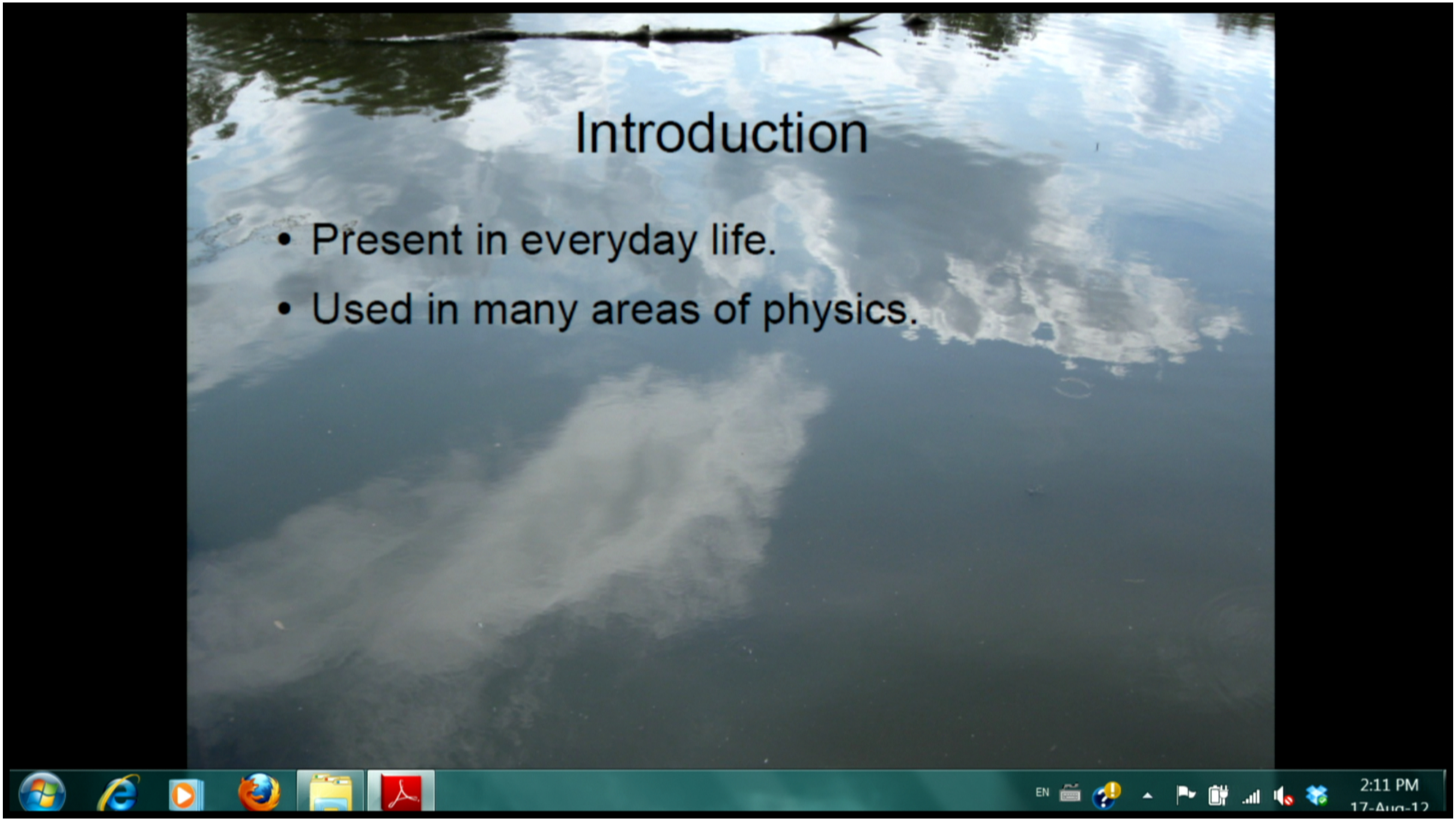
[1] No birds were harmed in this presentation.

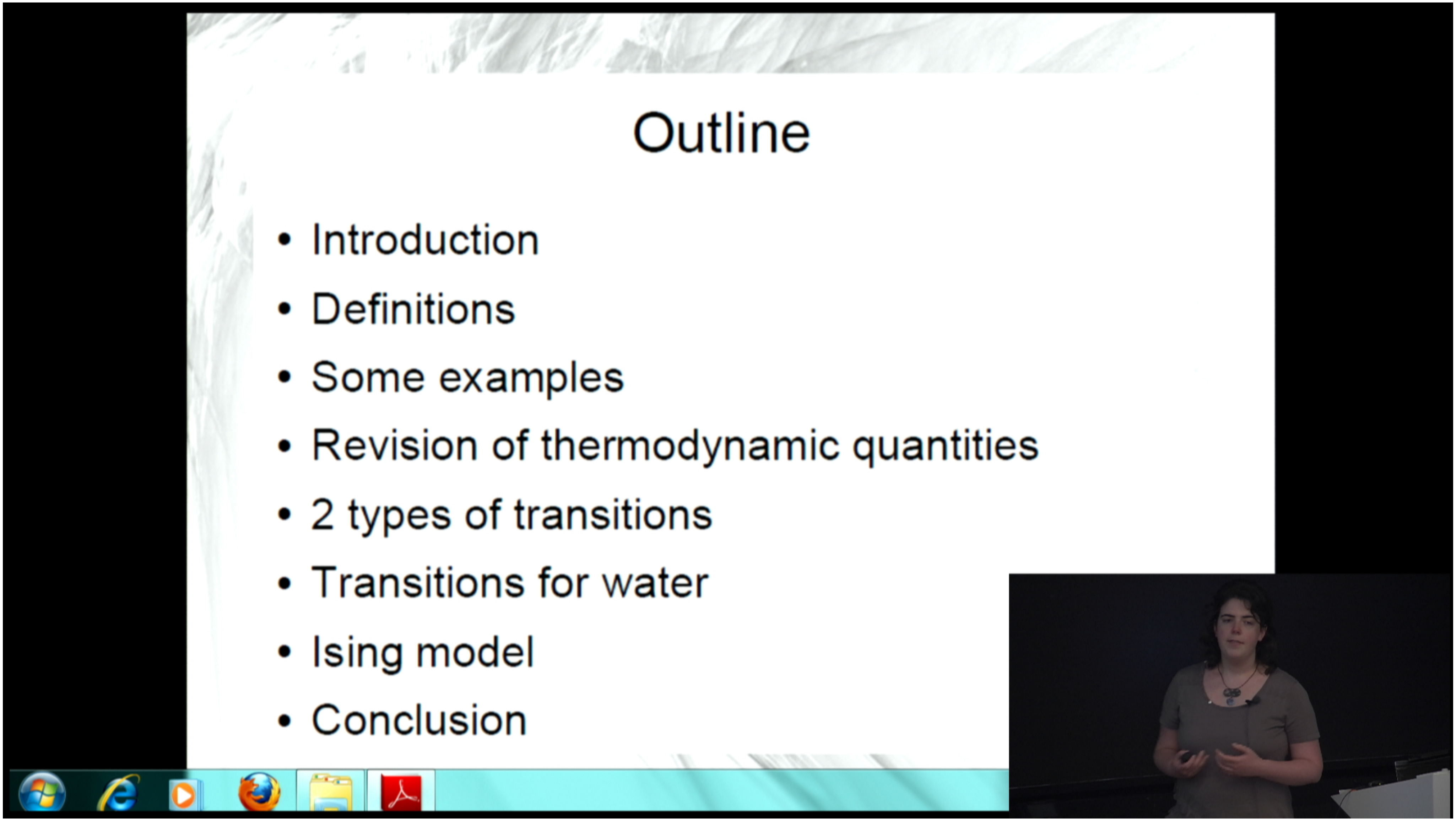

References
• Ball, P. Nature 431, 396-397(2004).
• Ball, P. Nature 474, 272-274 (2010).
• Gauger, E.M., Rieper, E., Morton, J. J. L, Benjamin, S. C. & Verdal, V. Phys. Rev. Lett. 106, 040503 (2011).
• Ritz, T. et al, Biophysical Journal. 96: (2009).
EN
2:07 PM

Physics in nature: Phase transitions

Presentation by Dominique Soutière

perimeter scholars international™


Introduction
• Present in everyday life.
• Used in many areas of physics.
EN
2:11 PM


Outline
• Introduction
• Definitions
• Some examples
• Revision of thermodynamic quantities
• 2 types of transitions
• Transitions for water
• Ising model
• Conclusion

Definitions

- Phase: An homogeneous system.
- A phase transition usually occurs by varying external conditions.
- Characteristic by a discontinuity in one of the derivatives of a thermodynamic property.
- Order parameter: A quantity that varies from 0 to a non-zero value during the transition.

Some examples

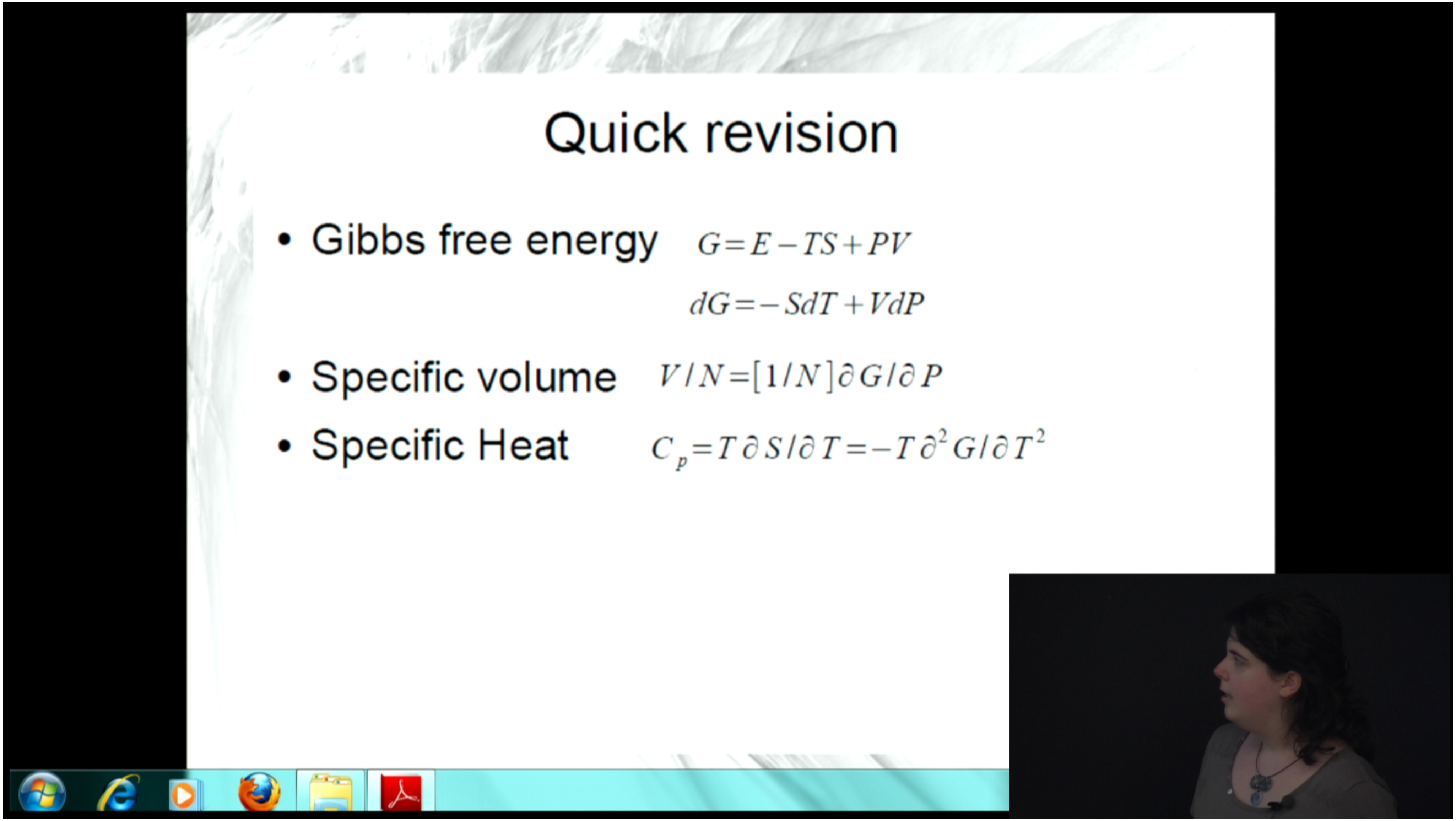
- Solid, liquid, gas and plasma
- Ferromagnetic and paramagnetic solids
- Superconductivity and superfluidity
- Breaking of symmetries (cosmology)

Quick revision

- Gibbs free energy $G = E - TS + PV$

  $dG = -SdT + VdP$

- Specific volume $V/N = [1/N]\partial G/\partial P$
- Specific Heat $C_p = T\partial S/\partial T = -T\partial^2 G/\partial T^2$


Quick revision
• Gibbs free energy $G = E - TS + PV$
$dG = -SdT + VdP$
• Specific volume $V/N = [1/N]\partial G/\partial P$
• Specific Heat $C_p = T\partial S/\partial T = -T\partial^2 G/\partial T^2$

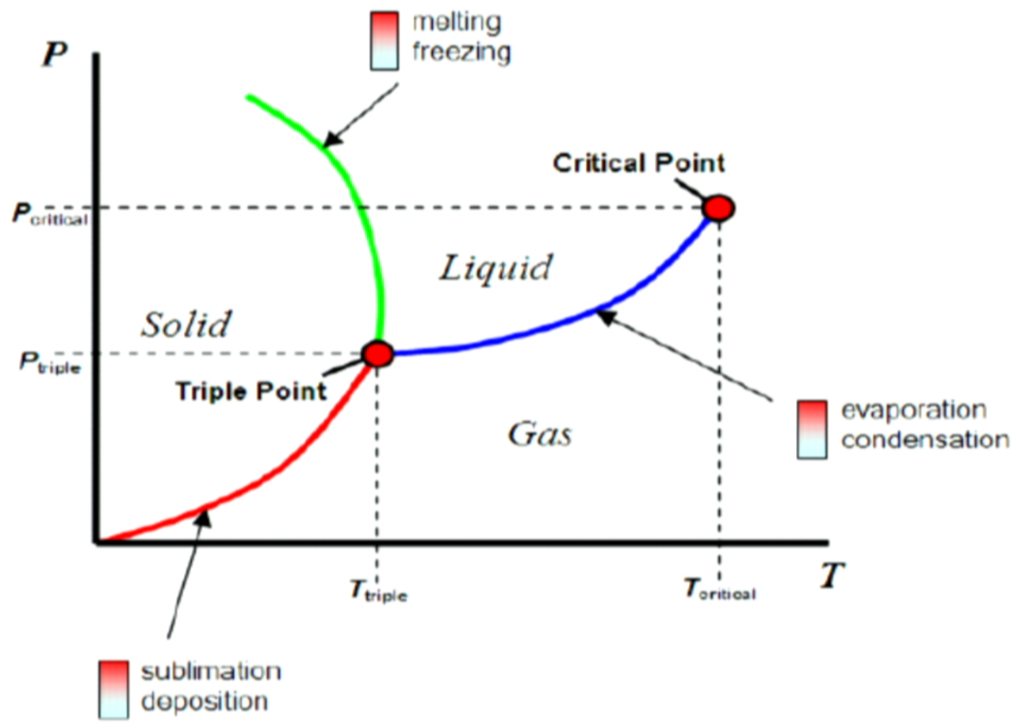
1^{st} order transitions

- A first derivative of the Energy is discontinuous.
- Latent heat: Fixed amount of energy absorbed or released.
- In liquid-gas transition below the critical point, the specific volume is discontinuous.

2^{nd} order transitions

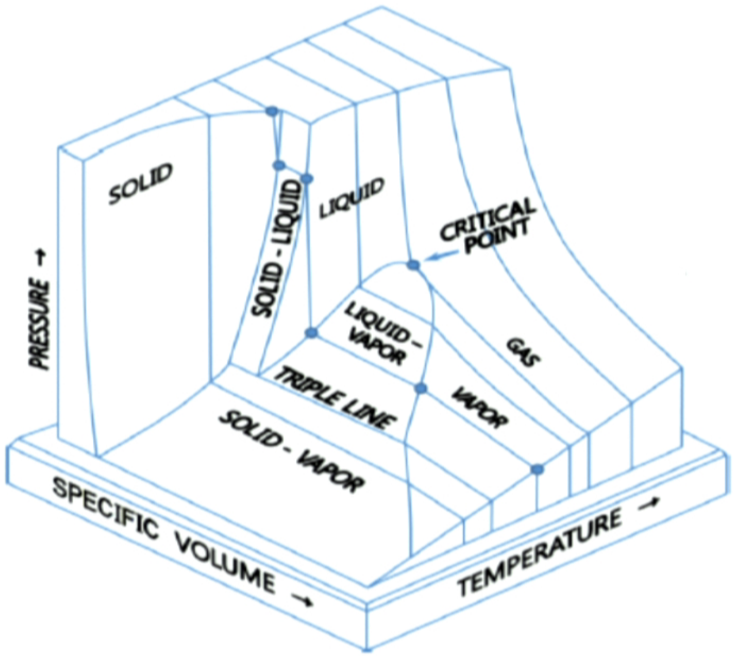
- A second derivative of the Energy is discontinuous.
- In liquid-gas transition beyond the critical point, the specific volume is continuous but the heat capacity is discontinuous

Transitions for water



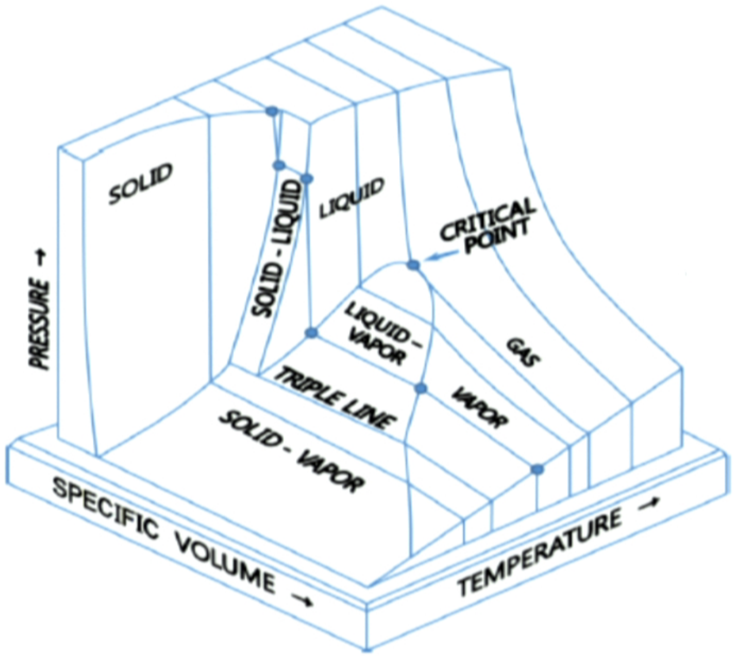
Ian O'Neill, http://www.marspedia.org

Transitions for water



Donald L. Smith, Addison-Wesley Publishing Co, 1950,1953.

Transitions for water

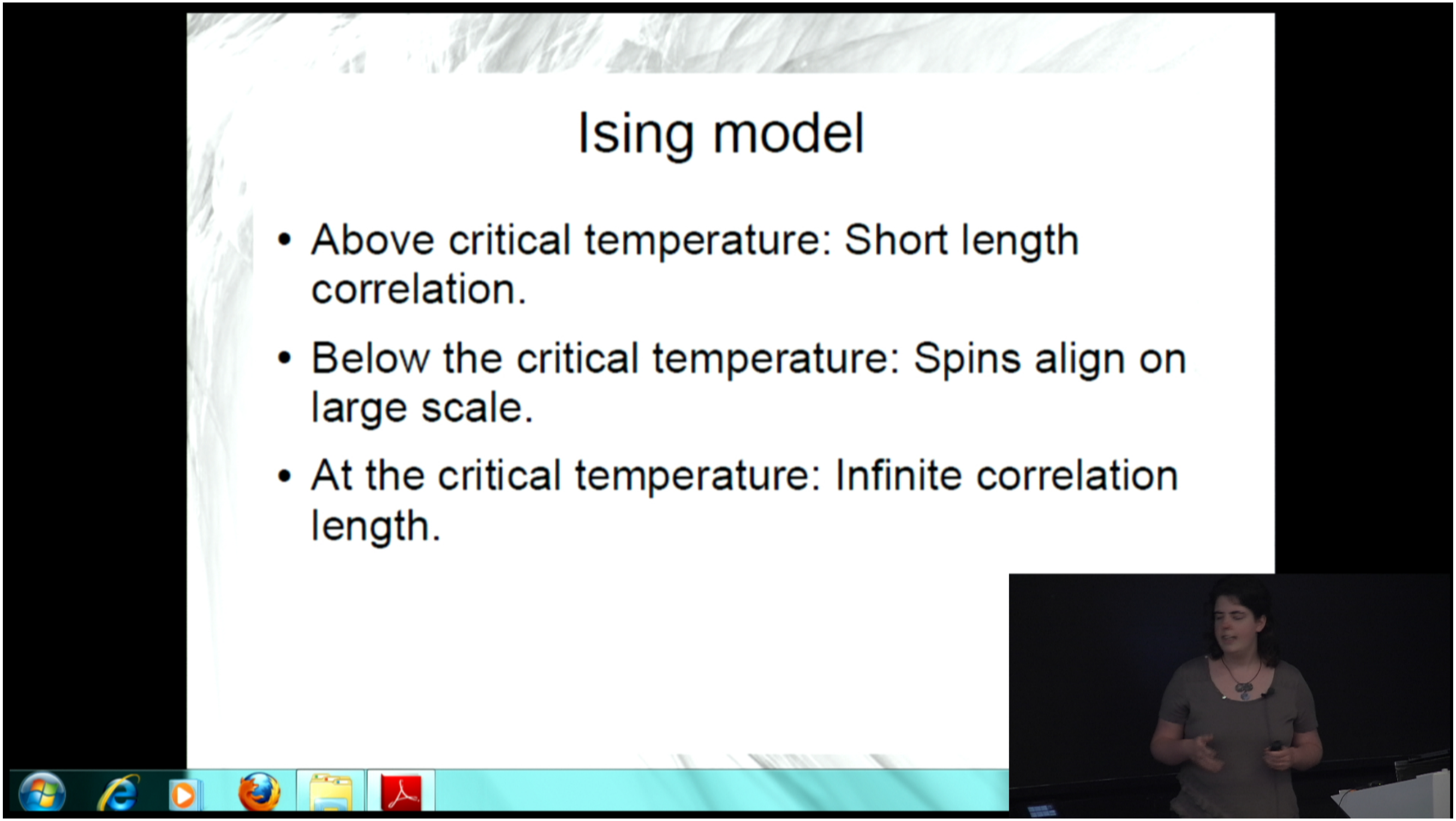


Donald L. Smith, Addison-Wesley Publishing Co, 1950,1953.

Ising model

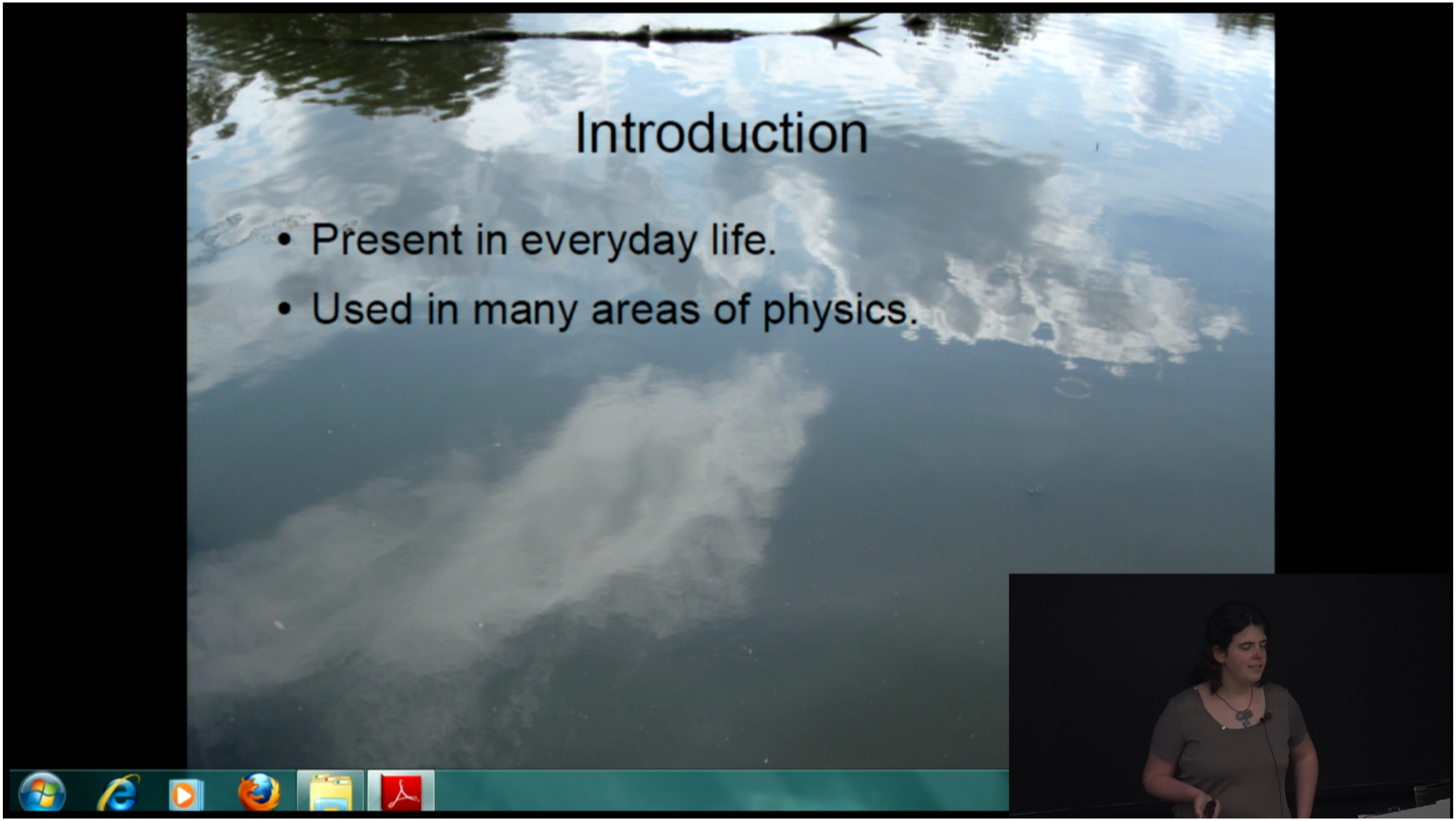
- Model of interacting particles in 2D placed on a square lattice.
- Short range spin interaction, 2 possible alignment.
- Energetic advantage to have nearby spins aligned

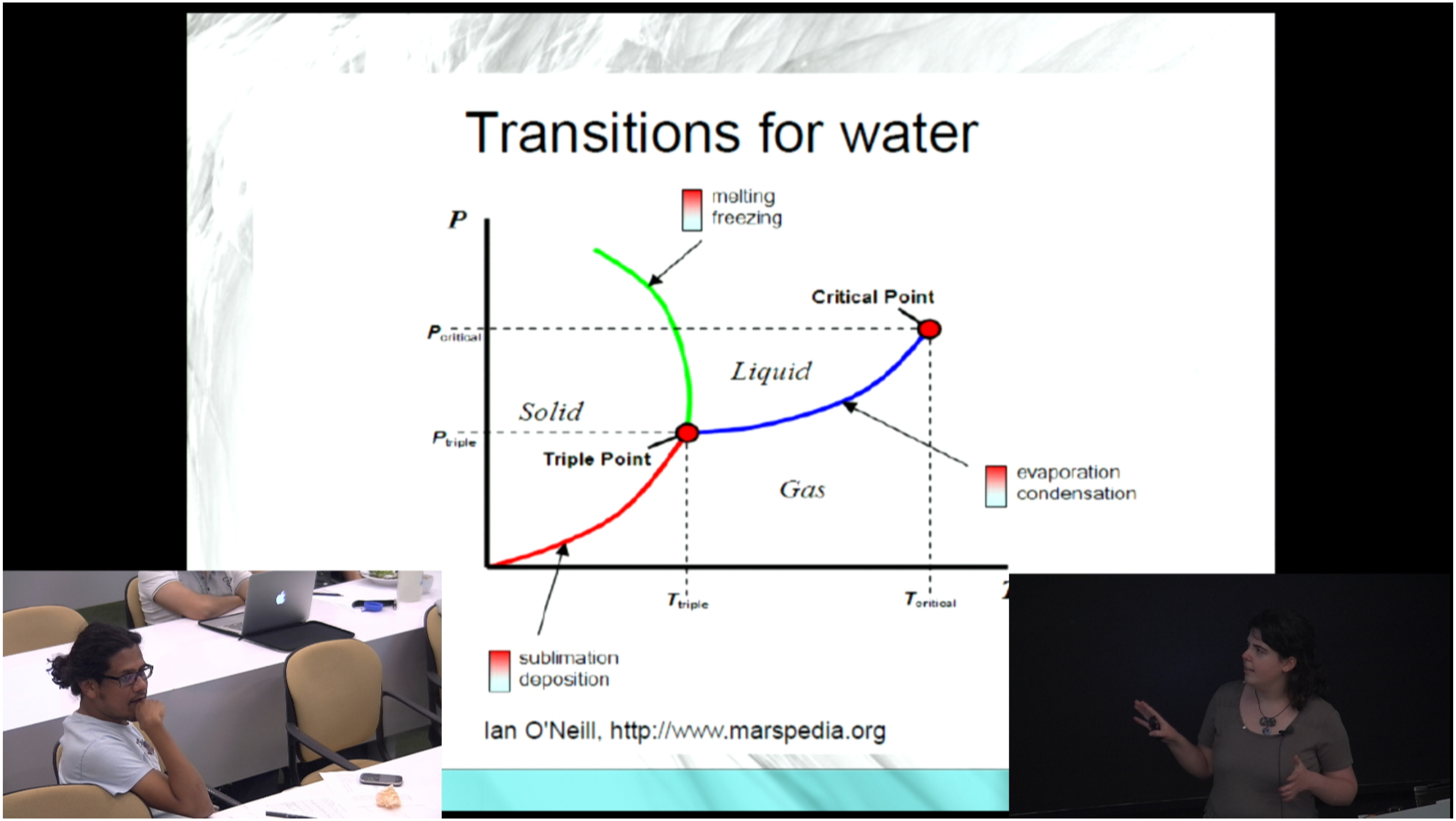
$$H = -J \sum s_i s_j, \quad s_i = \pm 1$$


Ising model
• Above critical temperature: Short length correlation.
• Below the critical temperature: Spins align on large scale.
• At the critical temperature: Infinite correlation length.

Conclusion

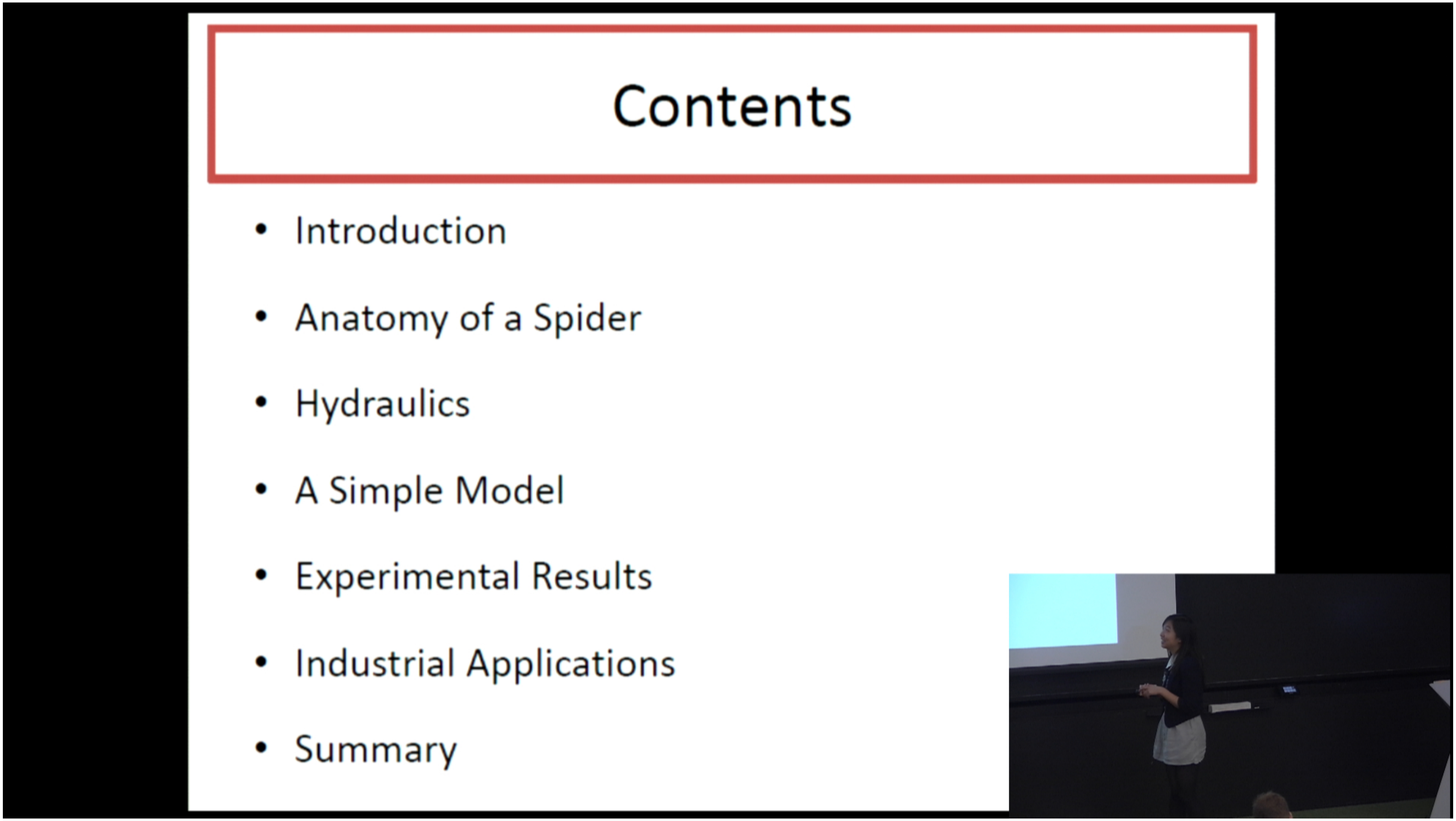
- 2 types of transitions depending on discontinuities.
- We use the order parameters to differentiate between phases.
- Is used in a variety of situations and scales, from condensed matter to renormalization groups.


Introduction
• Present in everyday life.
• Used in many areas of physics.


Transitions for water
P
melting
freezing
Critical Point
P critical
Liquid
Solid
P triple
Triple Point
Gas
evaporation
condensation
T triple
T critical
sublimation
deposition
Ian O'Neill, http://www.marspedia.org

The Hydraulic Mechanism in Spiders' Legs

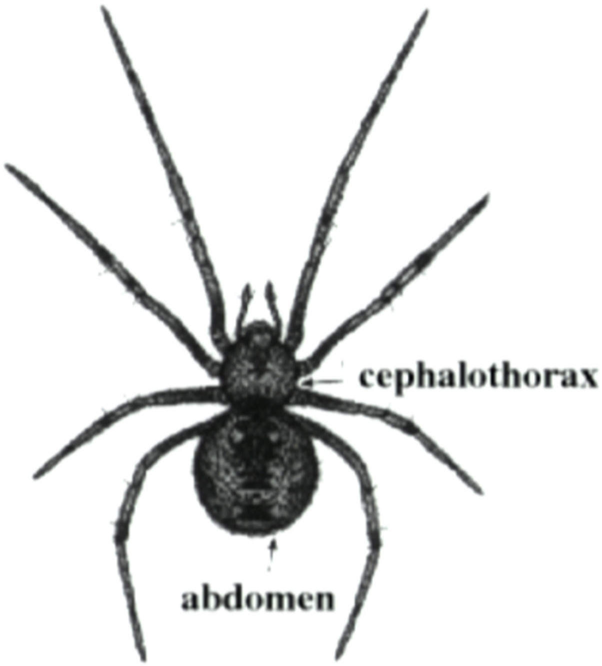
By Jin-Mann (Jenny) Wong


Contents
• Introduction
• Anatomy of a Spider
• Hydraulics
• A Simple Model
• Experimental Results
• Industrial Applications
• Summary

Introduction

- Hydraulic and muscular mechanisms
- No leg extension muscles

Anatomy of a Spider



- Open circulatory system
- Seven joints
- Cephalothorax muscles

Image from http://www.explorit.org/science/spider.html

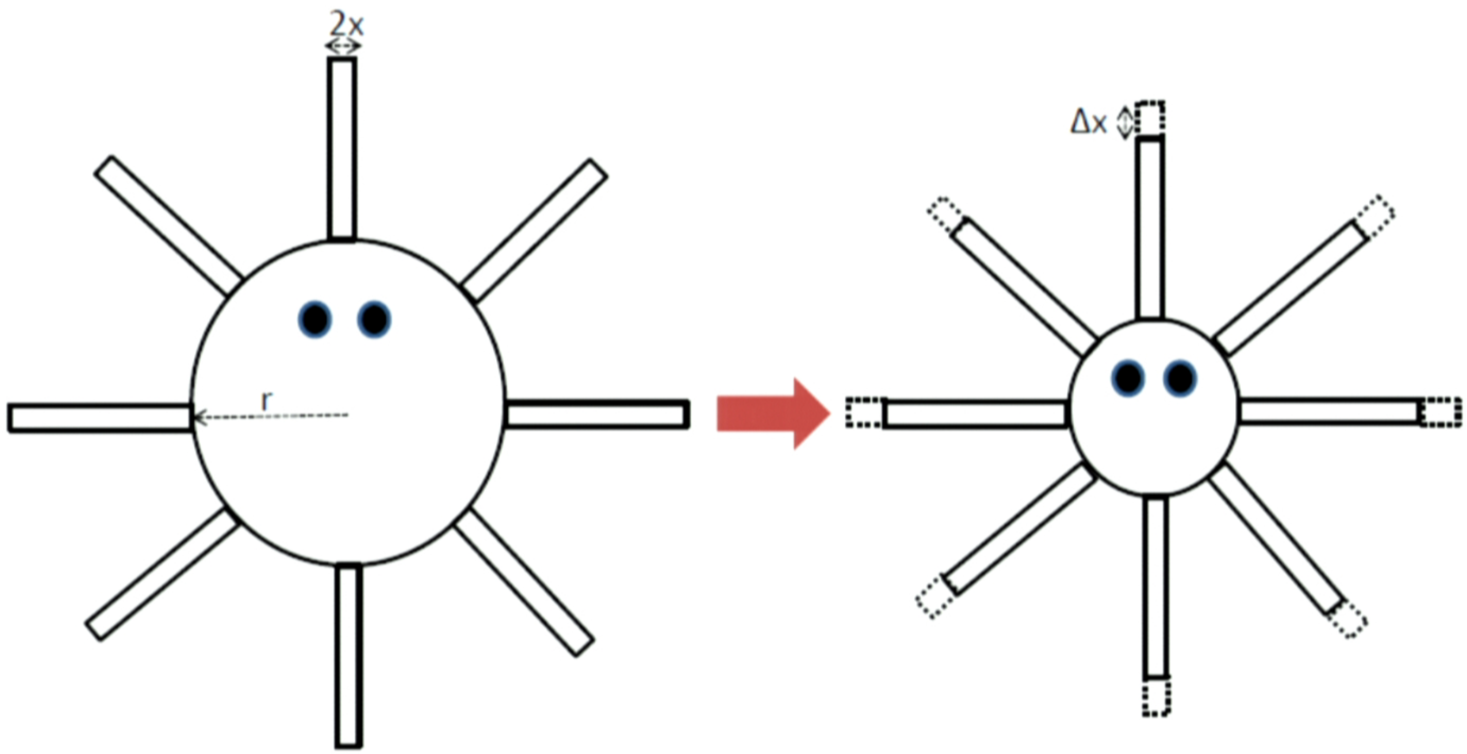
Hydraulics

- Pascal's principle
- Pressure = Force/Area
- $V_{in} = V_{out}$

Hydraulics

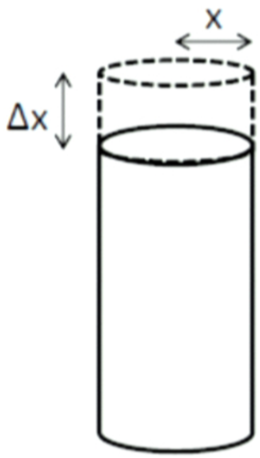
- Pascal's principle
- Pressure = Force/Area
- $V_{in} = V_{out}$

A Simple Model

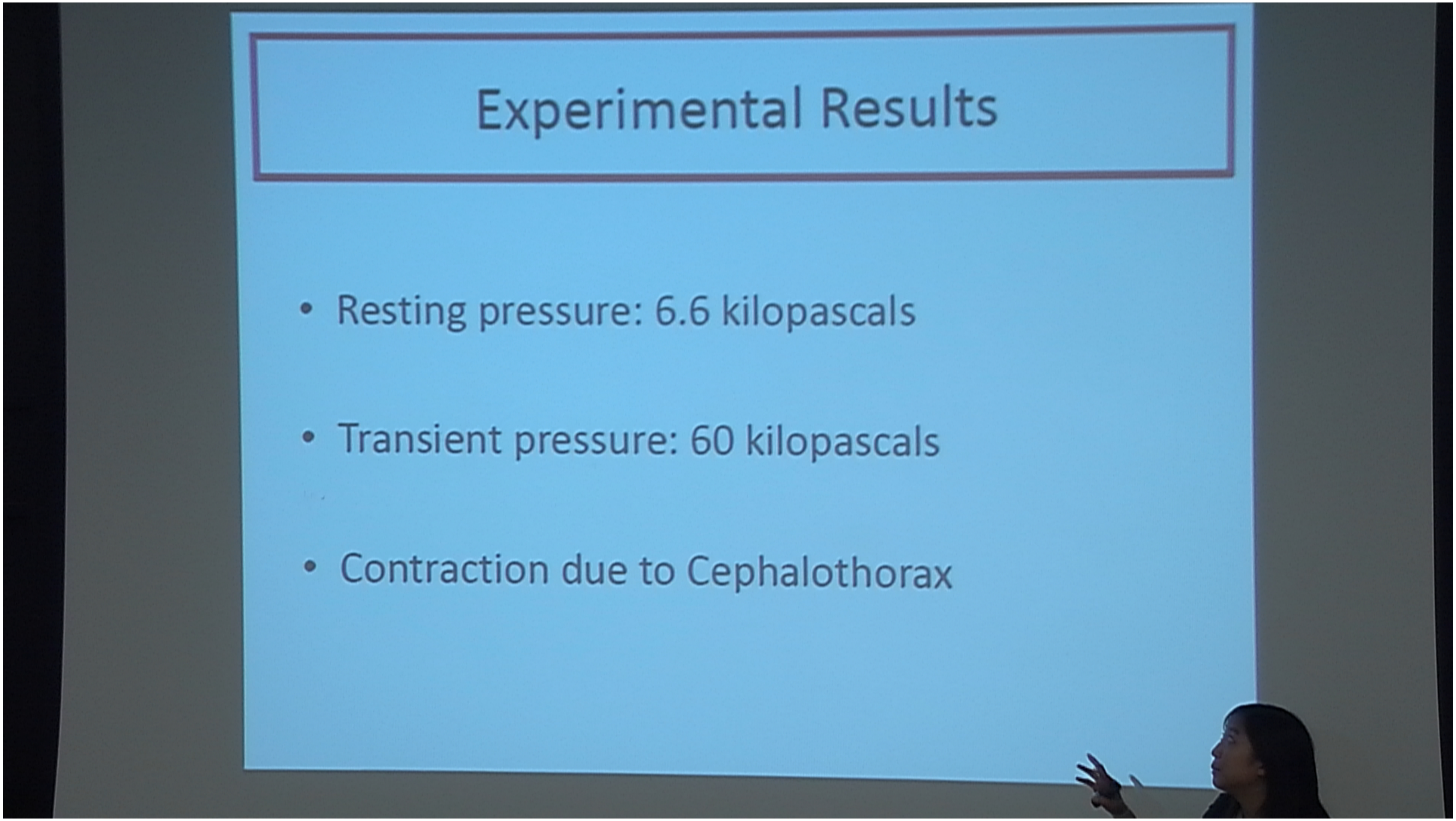


A Simple Model

$$\Delta V = \frac{4\pi}{3}\left(r^3 - \left(\frac{r}{2}\right)^3\right)$$



$$\Delta V = 8\pi x^2 \Delta x$$


Experimental Results
• Resting pressure: 6.6 kilopascals
• Transient pressure: 60 kilopascals
• Contraction due to Cephalothorax

Robotic Spider

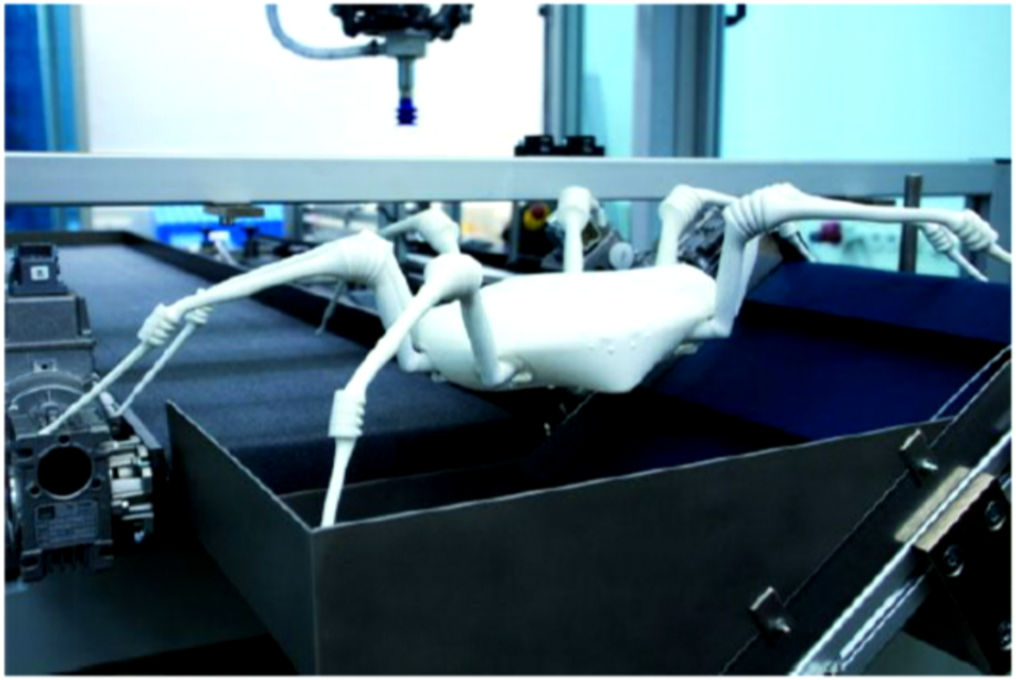


Image from http://www.engineeringontheedge.com/2011/11/3d-printing-spawns-robotic-spiders/

Smart Stick

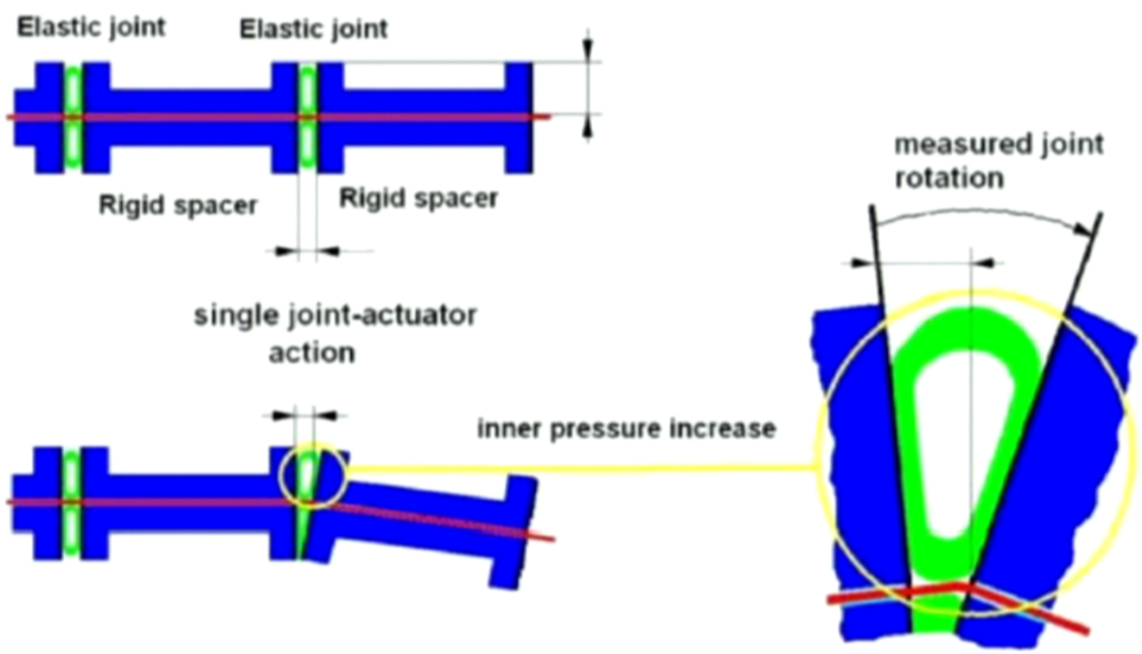


Image from C. Menon and C. Lira. "Spider-inspired embedded actuator for space applications."

Summary

- Hydraulic mechanism
- Cephalothorax muscles
- Simple model
- Applications

References

L. Zentner, S. Petkun and R. Blickham. (2000) *"From the Spider Leg to a Hydraulic Device."*

http://www.findaspider.org.au/info/Mobility.htm

D. Parry and R. Brown. (1959) *"The Hydraulic Mechanism of the Spider Leg."*

J. Anderson and K. Prestwich. (1975) *"The Pressure Fluid Pumps of Spiders."*

http://www.explorit.org/science/spider.html

C. Menon and C. Lira. "Spider-inspired embedded actuator for space applications."

Fraunhofer-Gesellschaf Research News. (2011) *"High-tech spider for hazardous missions."*

Physics in Nature: Surrounded by Waves!!

by Anabelle Spinoulas

perimeter scholars

Outline

- What is a wave and where do we see them in Nature
- Properties of Waves
- Types of Waves
- Study of ripples in pond water – waves in action!
- Conclusions

Waves are everywhere!!

- Sound waves, visible light waves, radio waves, microwaves, water waves, earthquake waves etc.
- Wavelike phenomenon in nature –throwing a pebble in a pond, earthquakes, a duck moving through water, motion of a child on a swing etc.

What is a wave?

- A **disturbance** that travels through a medium from one location to another.
- Medium (matter) ⟶ collection of interacting particles.
- Adjacent particles of the medium interact ⟶

disturbance is able to travel through the medium.

- Example: Water wave: medium - the water; interacting particles - the individual molecules of water.

What is a wave?

- A **disturbance** that travels through a medium from one location to another.
- Medium (matter) ⟶ collection of interacting particles.
- Adjacent particles of the medium interact ⟶

disturbance is able to travel through the medium.

- Example: Water wave: medium - the water; interacting particles - the individual molecules of water.

Waves transport energy, <u>not</u> matter

- Individual particles of medium

- **temporarily** displaced from their rest position

- restorative force brings them back to their original position.

- Therefore, while waves move, the medium (water) does not.

Waves transport energy, <u>not</u> matter

- Individual particles of medium

- **temporarily** displaced from their rest position

- restorative force brings them back to their original position.

- Therefore, while waves move, the medium (water) does not.

"Like the waves made in a field of grain by the wind, where we see the waves running across the field while the grain remains in place."

- Leonardo da Vinci

Different types of Mechanical Waves

.Transverse wave - the displacement of the particles of the medium is perpendicular to the direction that the wave moves.

Wave equation:

$$u(x,\ t) = y\ \sin(kx - \omega t + \phi)$$

Where, x is position, t is time, k is wave-number, ω is the angular frequency, φ is the phase

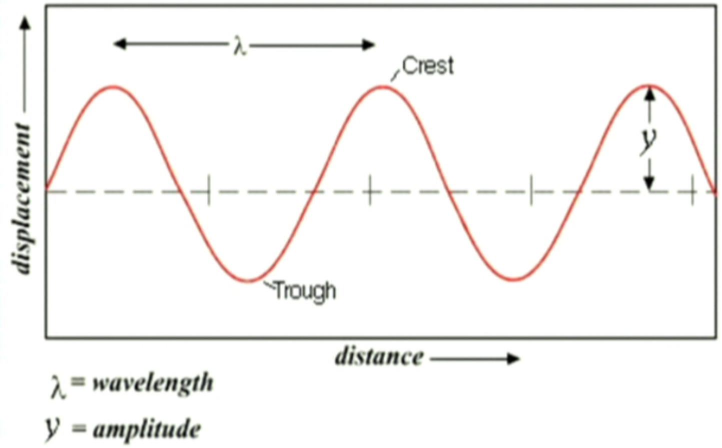


Figure 1: Diagram of transverse wave

Frequency, f:

$$f = \frac{v}{\lambda}$$

Where, v is the phase velocity of the wave

Period, T:

$$T = \frac{1}{f}$$

Different types of Mechanical Waves

•Transverse wave - the displacement of the particles of the medium is perpendicular to the direction that the wave moves.

Wave equation:

$$u(x,\ t) = y\ \sin(kx - \omega t + \phi)$$

Where, x is position, t is time, k is wave-number, ω is the angular frequency, φ is the phase

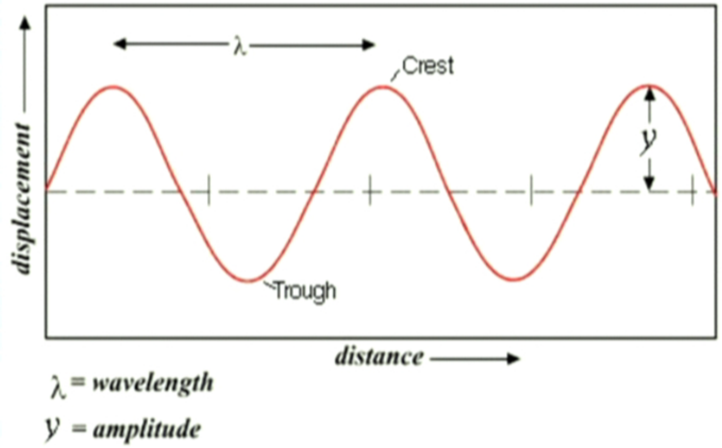


Figure 1: Diagram of transverse wave

Frequency, f:

$$f = \frac{v}{\lambda}$$

Where, v is the phase velocity of the wave

Period, T:

$$T = \frac{1}{f}$$

Different types of Mechanical Waves

- A longitudinal wave – the displacement of the particles of the medium is parallel to the direction that the wave moves. Example: sounds waves

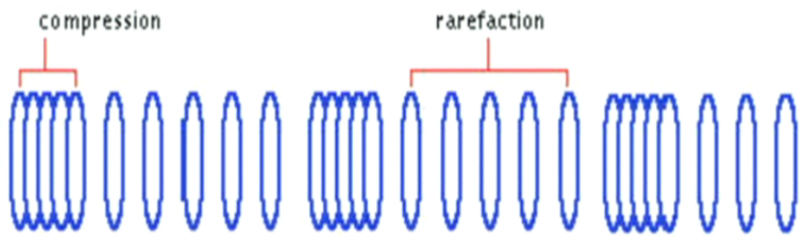
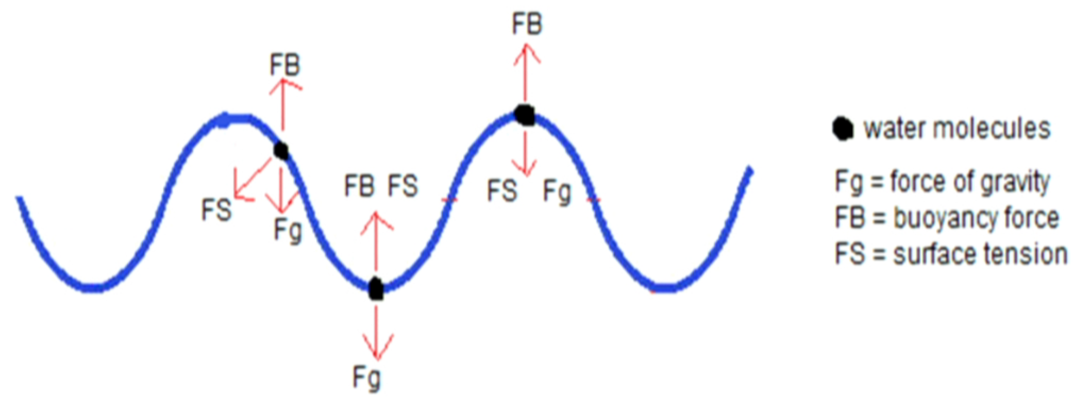


Figure 2: Longitudinal Wave (Edlin, 2012)

- Three main forces acting on each water molecule – force of gravity, buoyant force and most importantly surface tension.
- Longitudinal component of the surface tension.
- **Surface wave** - Combination of both transverse and longitudinal waves.



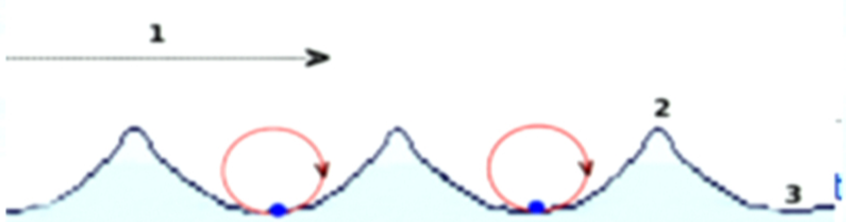
.These surface waves execute simple harmonic motion in 2-dimensions.

Ripples on the surface of a pond

Surface wave (combination of transverse and longitudinal waves)

↓

Particles along the surface of the water move in a circular motion



1 = Progression of wave
2 = Crest
3 = Trough

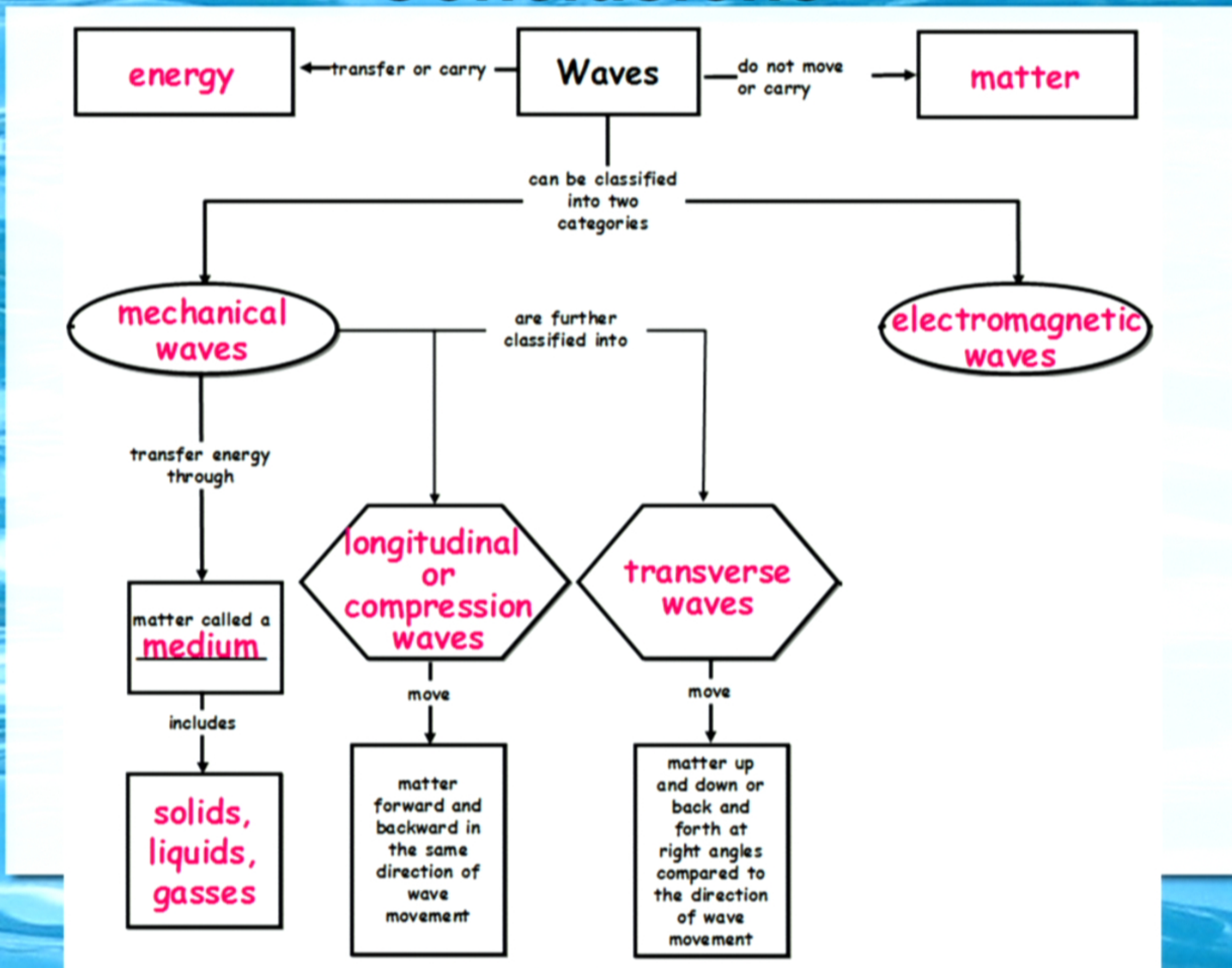
Figure 4: Diagram of surface wave showing circular motion of particles on surface of the medium (Zimbres, 2006)

- Once the effects of the disturbance dissipate, the water will return to a still pond.

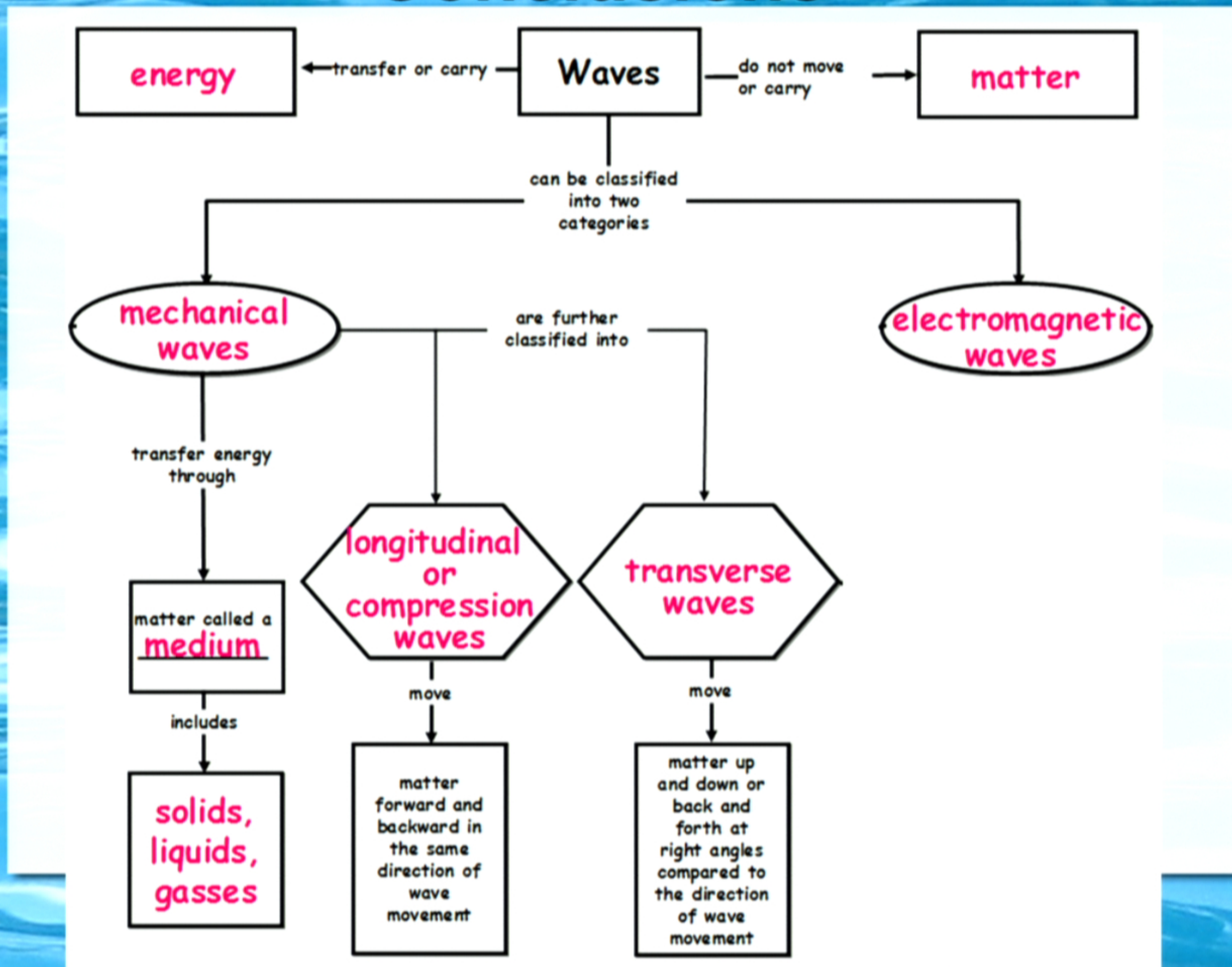
Assumptions

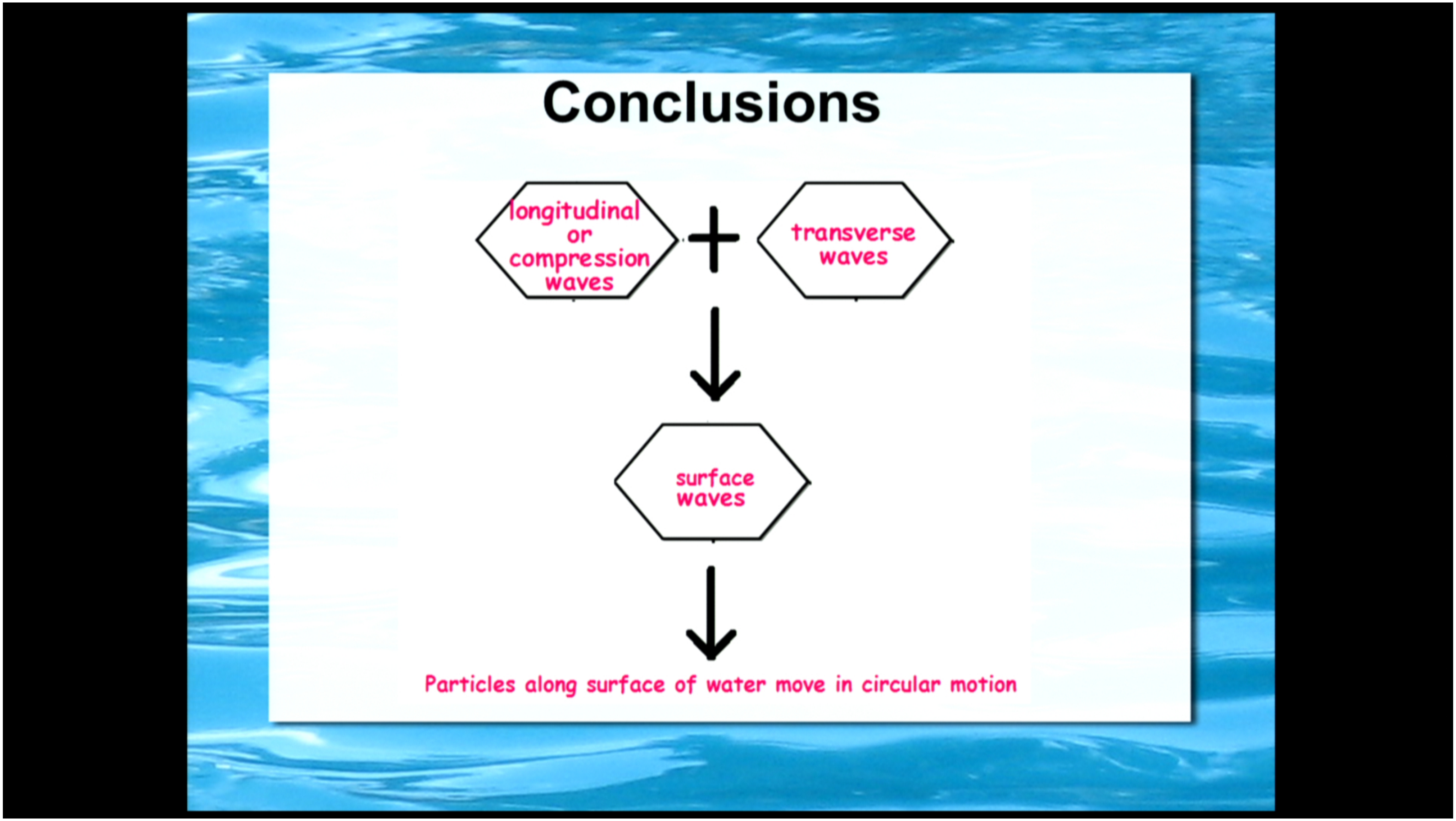
- Originally a flat and still pond.
- Considered the pebble to be a point source when it comes in contact with the water.
- Only the three forces mentioned are involved.
- Wind, under-currents, biological factors are all excluded.
- Boundaries of pond not included therefore no interference.
- NOTE: The parameter of depth has not been investigated.

Conclusions



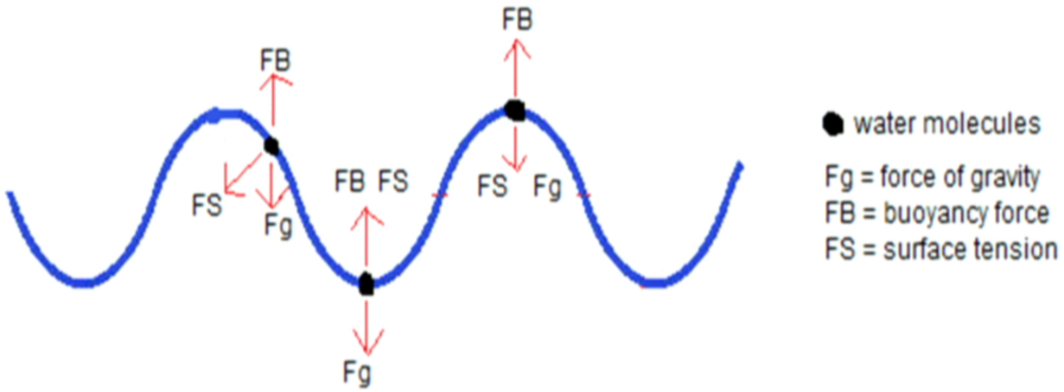
Conclusions





Conclusions
longitudinal or compression waves
transverse waves
surface waves
Particles along surface of water move in circular motion

- Three main forces acting on each water molecule – force of gravity, buoyant force and most importantly surface tension.
- Longitudinal component of the surface tension.
- **Surface wave** - Combination of both transverse and longitudinal waves.



- These surface waves execute simple harmonic motion in 2-dimensions.