Title: 12/13 PSI - Student Presentations 1B

Date: Aug 17, 2012 10:30 AM

URL: http://pirsa.org/12080041

Abstract:

How Aristotle Would Have Besieged Perimeter:

From Greek Ballistics to Reynolds numbers

Nicole Yunger Halpern, Masters student,
Perimeter Institute for Theoretical Physics

PERIMETER INSTITUTE FOR THEORETICAL PHYSICS

10:44 AM
17-Aug-12

Thought experiment: Aristotle wakes from the dead.

(Sorry, Second Law of Thermodynamics!)

10:45 AM
17-Aug-12

Thought experiment: Aristotle wakes from the dead.

(Sorry, Second Law of Thermodynamics!)

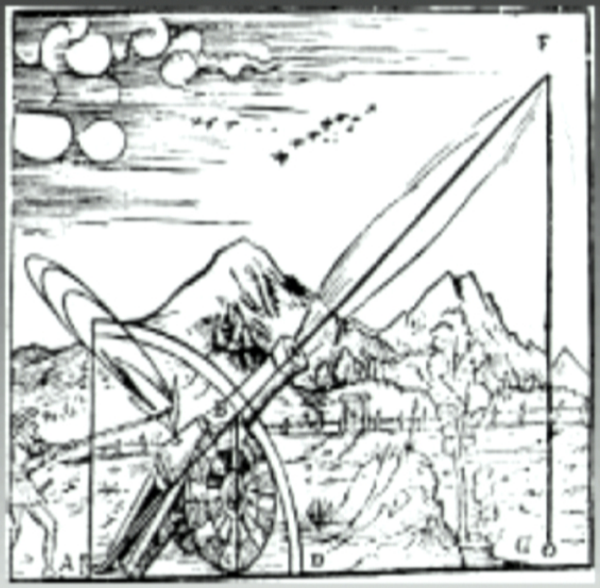
Thought experiment: Aristotle wakes from the dead.

(Sorry, Second Law of Thermodynamics!)

10:46 AM

The Aristotelian projectile

The Aristotelian projectile



http://anadder.com/inertia_as_brute_facT
The Dancing Universe, M. Gleiser *Plume* (1998).

- "Impetus"

10:46 AM
17-Aug-12

The Aristotelian projectile

http://anadder.com/inertia_as_brute_facT
The Dancing Universe, M. Gleiser *Plume* (1998).

- "Impetus"
- Does any real projectile near the Earth's surface move like Aristotle's cannonball?

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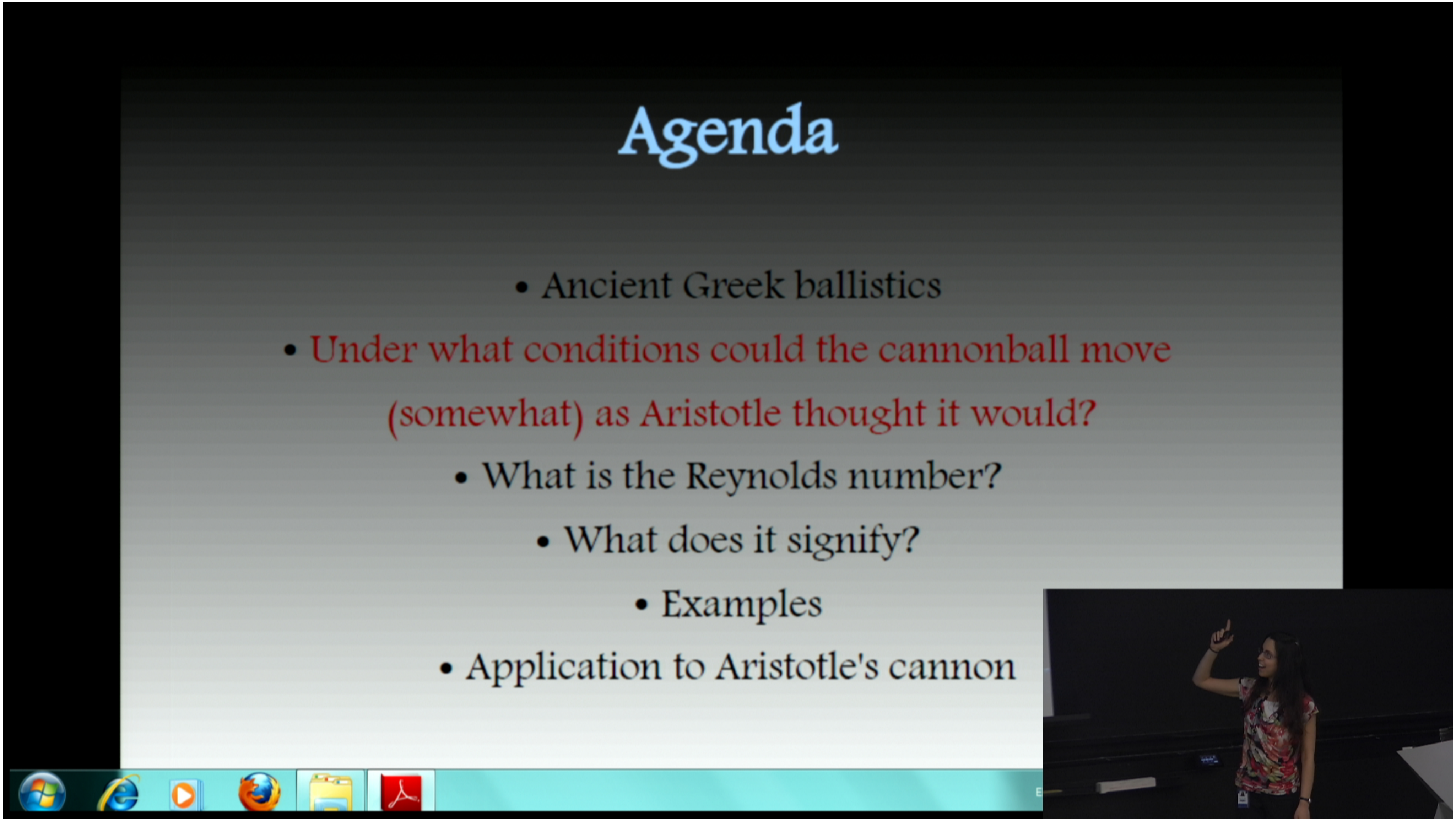
Maybe...Consider a fly in honey.

10:47 AM


Maybe...Consider a fly in honey.
We need to meet the Reynolds number.


Agenda
• Ancient Greek ballistics
• Under what conditions could the cannonball move (somewhat) as Aristotle thought it would?
• What is the Reynolds number?
• What does it signify?
• Examples
• Application to Aristotle's cannon

Definition of the Reynolds number

- Notation: $\mathcal{R}$
- Definition: $\mathcal{R} := \frac{\rho v L}{\eta}$
- What do the parameters in the definition signify?
  - $\rho =$ density of the medium
  - $v =$ characteristic speed
  - $L =$ characteristic length scale
  - $\eta =$ fluid viscosity

What does the Reynolds number signify?

- Multiple derivations and interpretations exist.
- $R = \dfrac{\text{Inertial force}}{\text{Viscous force}}$

Life at Low Reynolds number. E. M. Purcell. *Am. J. Phys.* 45, 3 (1977)

2 length scales, 2 worlds, no quantum mechanics

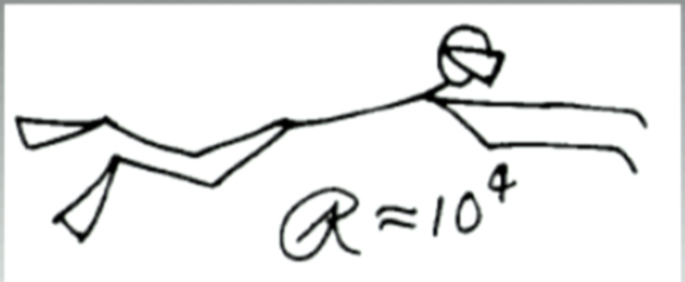
2 length scales, 2 worlds, no quantum mechanics

- R ~ 1,000
  - Turbulent flow
  - Nonlinear, not time reversible
  - Physics of our world
- R << 1
  - Laminar flow
  - Equation of motion (Navier-Stokes) approximately doesn't depend on time
  - Time reversible – Ask for an example during Q&A!

Informal, but deep, introduction:

Life at Low Reynolds number, E. M. Purcell,

Am. J. Phys. **45**, 3 (1977)



More facts about the Reynolds number

- Dimensionless
- Applied in biophysics, fluid mechanics, and geophysics
- Uses involve rough estimates

Example #2: Reynolds number of a cannonball in air

- $\rho \sim 1kg \cdot m^{-3}$ (1)
- $v \sim 10^2 m/s$ (2)
- $L \sim 10^{-1} m$ (3)
- $\eta \sim 10^{-5}\ Pa \cdot s$ (4)

$$\mathcal{R} = \frac{\rho v L}{\eta} \sim 10^6 \gg 1$$

(1) http://www.mhtl.uwaterloo.ca/old/onlinetools/airprop/airprop.html
(2) Seems reasonable, no?
(3) http://hypertextbook.com/facts/2009/JenniferChung.shtml

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Under what conditions could a cannonball have R < 1?

- If the viscosity ~ 10^2 Pa . s, $R \sim 10^{-1}$.
- This viscosity is of the order of magnitude of peanut butter's.

Under what conditions could a cannonball have R < 1?

- If the viscosity ~ 10^2 Pa . s, $R \sim 10^{-1}$.
- This viscosity is of the order of magnitude of peanut butter's.
- Frictional drag would affect the cannonball more than gravity.
  - Stokes Law for frictional force:

$$F_d = 6\Pi\eta R v \sim 6\Pi(10^2\ Pa \cdot s)(10^-1\ m)(10^2\ m/s) \sim 20,000\ N$$

  - Gravitational force: $F_g = mg \sim (5\ kg)(10m \cdot s^{-2}) = 50\ N$

EN 10:53 AM 17-Aug-12

Under what conditions could a cannonball have R < 1?

- But the cannonball wouldn't progress far.

$$t = \frac{v_f - v_i}{a} \sim 10^{-3}\ s$$

Conclusions

- The Reynolds number differentiates two classical worlds.
- $\mathcal{R} := \frac{\rho v L}{\eta}$
- Characteristics associated with R: dominant force, flow type, time reversibility, how long momentum carries you

...but he might as well attack Perimeter with a water gun.

www.hobbytron.com/

I think we're safe from the undead Aristotle.

10:56 AM
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Surface Gravity Wave

Tian Lan

Perimeter Scholars International
Perimeter Institute for Theoretic Physics

August 16, 2012

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11:01 AM
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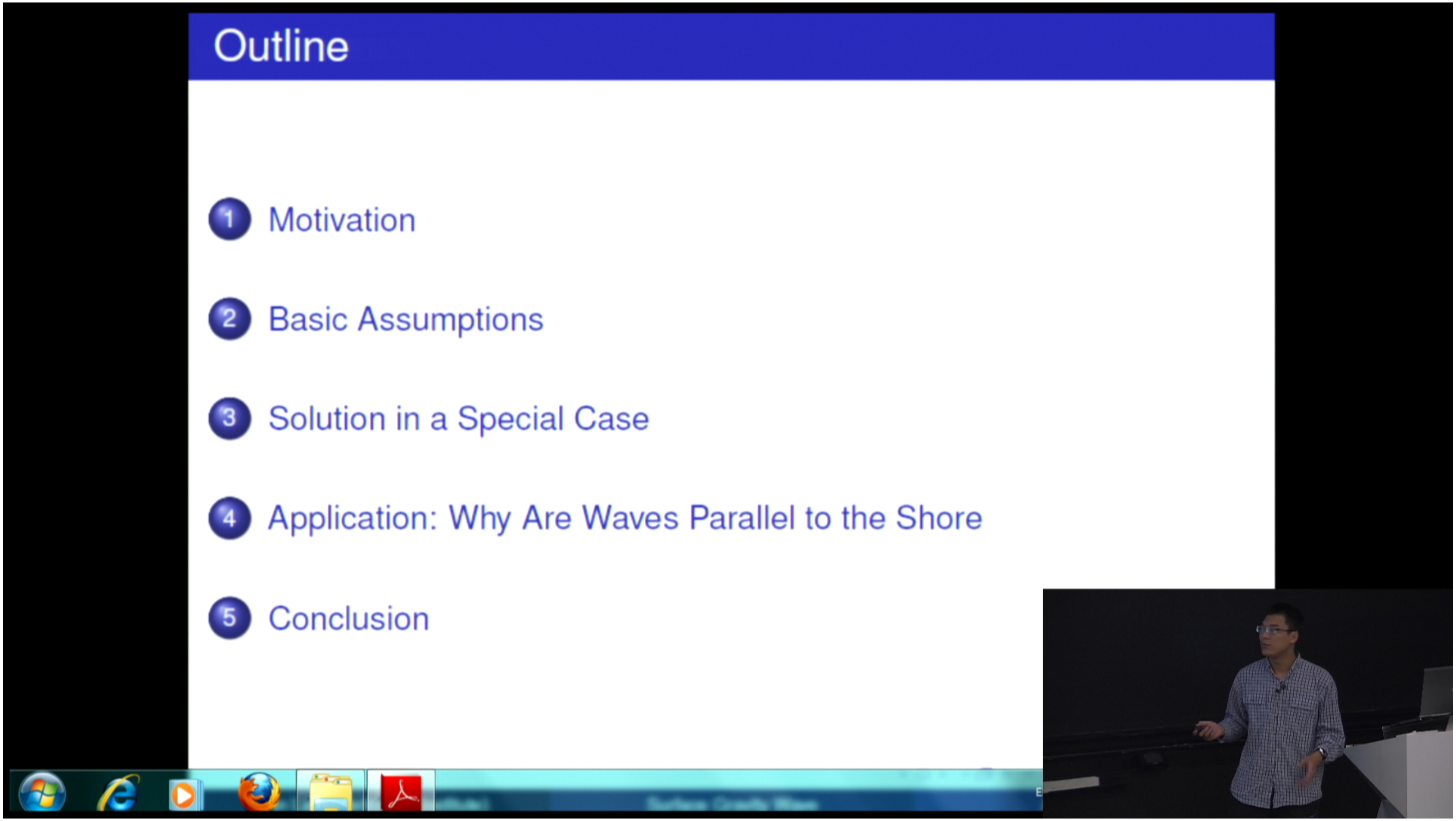
Outline
1 Motivation
2 Basic Assumptions
3 Solution in a Special Case
4 Application: Why Are Waves Parallel to the Shore
5 Conclusion

Motivation

The water wave is the most familiar and intuitive wave motion

- Not so simple
- Neither longitudinal nor transverse
- Non-trivial dispersion relation
- Airy wave theory or Line theory

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11:04 AM
17-Aug-12

Basic Assumptions

- Inviscid
  The stress tensor is $p\delta_{ij}$
- Irrotational
  $\nabla \times \boldsymbol{u} = 0 \Rightarrow \boldsymbol{u} = \nabla \phi$
  ϕ is called the velocity potential
- Incompressible
  $\frac{\partial \rho}{\partial t} = 0 \Rightarrow \nabla \cdot \boldsymbol{u} = 0 \Rightarrow \nabla^2 \phi = 0$

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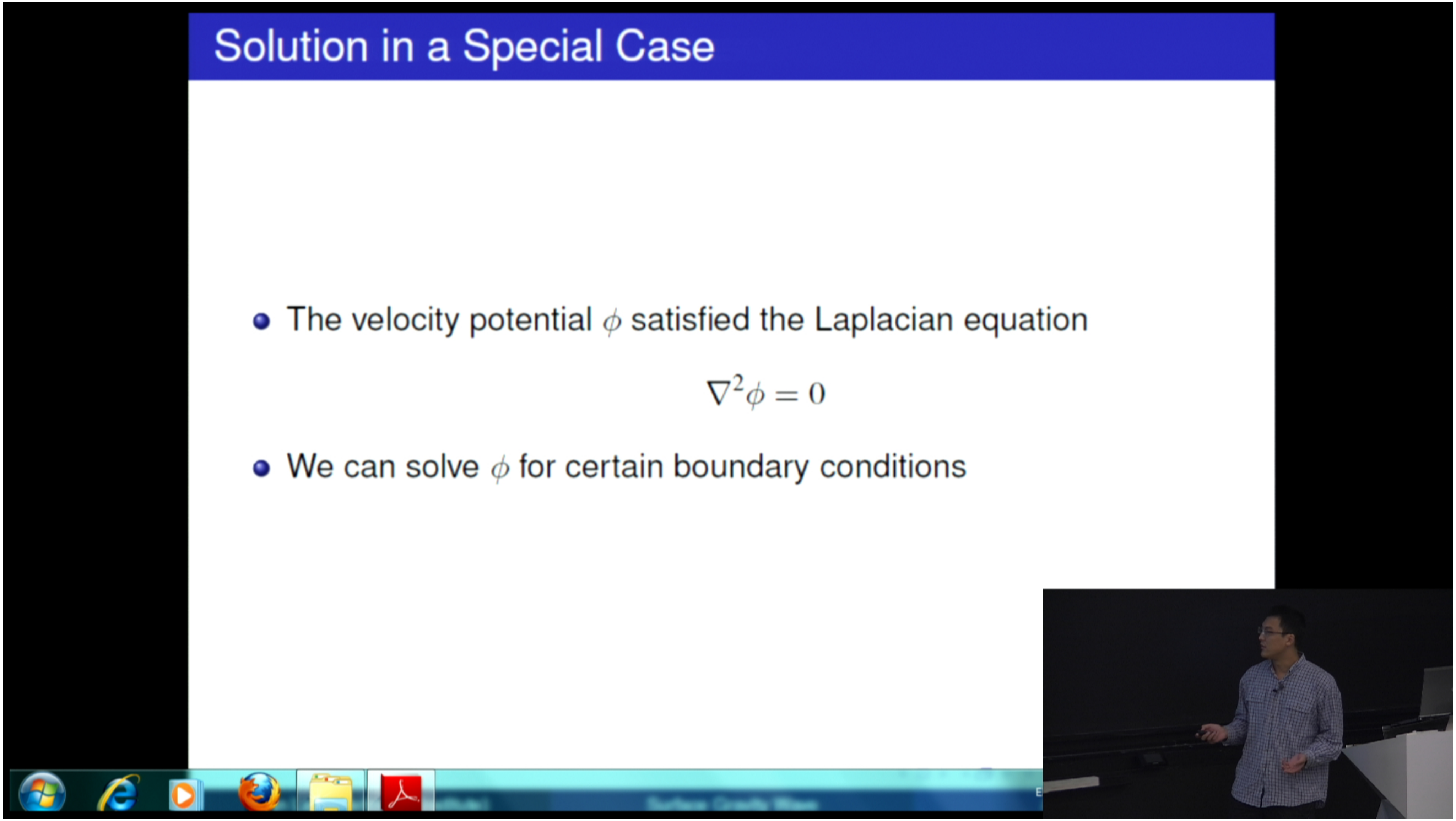
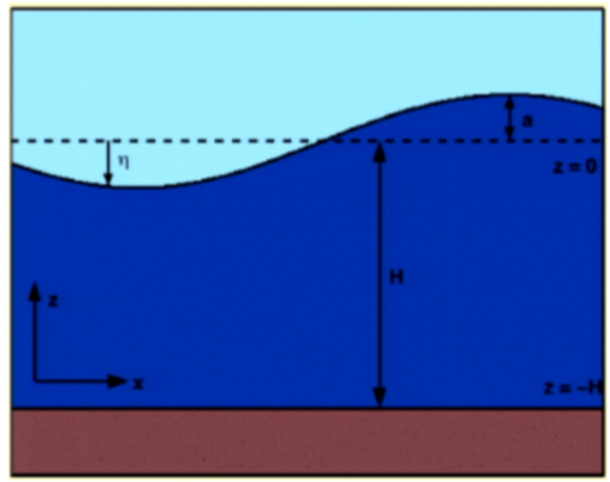

Solution in a Special Case
The velocity potential ϕ satisfied the Laplacian equation
$\nabla^2\phi = 0$
We can solve ϕ for certain boundary conditions

Solution in a Special Case

- The depth of the water is a constant H
- the surface of the water is the shape of $\eta = a\sin(kx - \omega t)$
- The amplitude a is small so we can linearise the boundary condition.
- The wave is uniform in the y direction

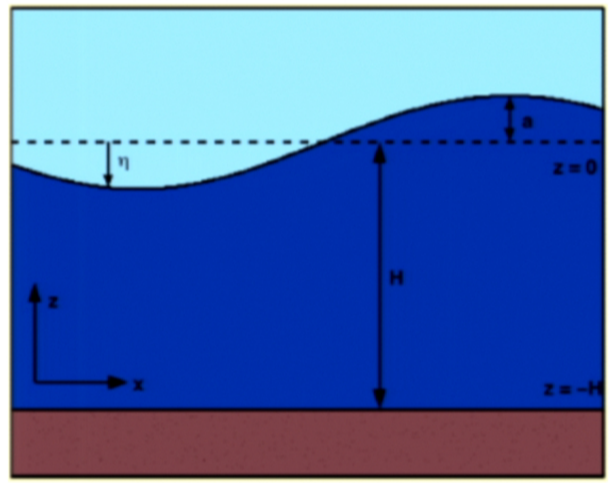


Solution in a Special Case

The linearised boundary conditions are

$$\partial_z \phi = \partial_t \eta, \quad z = 0$$

$$\partial_z \phi = 0, \quad z = -H$$



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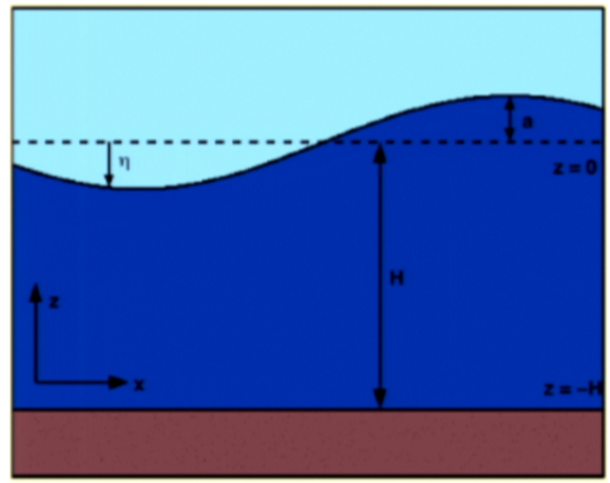

Neither longitudinal nor transverse

The corresponding solution is

$$\phi = -\frac{a\omega}{k}\frac{\cosh(k(z+H))}{\sinh(kH)}\cos(kx-\omega t)$$

Take the derivative of ϕ we get the velocity field

$$u_x = \partial_x \phi = a\omega\frac{\cosh(k(z+H))}{\sinh(kH)}\sin(kx-\omega t)$$

$$u_z = \partial_z \phi = -a\omega\frac{\sinh(k(z+H))}{\sinh(kH)}\cos(kx-\omega t)$$

and we see neither of u_x and u_z is zero, i.e. the Surface G
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and we see neither of u_x and u_z is zero, i.e. the Surface Gravity Wave is neither longitudinal nor transverse.

Non-trivial dispersion relation

The relation between ω and k comes from the unsteady Bernoulli's equation (linearised version)

$$\frac{\partial \phi}{\partial t} + g\eta = \frac{\sigma}{\rho}\frac{\partial^2 \eta}{\partial x^2}, \quad z = 0$$

where σ is the surface tension coefficient.

Plug the previous solution in we get

$$\omega^2 = (gk + \frac{\sigma}{\rho}k^3)\tanh(kH)$$

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11:10 AM
17-Aug-12

Application: Why Are Waves Parallel to the Shore

The waves on the beach always come parallel to the shore.

$$\omega^2 = (gk + \frac{\sigma}{\rho}k^3)\tanh(kH)$$

- Near the shore Large wavelength and Shallow water$\Rightarrow$ small k, H
- $g >> \sigma k^2/\rho$ and $kH << 1$, the dispersion relation is simplified

$$\omega^2 = gHk^2$$

- The wave velocity is $c = \sqrt{gH}$, decreasing as the wave approaching the shore.
- The wave is refracted such that in the end it propagates nearly perpendicular to the shore.

11:10 AM
17-Aug-12

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Conclusion

- Inviscid irrotational incompressible water
- Solve Laplacian equation for certain boundary condition
- Got the velocity field and the dispersion relation

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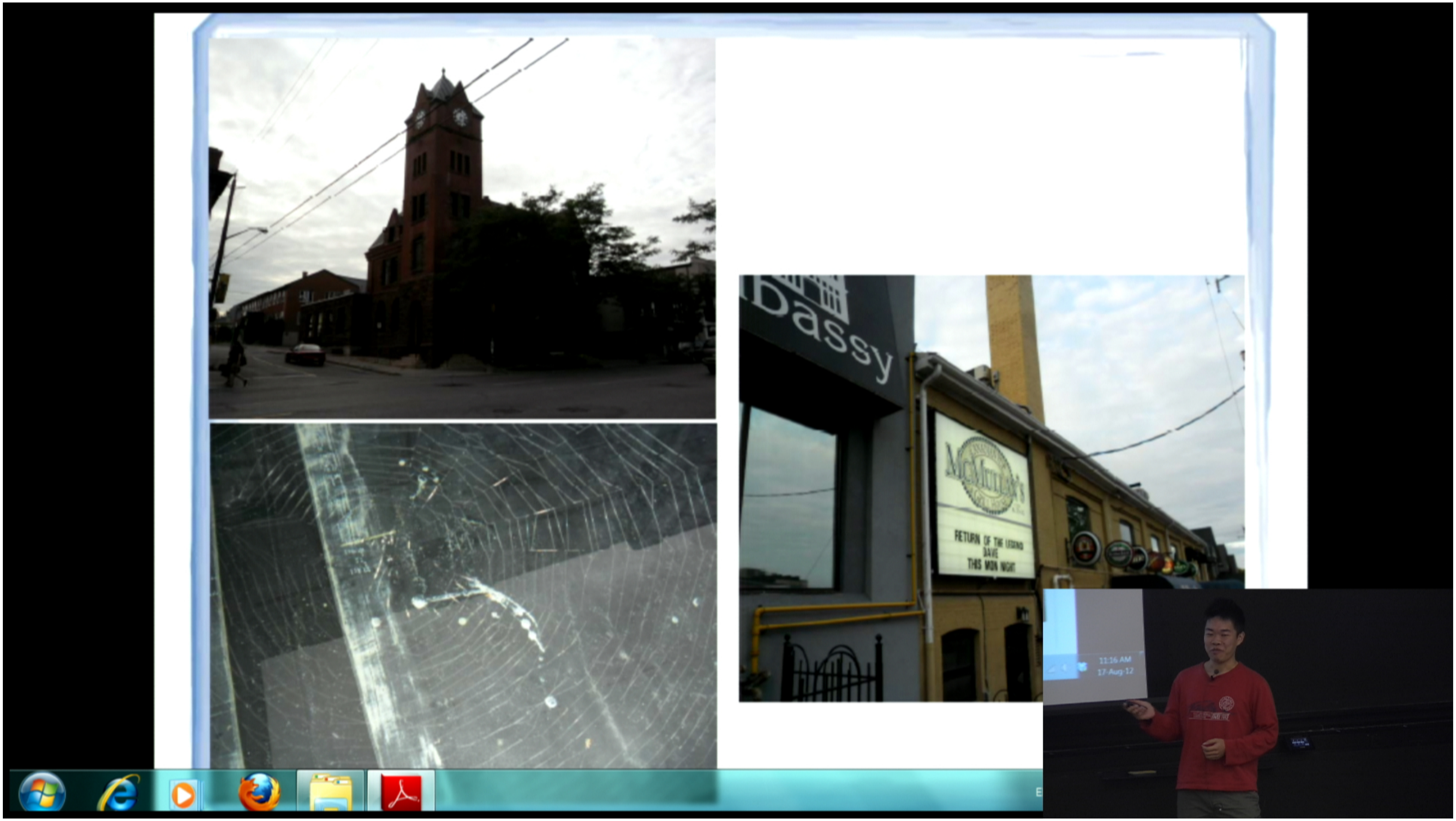

bassy
RETURN OF THE LEGEND
DAVE
THIS MON NIGHT
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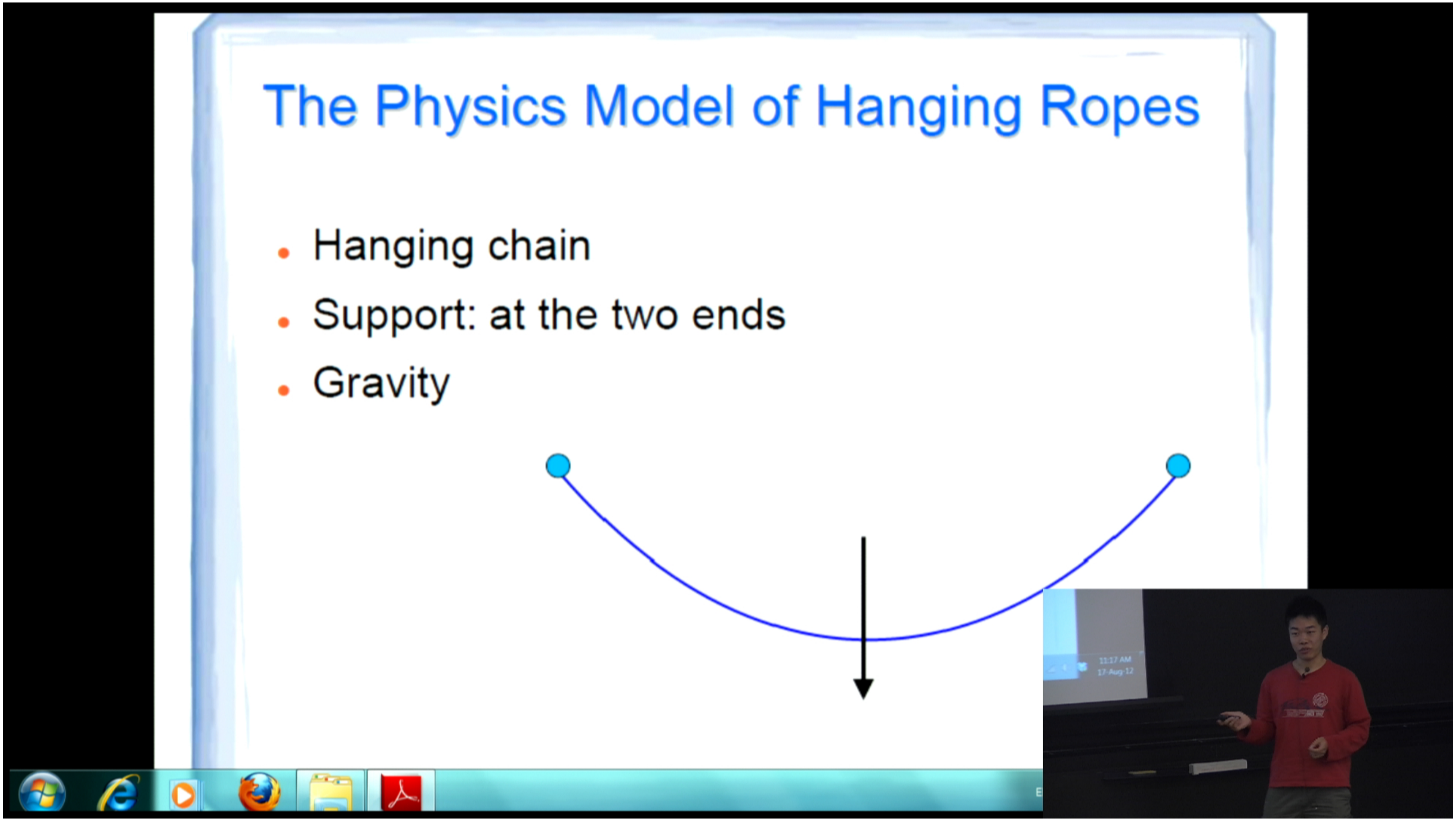
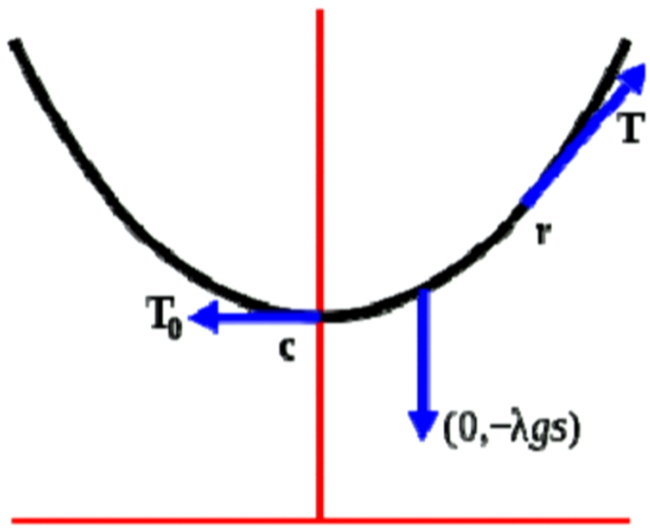
17-Aug-12


The Physics Model of Hanging Ropes
Hanging chain
Support: at the two ends
Gravity

The Exact Shape of Hanging Ropes

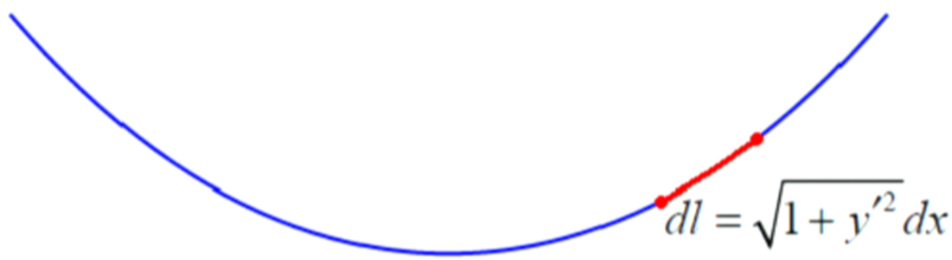


The Exact Shape of Hanging Ropes

- The potential energy functional

$$U = \int \rho g y \sqrt{1+(y')^2}\, dx$$

should reach its minimum



The Exact Shape of Hanging Ropes

- Euler-Lagrange Equation

$$U = \int u\left(x, y(x), y'(x)\right)dx = \int \rho g y \sqrt{1+\left(y'\right)^2}\,dx$$

11:20 AM
17-Aug-12

The Exact Shape of Hanging Ropes

- Euler-Lagrange Equation

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$$y(x) \rightarrow y(x) + \varepsilon(x),\ \delta U = 0$$

The Exact Shape of Hanging Ropes

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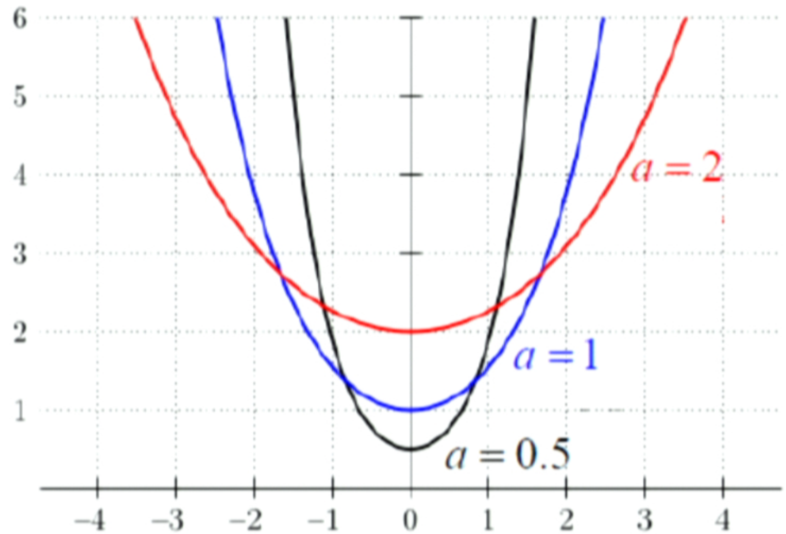
$$y(x) \rightarrow y(x) + \varepsilon(x),\ \delta U = 0$$

$$\frac{\mathrm{d}}{\mathrm{d}x}\frac{\partial u}{\partial y'} - \frac{\partial u}{\partial y} = 0$$

The Exact Shape of Hanging Ropes

- Result: hyperbolic cosine function

$$y(x) = a\cosh(x/a),\ a = T_0/(\rho g)$$



The Exact Shape of Hanging Ropes

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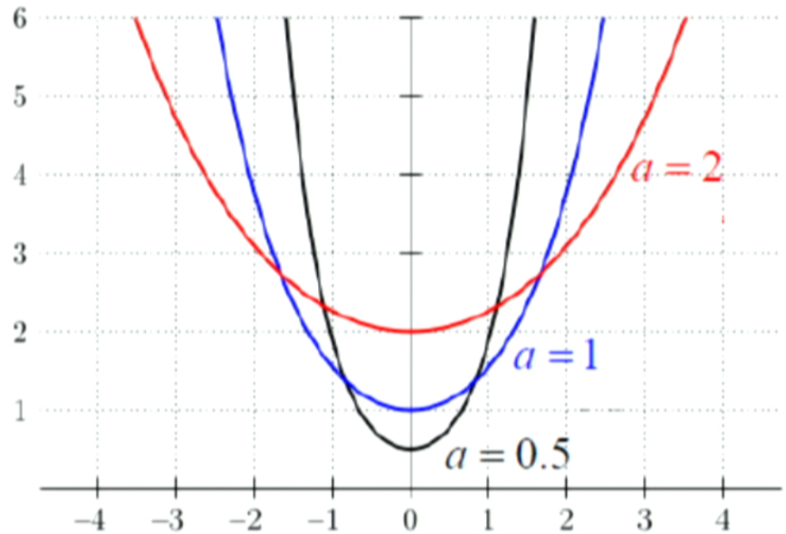

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17-Aug-12

The Application of Hanging Ropes

The Application of Hanging Ropes

Reference

- http://en.wikipedia.org/wiki/Catenary
- *Classical Mechanics*, Herbert Goldstein, Charles P. Poole, John L. Safko

Thank you!


Slipstreaming:
Nature's Fast Lane
Marie Rider
17th August 2012
perimeter scholars
EN
11:28 AM

Overview

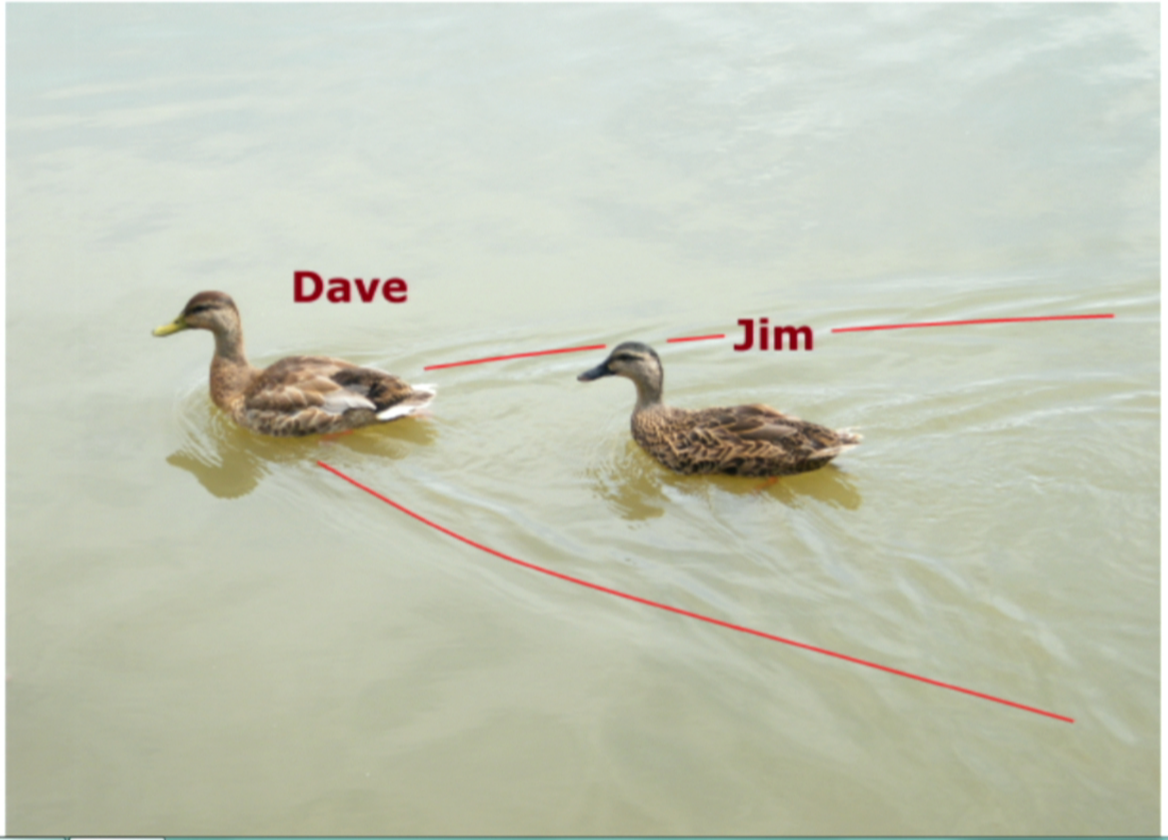
- Why do we need to talk about slipstreaming?
- What is the physics behind slipstreaming?

Motivation

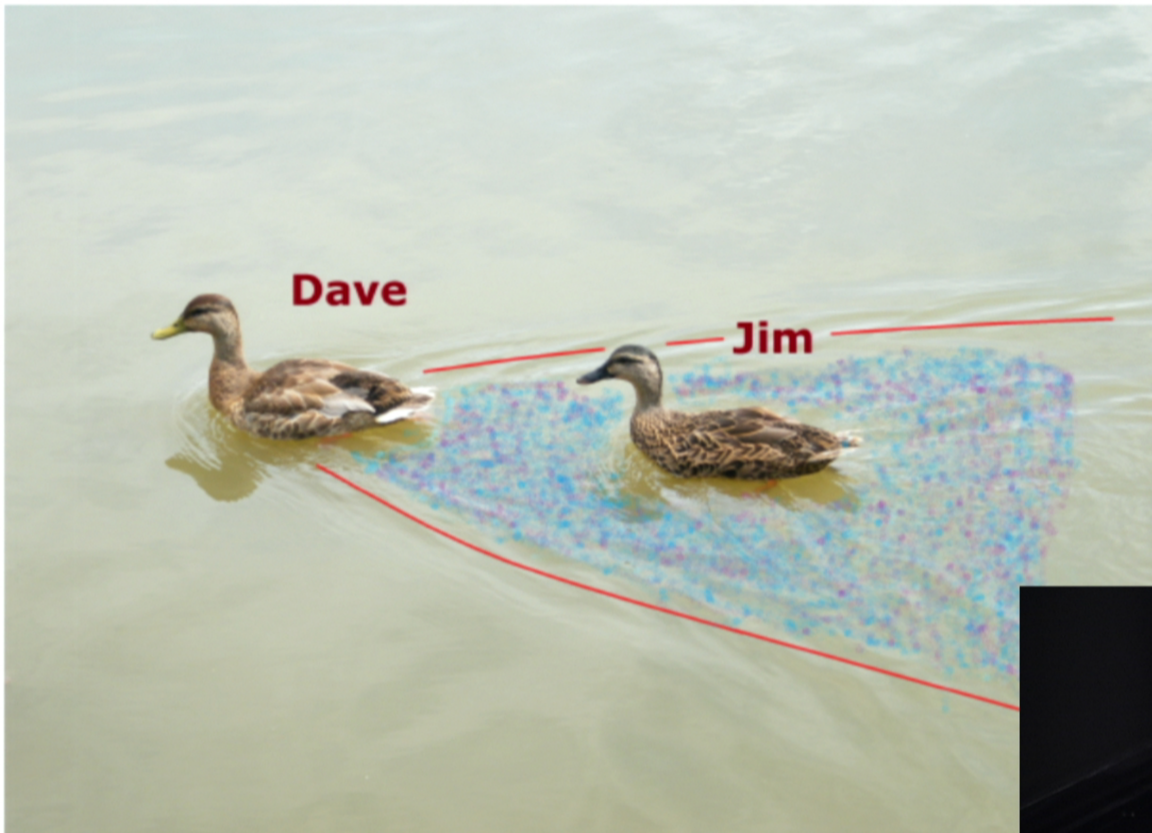
Motivation

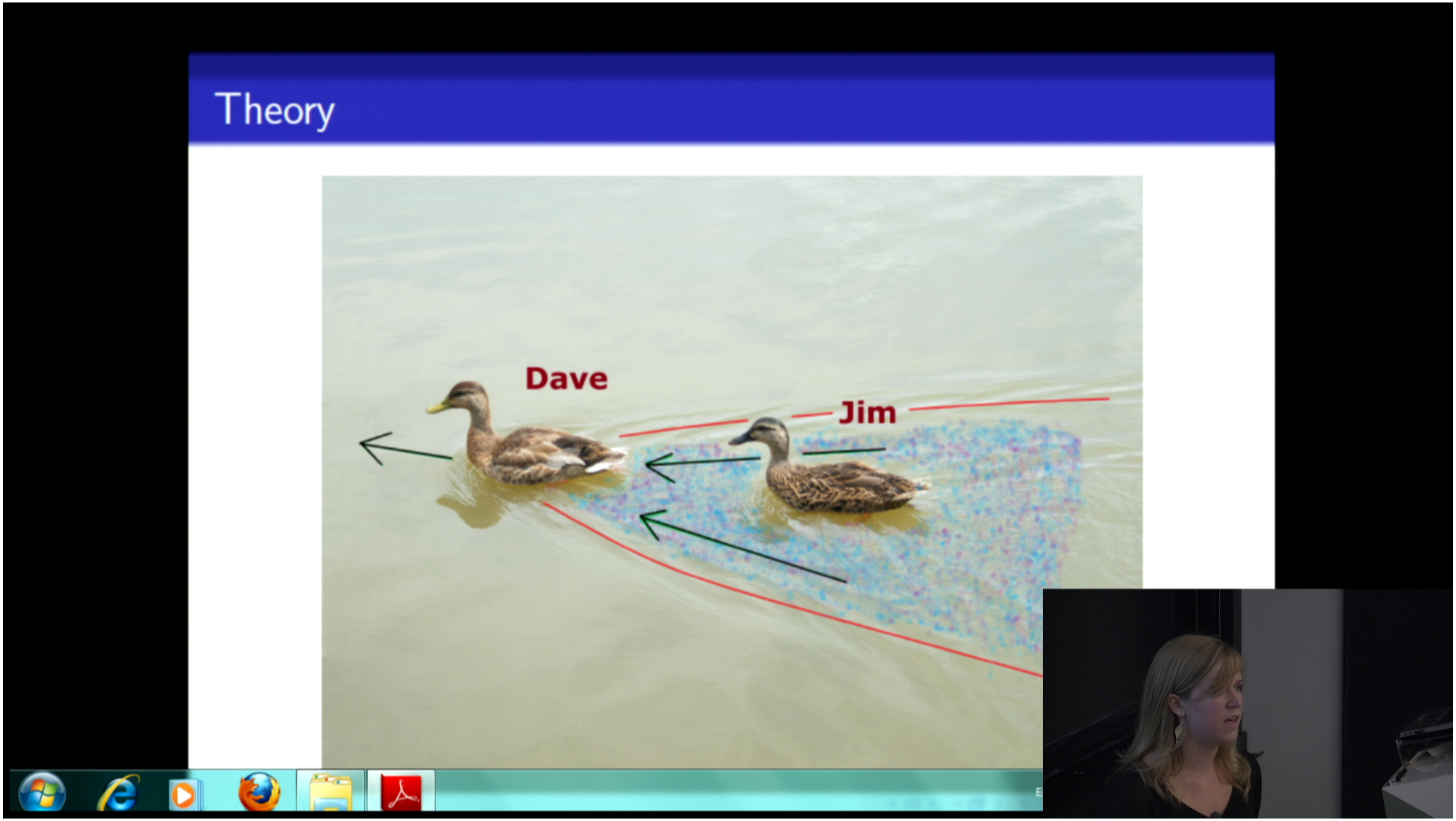
Theory

Theory

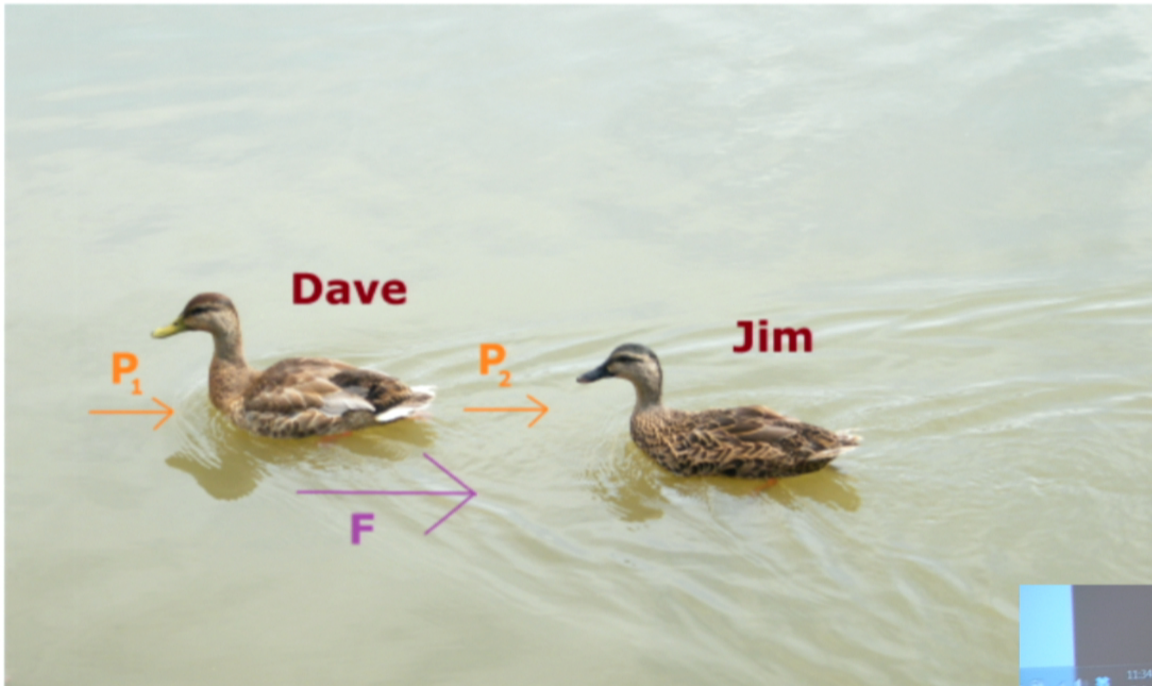


Theory




Theory
Dave
Jim

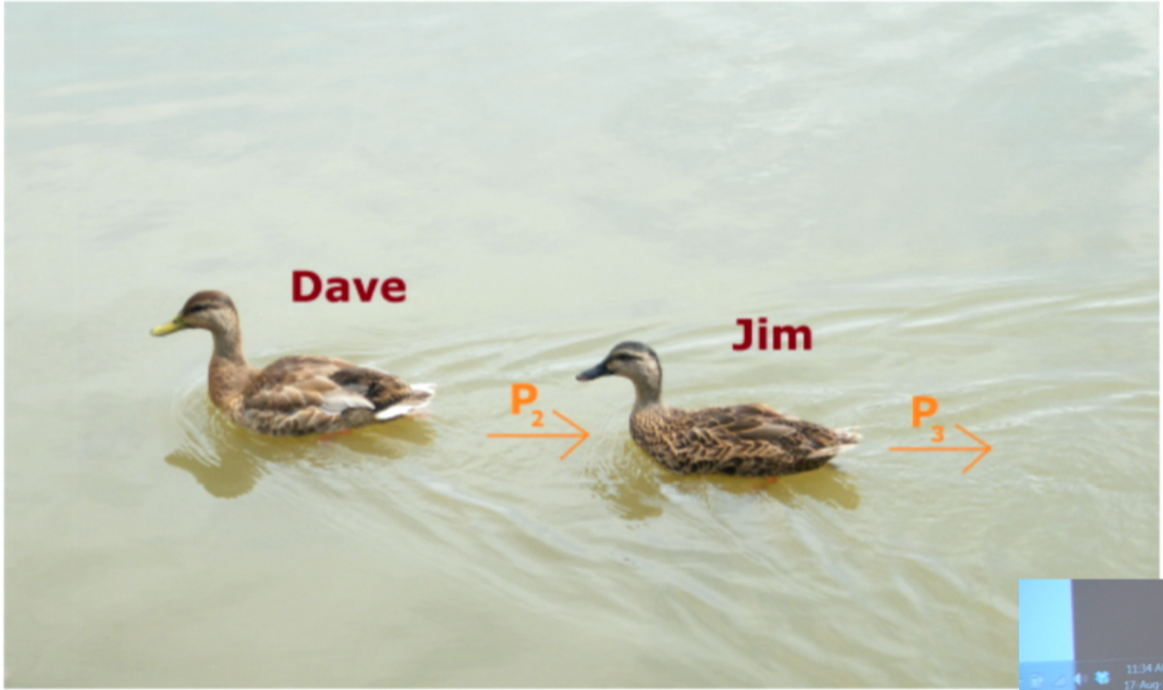
Theory



$\Delta P = P_1 - P_2$

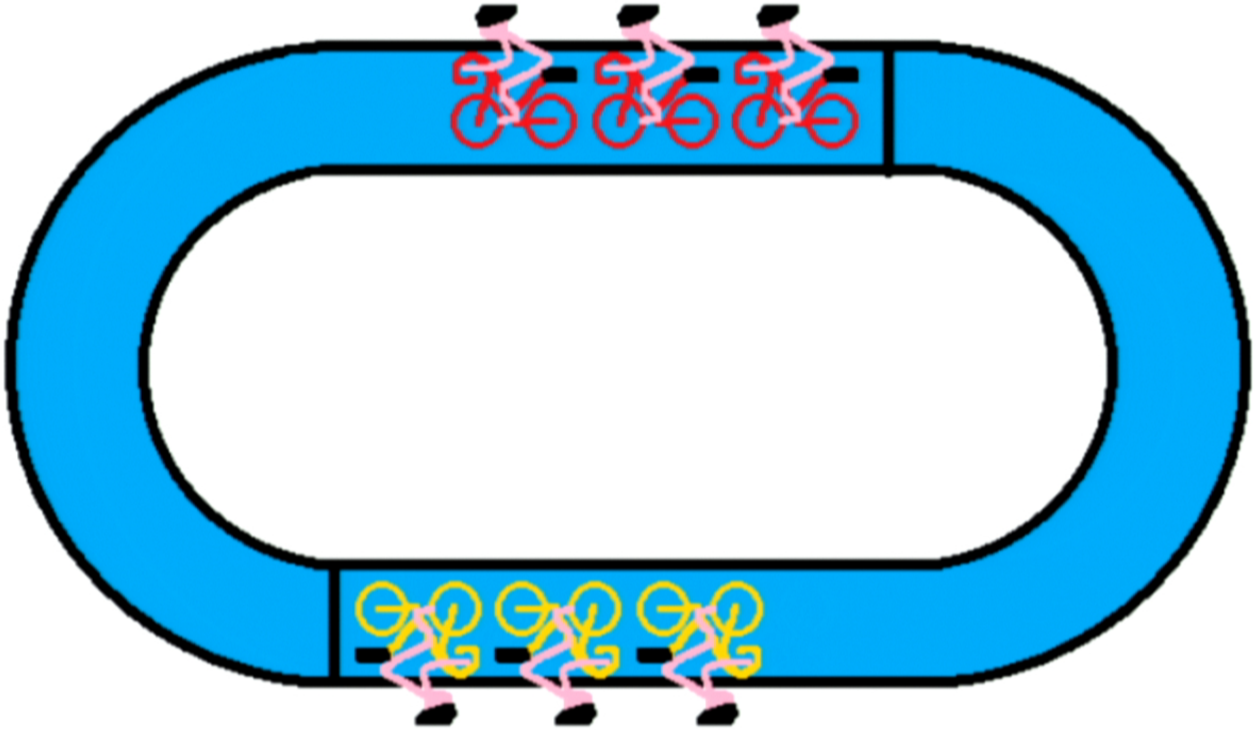
$P_1 > P_2 \therefore \Delta P > 0$

Theory

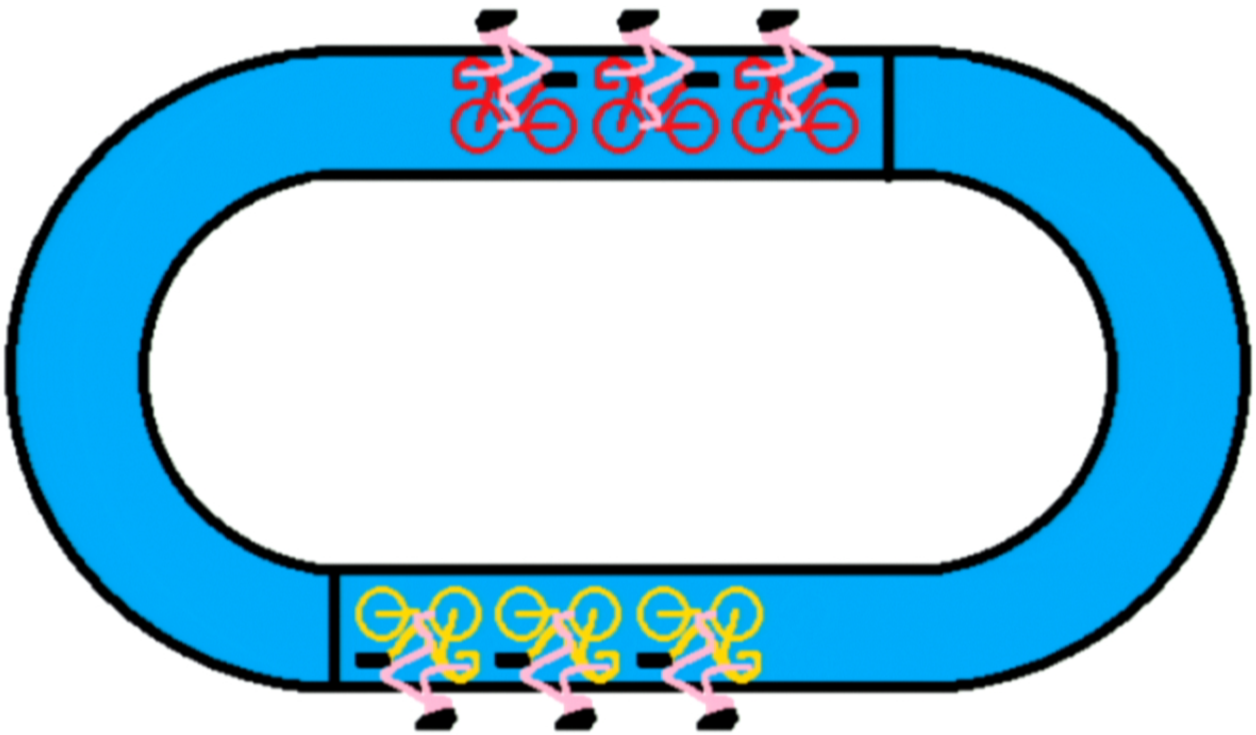


$$\Delta P = P_2 - P_3$$

Applications in Sport



Applications in Sport



Summary

- The Physics of Slipstreaming:

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17-Aug-12

Summary

- The Physics of Slipstreaming:
  - Travelling objects give the medium behind them a net velocity

Summary

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  - Pressure differences in front and behind of a travelling object cause a net force on the object

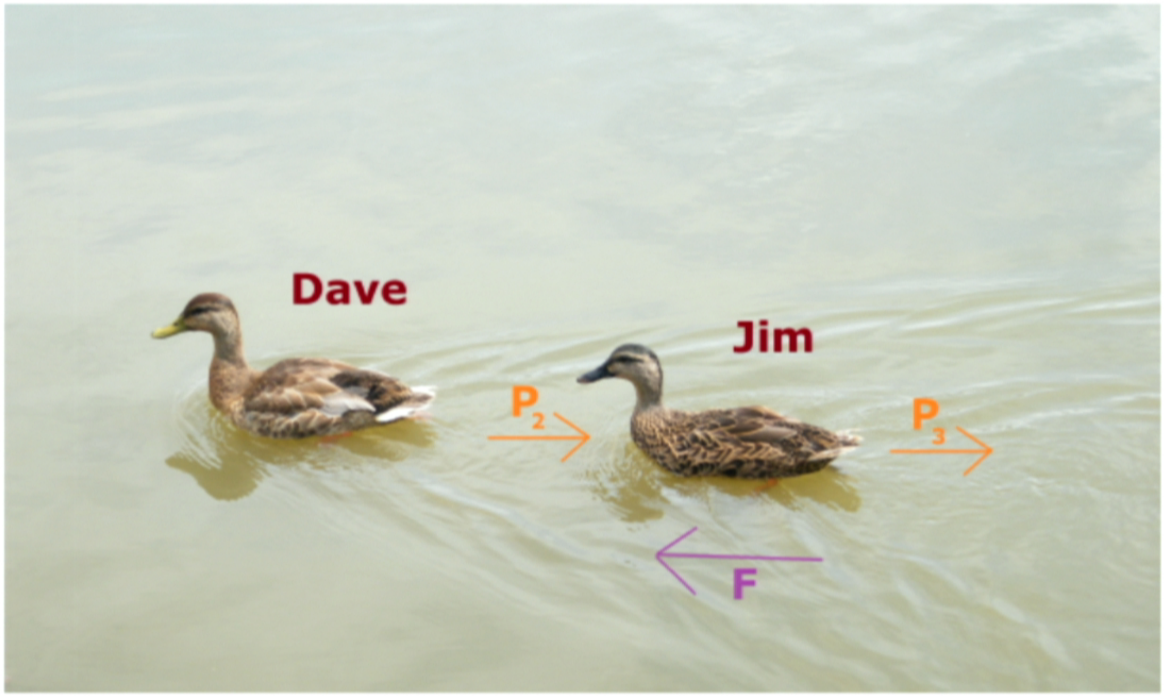
Summary

- The Physics of Slipstreaming:
  - Travelling objects give the medium behind them a net velocity
  - Pressure differences in front and behind of a travelling object cause a net force on the object
- Slipstreaming in Nature:
  - Allows animals to extend less energy by travelling in groups
  - This means longer distances can be traversed
- Applications in Sport:
  - Knowledge of aerodynamics: Better equipment and techniques in sports such as cycling

Summary

- The Physics of Slipstreaming:
  - Travelling objects give the medium behind them a net velocity
  - Pressure differences in front and behind of a travelling object cause a net force on the object
- Slipstreaming in Nature:
  - Allows animals to extend less energy by travelling in groups
  - This means longer distances can be traversed
- Applications in Sport:
  - Knowledge of aerodynamics: Better equipment and techniques in sports such as cycling
  - Knowledge of slipstreaming: Better cycling techniques and strategies

Theory



$\Delta P = P_2 - P_3$

$P_2 < P_3 \therefore \Delta P < 0$

11:40 AM


Physics in Nature
perimeter scholars
international
The nature of movement and the movement of nature
(Newton's Laws)
Natacha Altamirano
Perimeter Institute
17th of July 2012
EN
11:44 AM

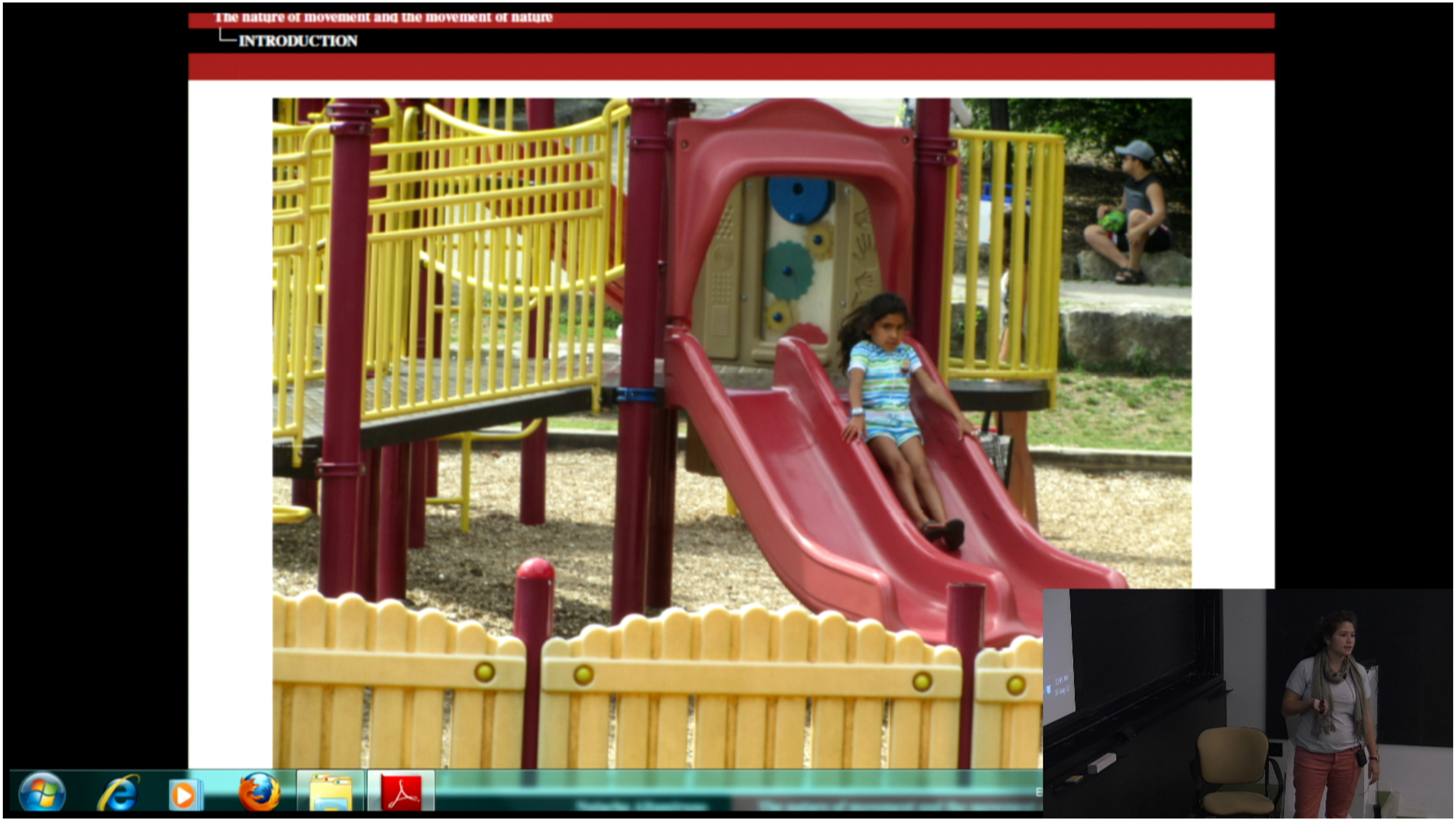
Structure of talk

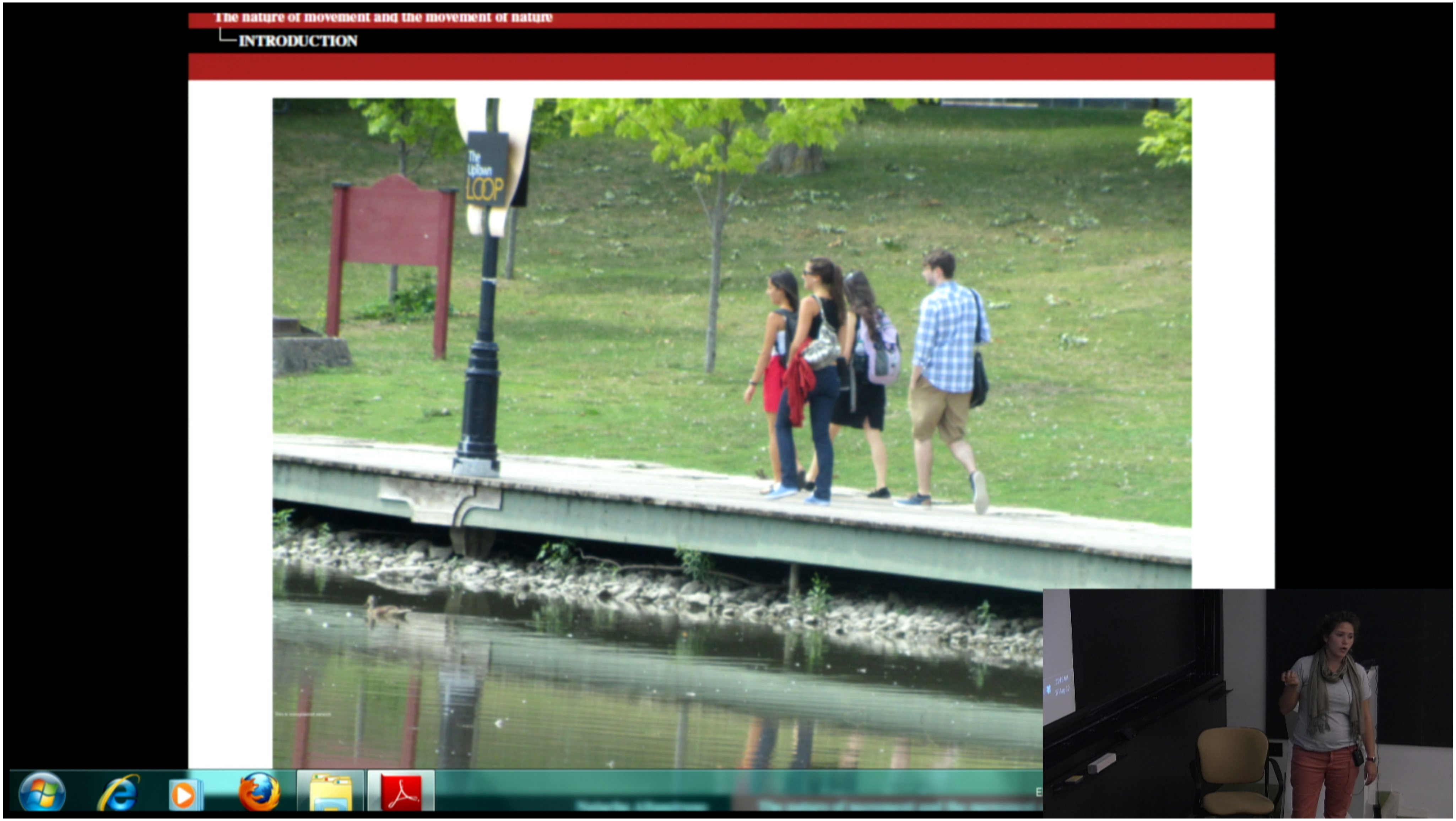
1. INTRODUCTION
2. THE MOVEMENT OF NATURE
3. THE NATURE OF MOVEMENT
4. CONCLUSIONS

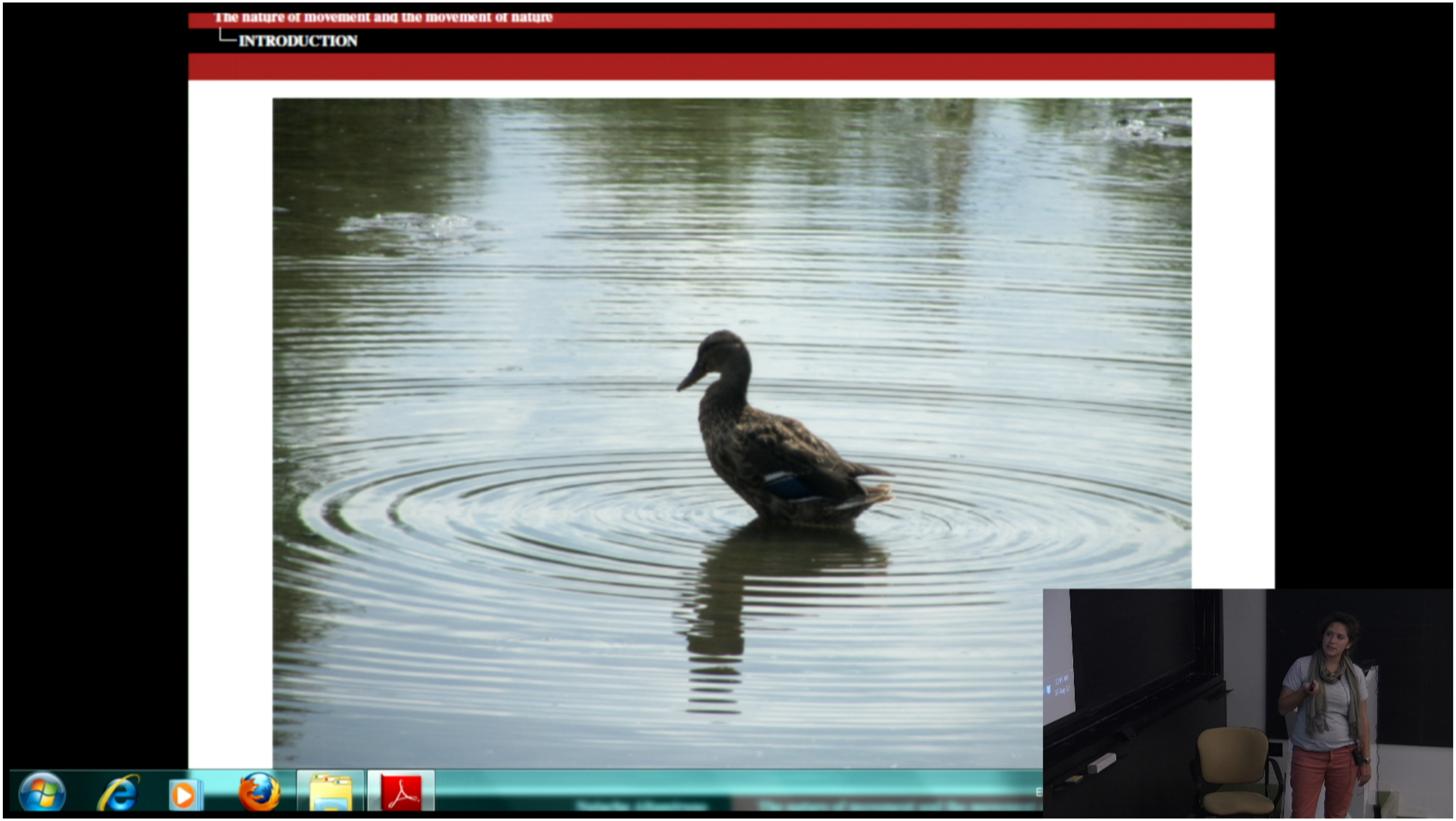
Structure of talk

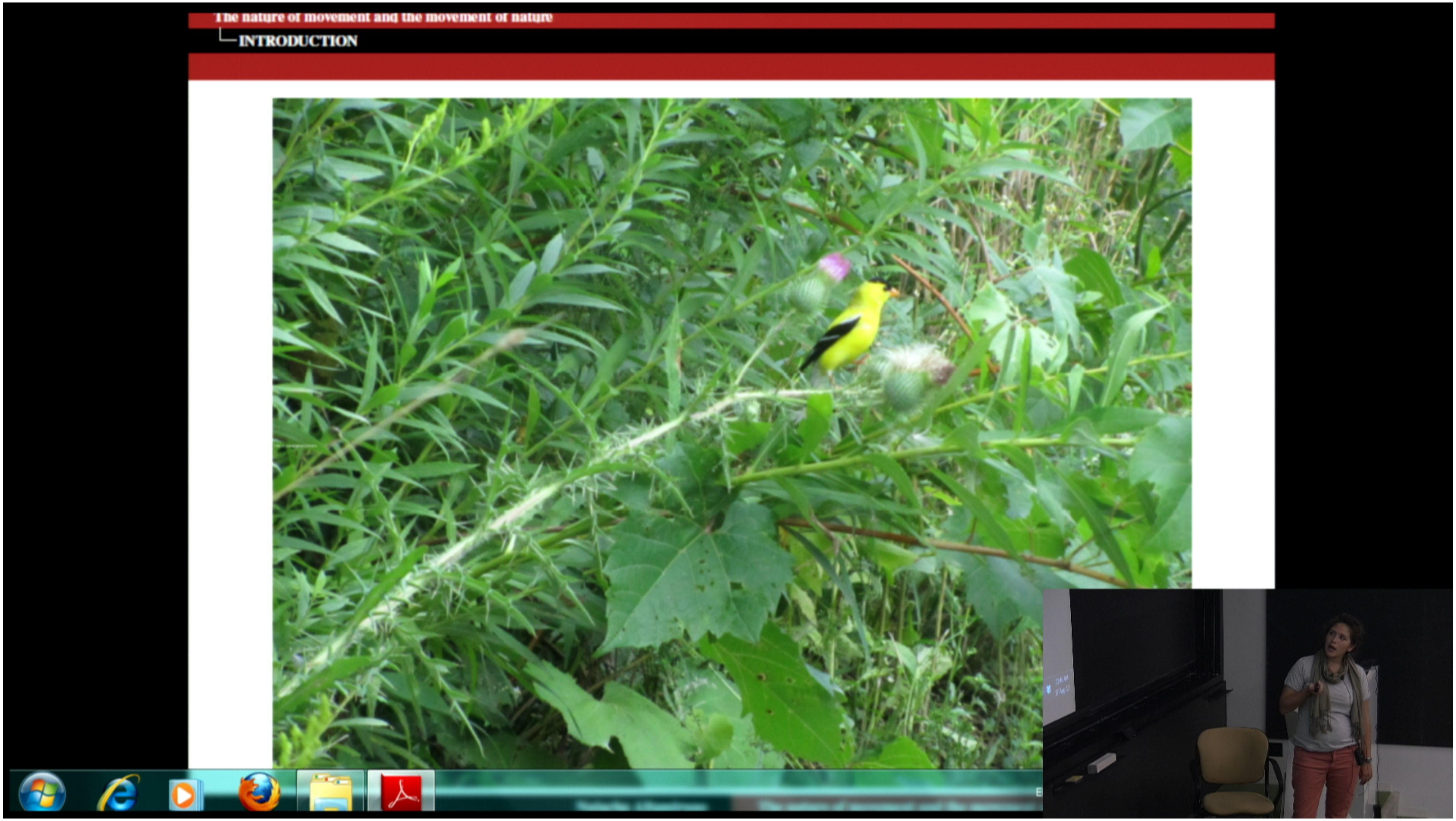
1. INTRODUCTION
2. THE MOVEMENT OF NATURE
3. THE NATURE OF MOVEMENT
4. CONCLUSIONS


The nature of movement and the movement of nature
Structure of talk
1 INTRODUCTION
2 THE MOVEMENT OF NATURE
3 THE NATURE OF MOVEMENT
4 CONCLUSIONS


The nature of movement and the movement of nature
INTRODUCTION


The nature of movement and the movement of nature
INTRODUCTION
The Uptown LOOP


The nature of movement and the movement of nature
INTRODUCTION


The nature of movement and the movement of nature
INTRODUCTION

The nature of movement and the movement of nature
INTRODUCTION


The nature of movement and the movement of nature
INTRODUCTION

The objective of this talk is to introduce the three Newton Laws analysing the nature that surrounds us.

The movement of Nature

There are two important fields of physics that studies movement

- **KINEMATICS** is the study of the movement of bodies and once the equation is established it is possible to determine the body's position and velocity at any time.
- **DYNAMICS** is the study of the causes for a body to change position and velocity.

The movement of nature

A BODY CHANGES ITS VELOCITY IF A FORCE ACTS ON IT.

The nature of movement and the movement of nature

└THE MOVEMENT OF NATURE

The movement of nature

FORCE HAS A DIRECTION AND A MAGNITUDE.

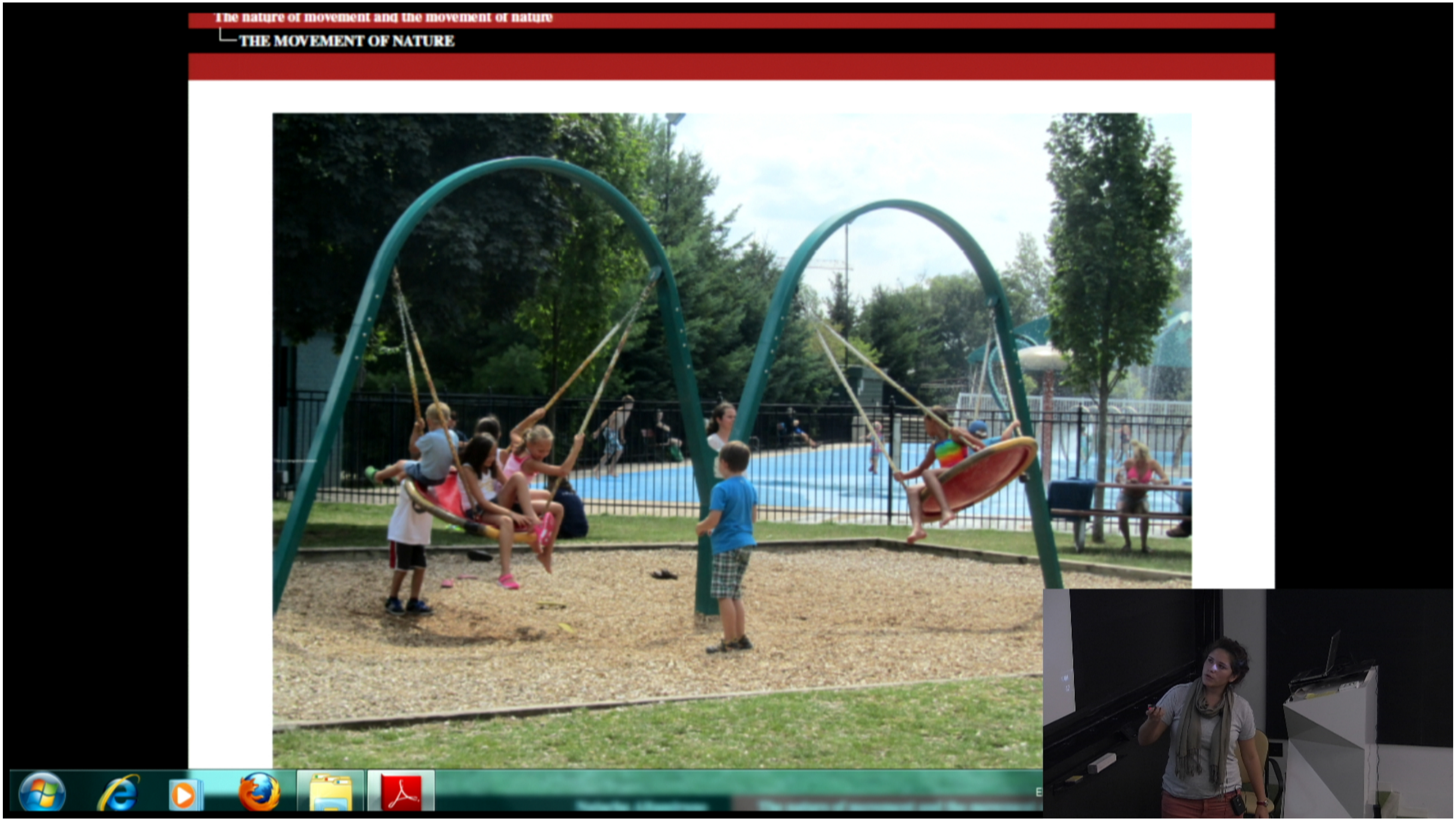
The nature of movement and the movement of nature

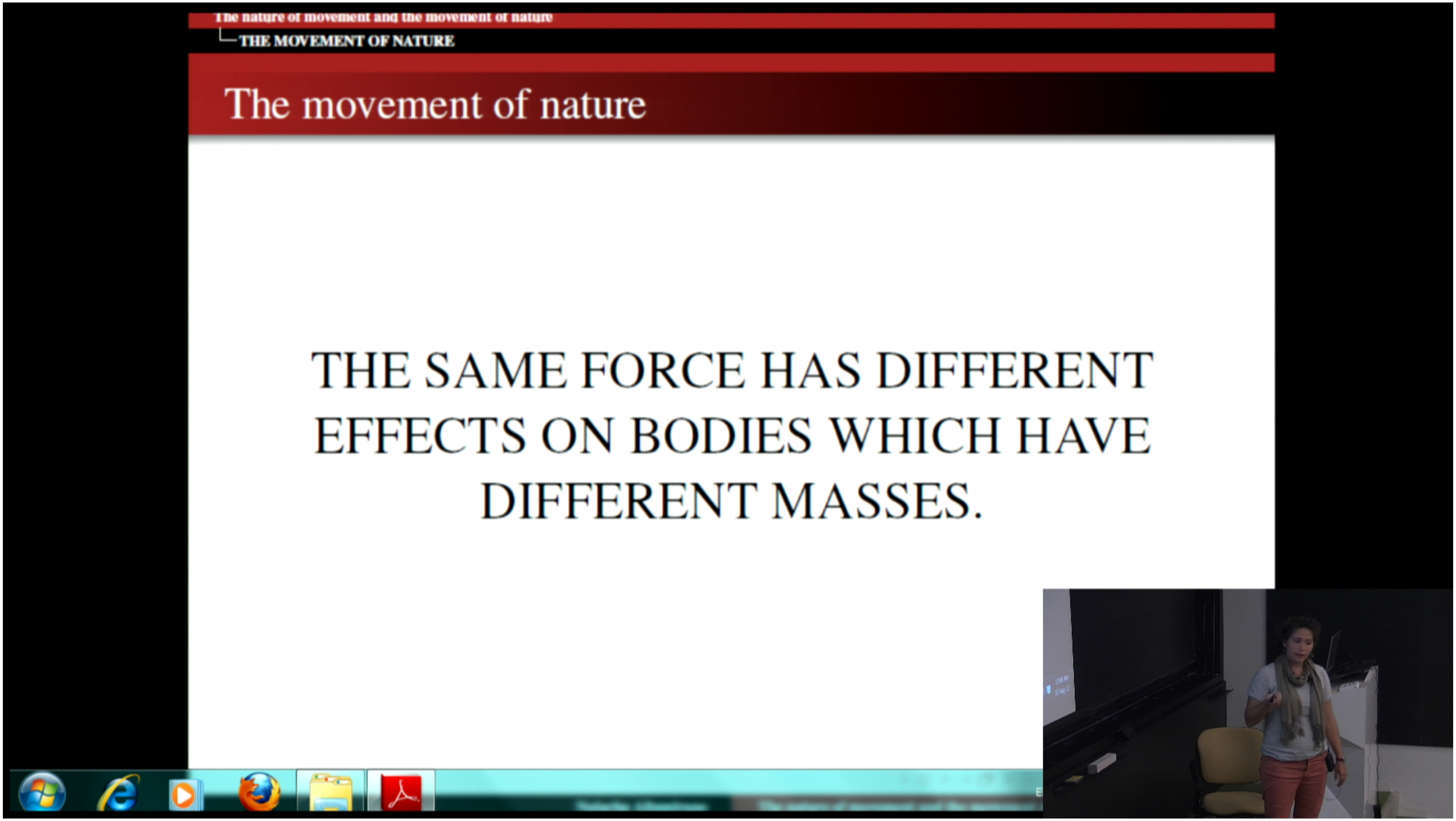
└ THE MOVEMENT OF NATURE

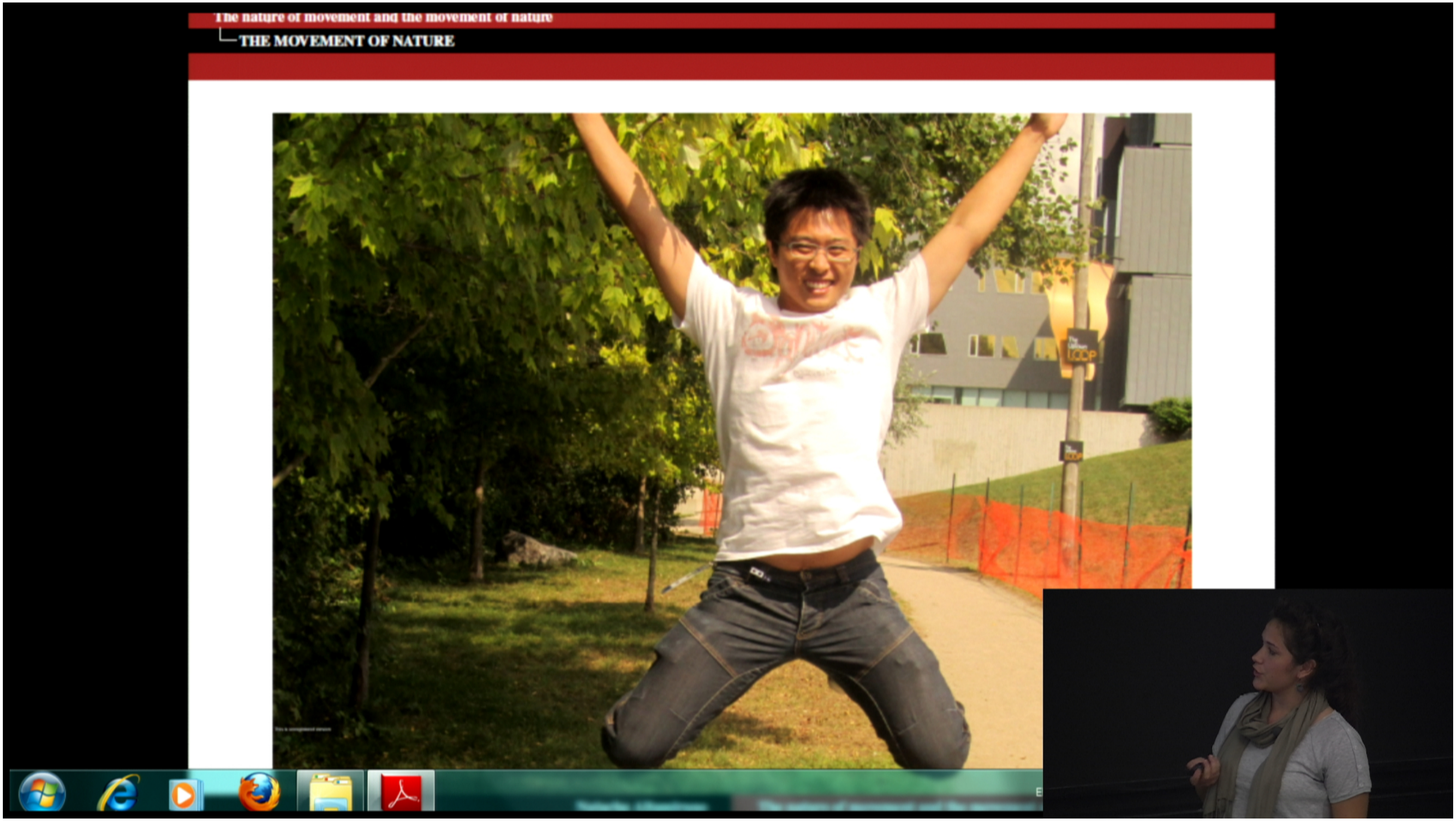
The movement of nature

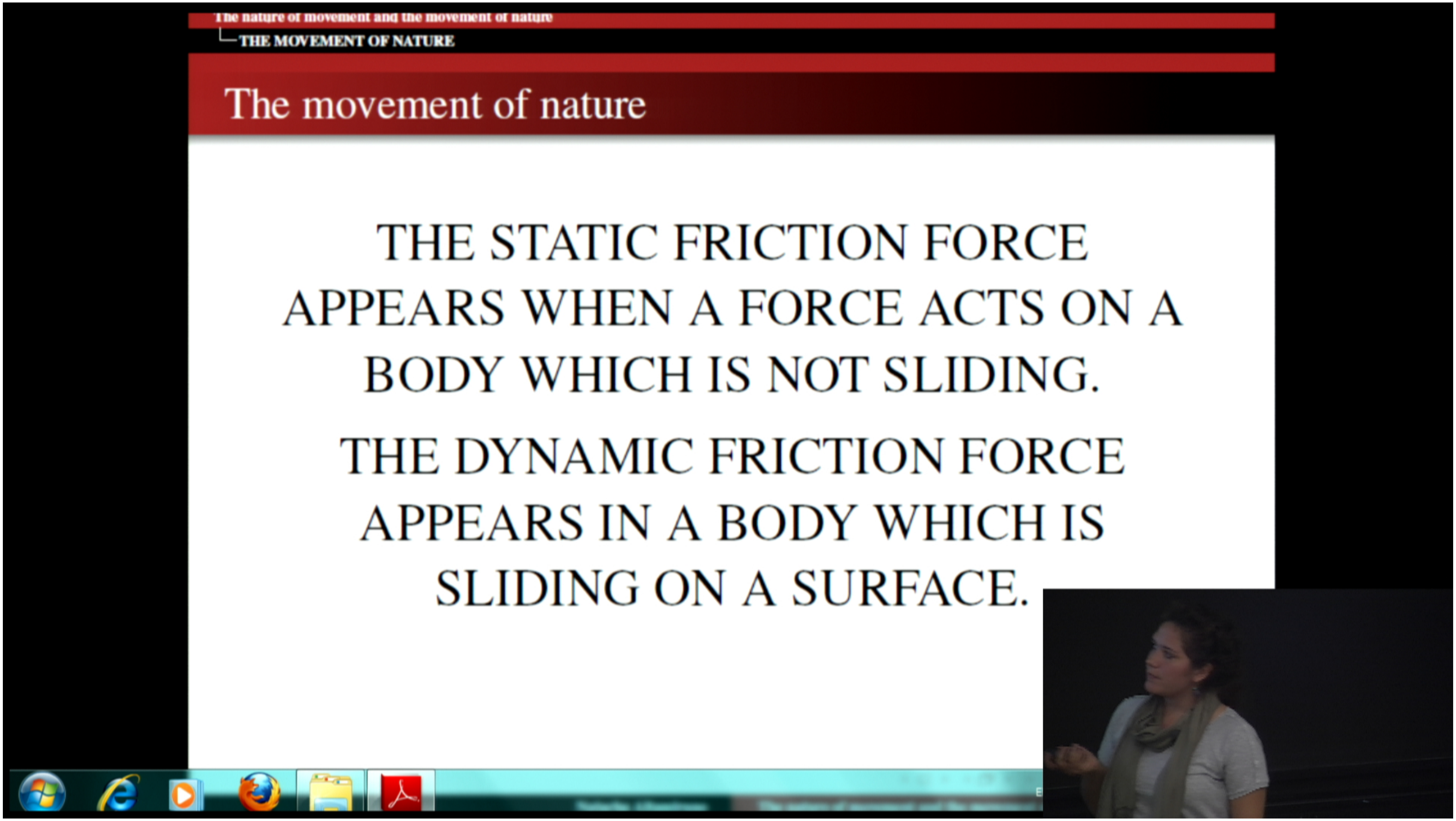
IF THE FORCE IS PERPENDICULAR TO THE DIRECTION OF MOTION, THIS FORCE WONT CHANGE THE VELOCITY.

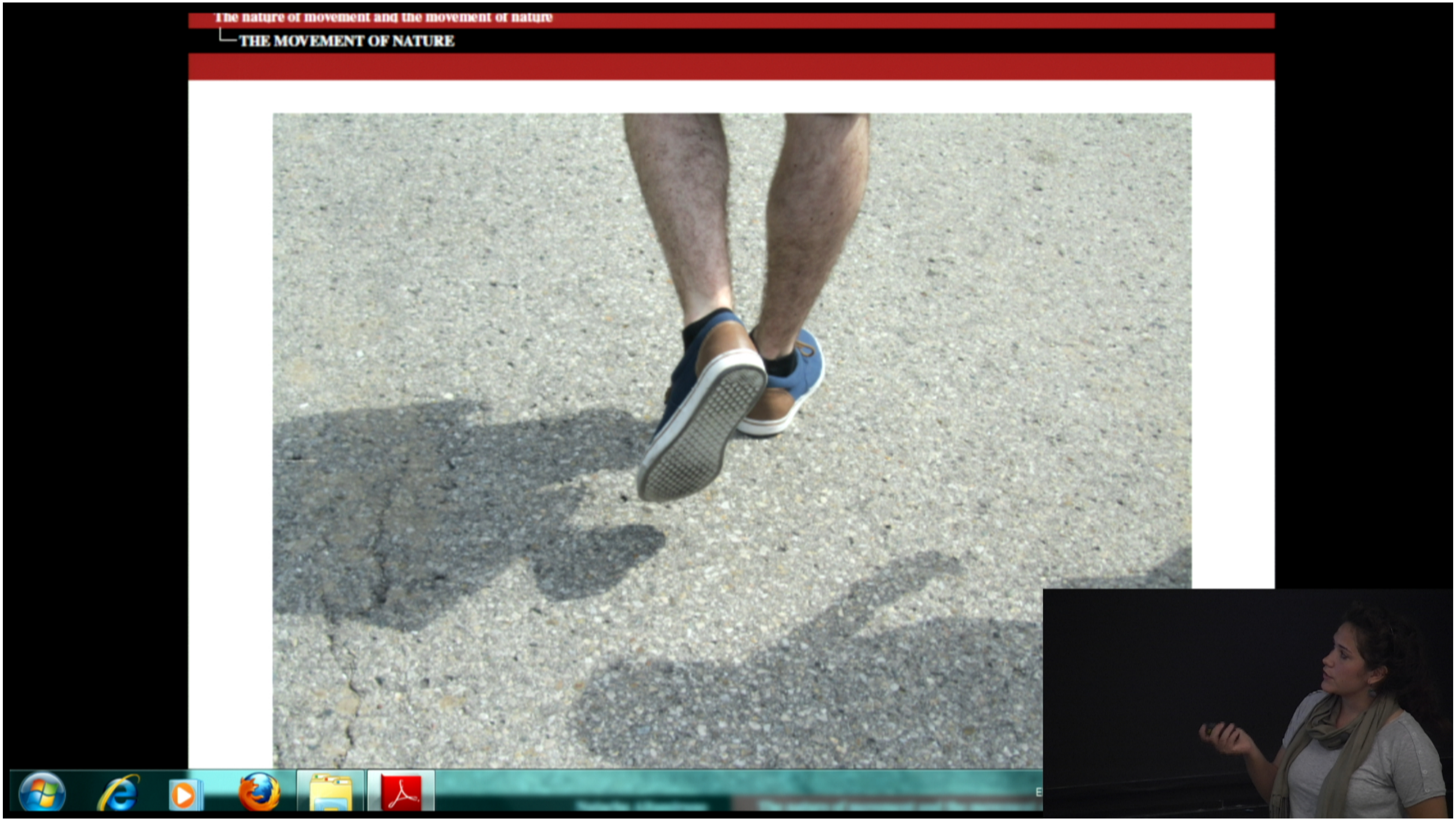
(Circular motion.)


The nature of movement and the movement of nature
THE MOVEMENT OF NATURE

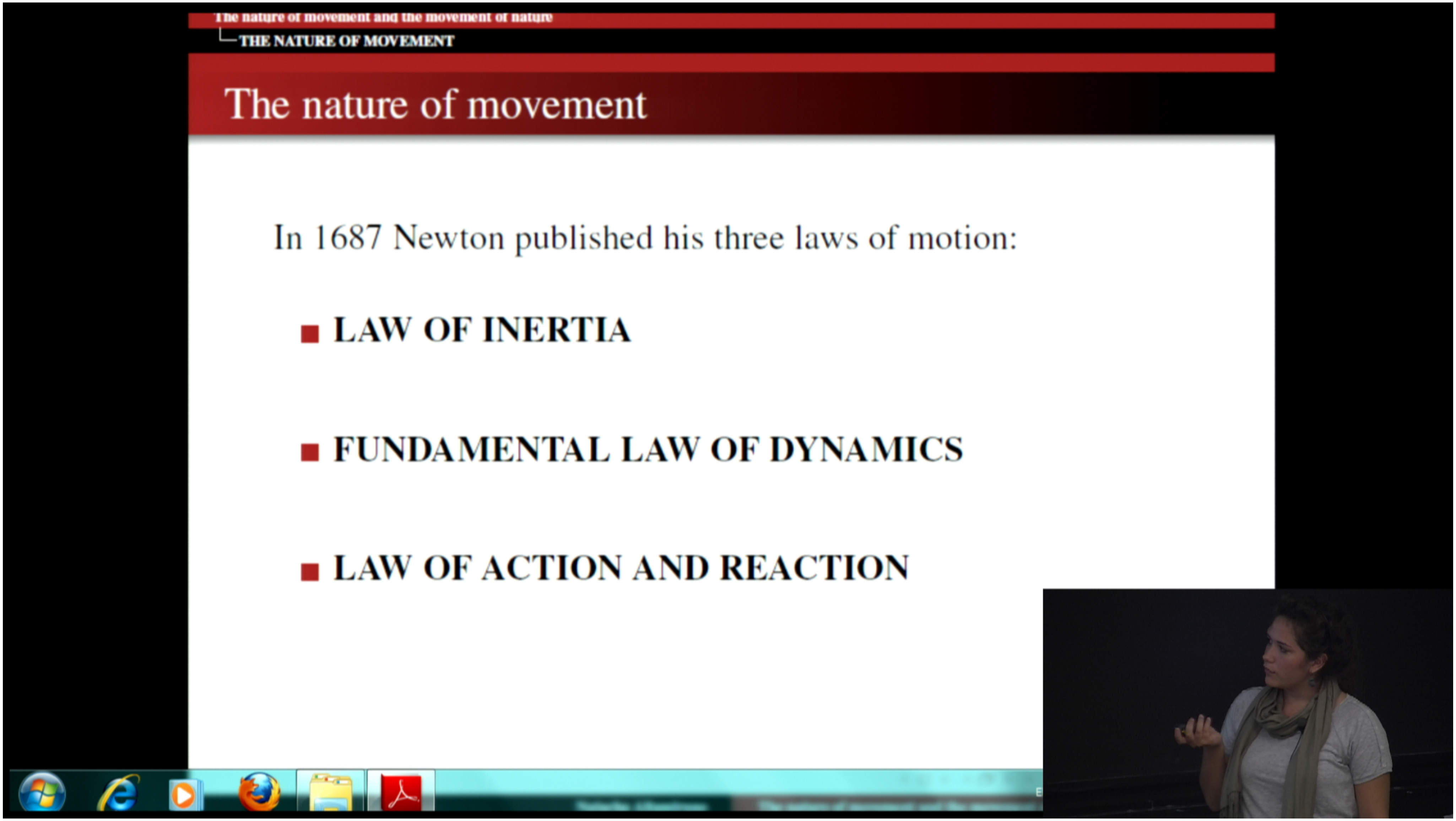

The nature of movement and the movement of nature
THE MOVEMENT OF NATURE
The movement of nature
THE SAME FORCE HAS DIFFERENT EFFECTS ON BODIES WHICH HAVE DIFFERENT MASSES.


The nature of movement and the movement of nature
THE MOVEMENT OF NATURE


The nature of movement and the movement of nature
THE MOVEMENT OF NATURE
The movement of nature
THE STATIC FRICTION FORCE APPEARS WHEN A FORCE ACTS ON A BODY WHICH IS NOT SLIDING.
THE DYNAMIC FRICTION FORCE APPEARS IN A BODY WHICH IS SLIDING ON A SURFACE.


The nature of movement and the movement of nature
THE MOVEMENT OF NATURE


The nature of movement and the movement of nature
THE NATURE OF MOVEMENT
1 INTRODUCTION
2 THE MOVEMENT OF NATURE
3 THE NATURE OF MOVEMENT
4 CONCLUSIONS


The nature of movement and the movement of nature
THE NATURE OF MOVEMENT
The nature of movement
In 1687 Newton published his three laws of motion:
LAW OF INERTIA
FUNDAMENTAL LAW OF DYNAMICS
LAW OF ACTION AND REACTION

The nature of movement-1st Law

If there are no forces acting on a body (or all the forces cancels), then the velocity of this body will not change.

The nature of movement and the movement of nature

└THE NATURE OF MOVEMENT

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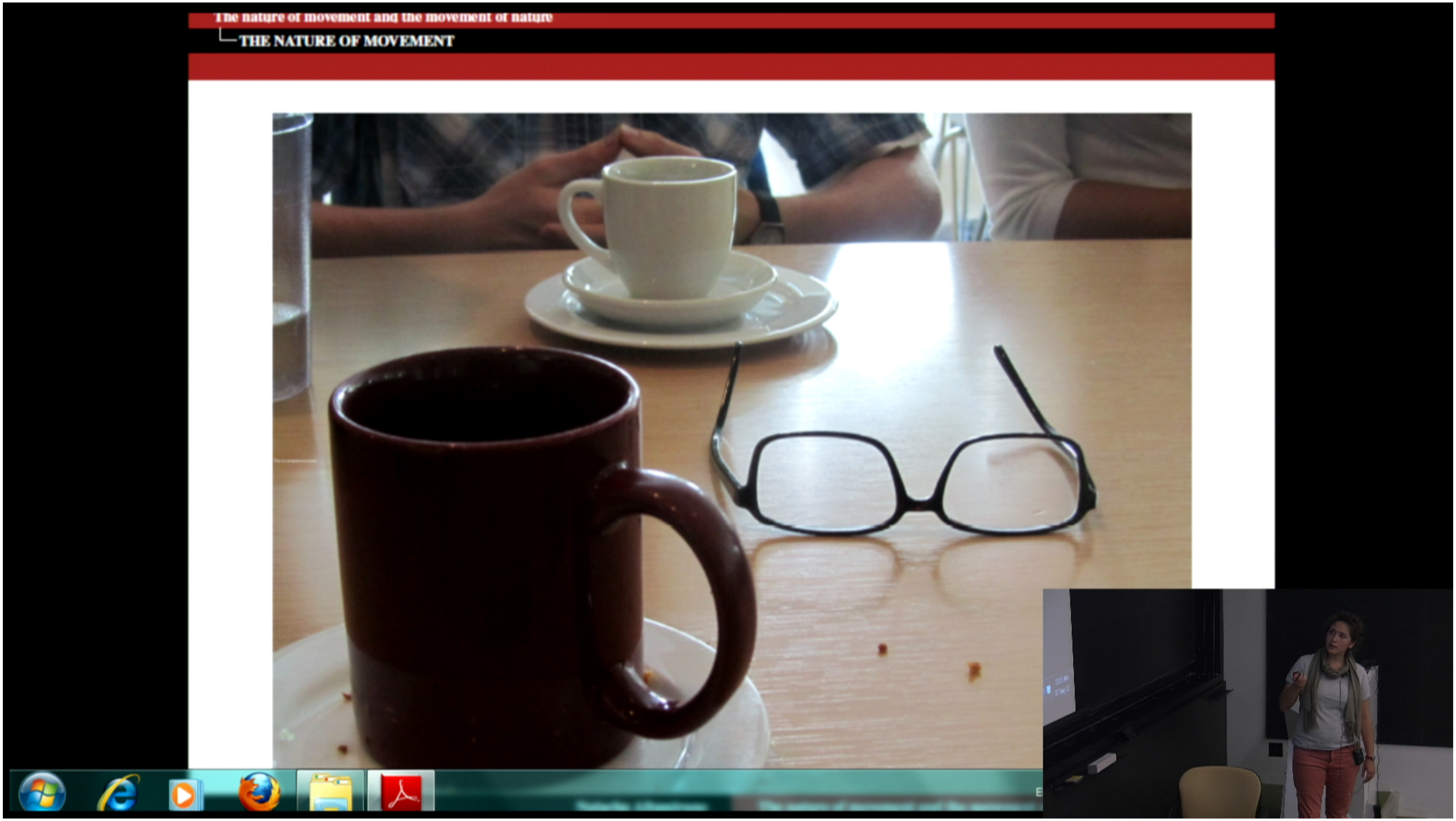
The nature of movement-2nd Law

If a force acts on a body its velocity will change (the body will be accelerated)

$$F = ma$$

The nature of movement-3rd Law

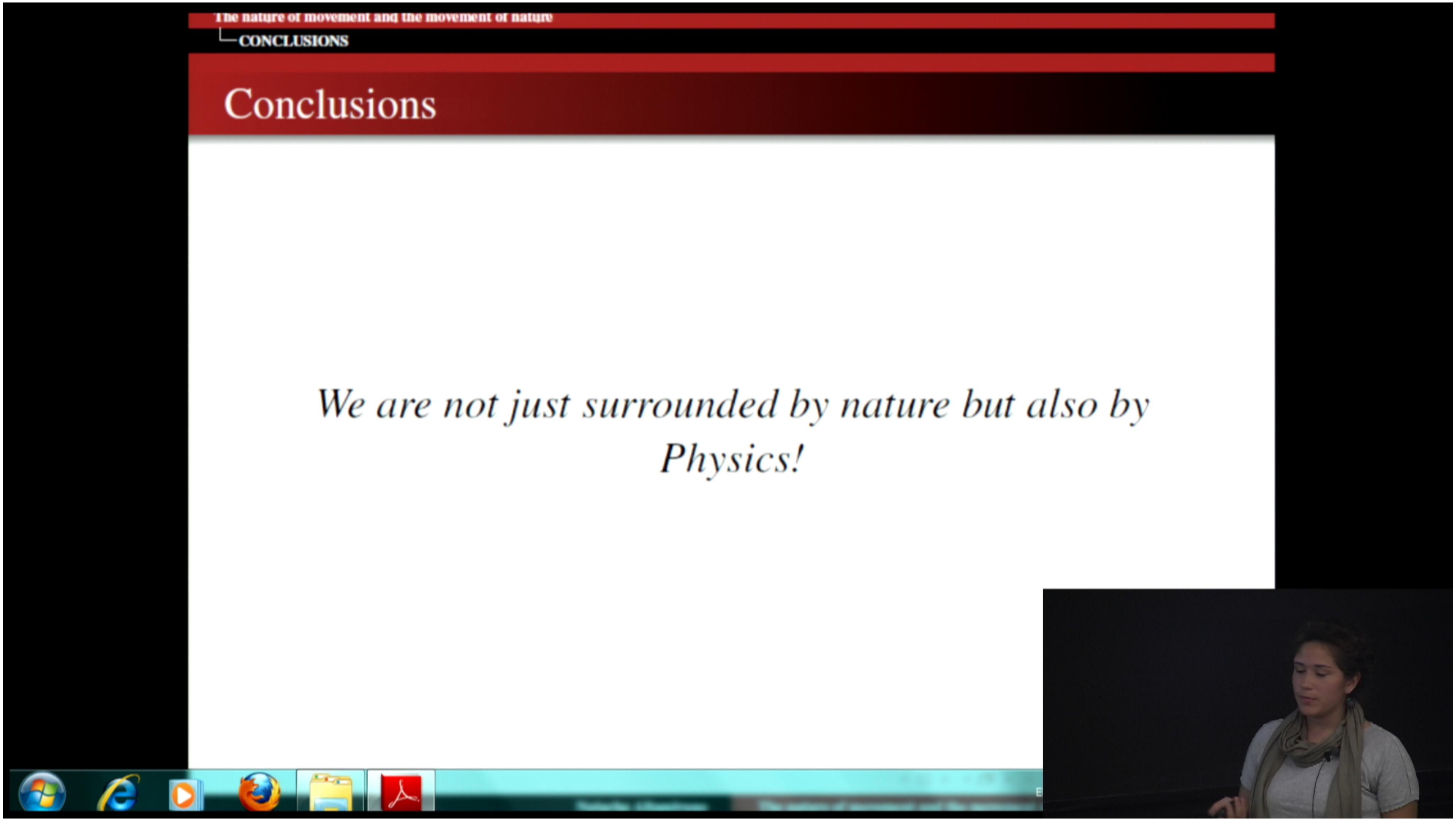
If a body applies a force to another body, this one would 'react' to this action applying a force with the same magnitude and opposite direction on the first one.

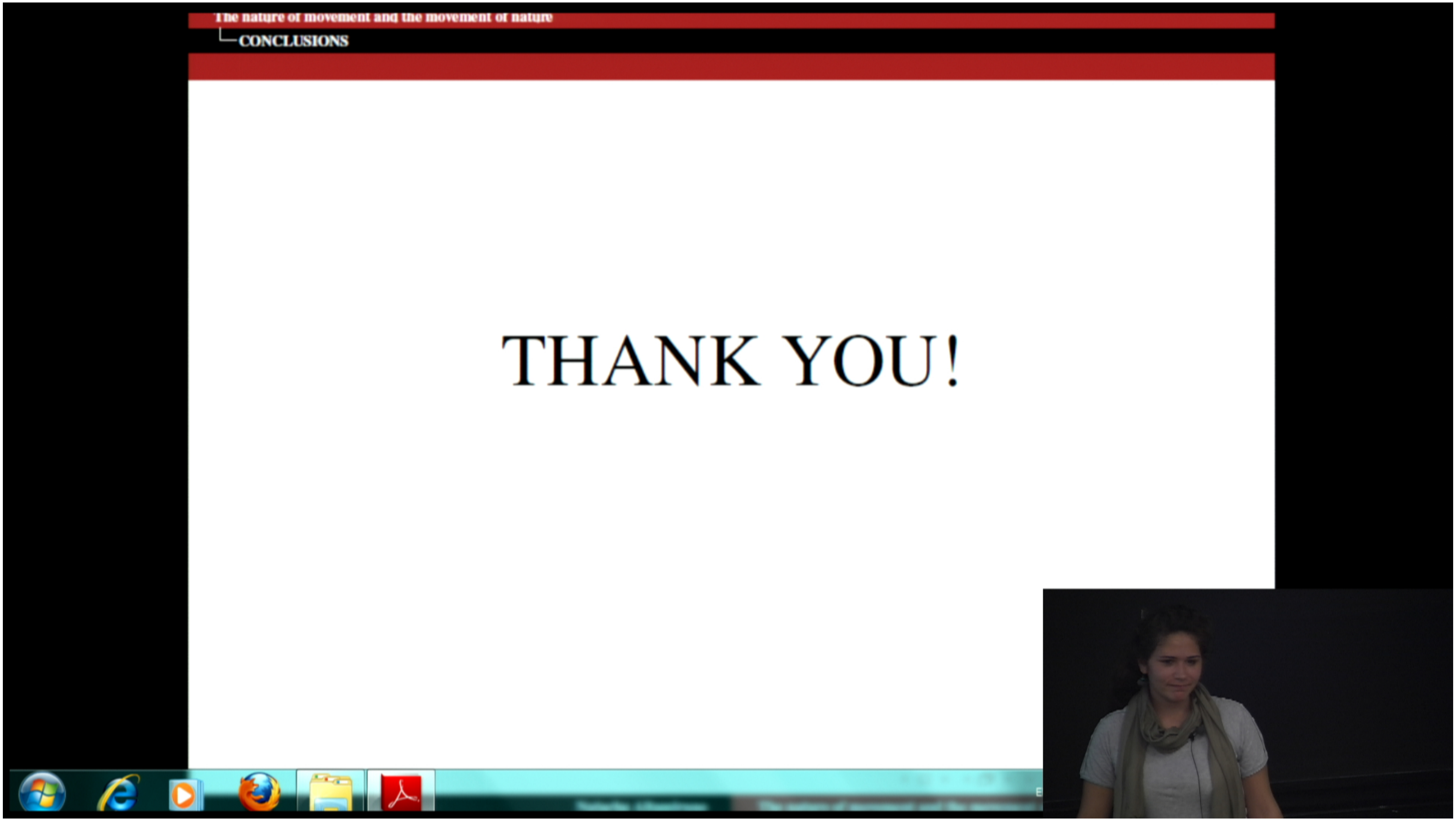

The nature of movement and the movement of nature
THE NATURE OF MOVEMENT

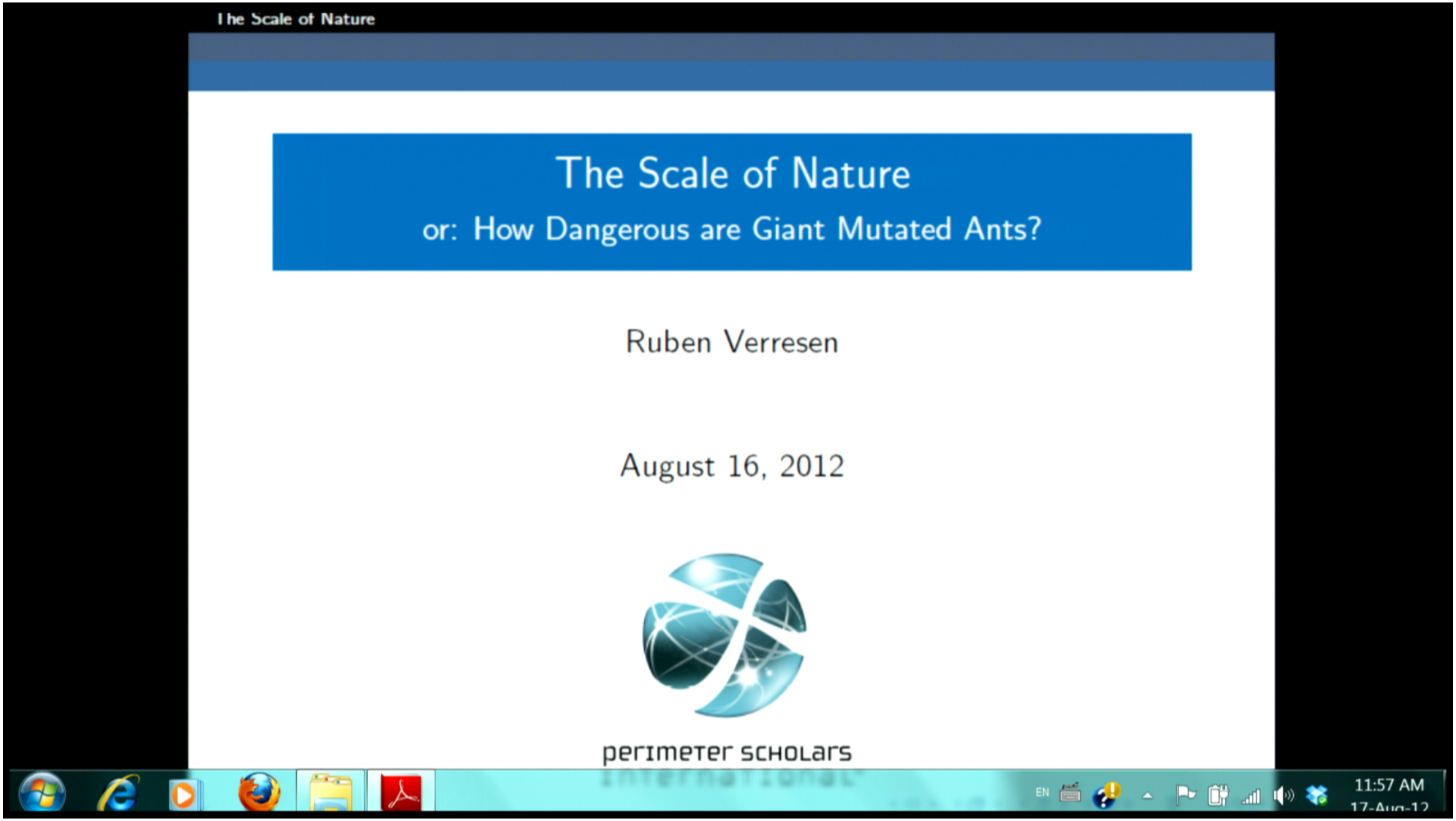
Conclusions

During the talk we've

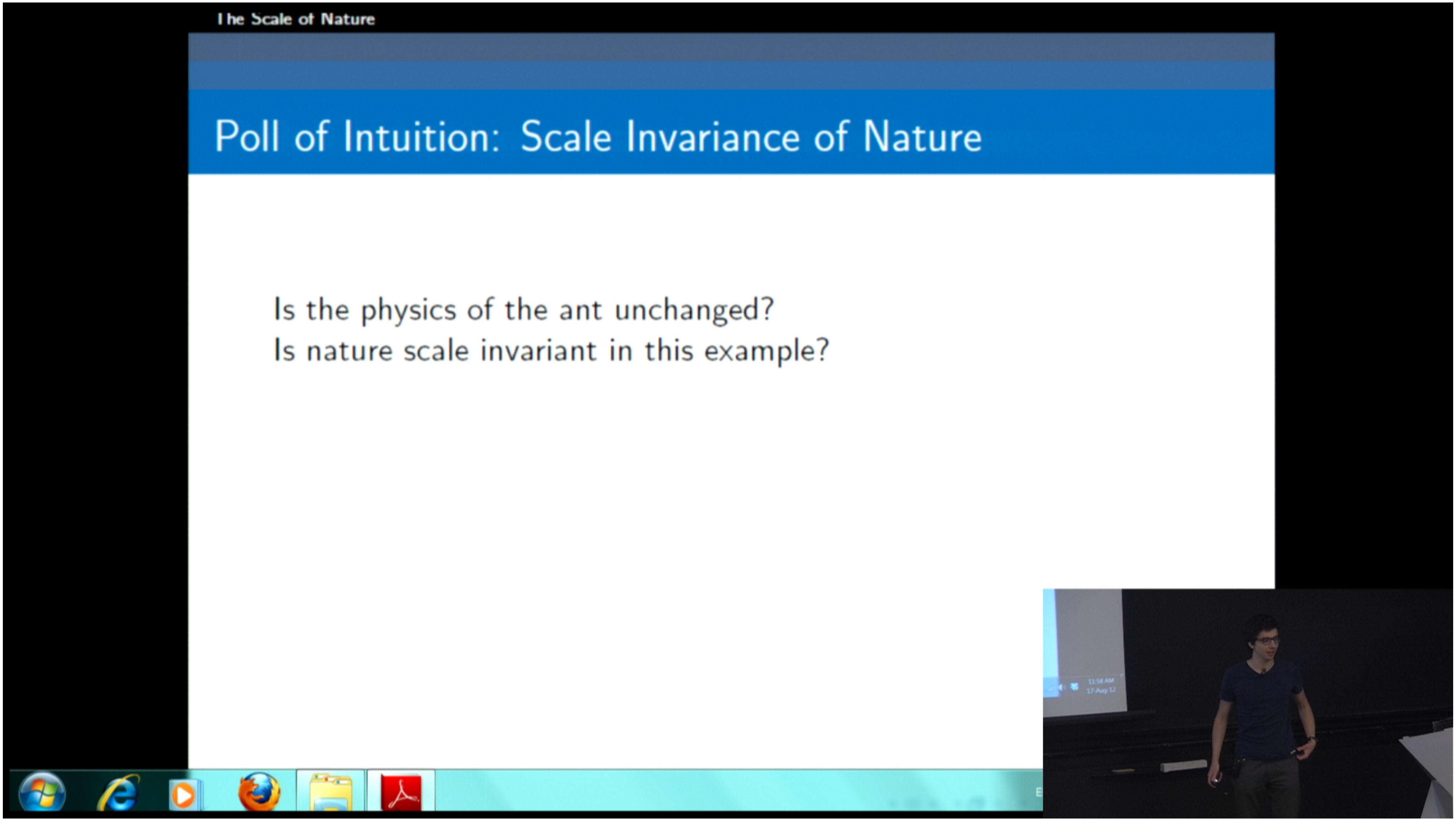
- seen pictures that could have been taken in a normal day walk
- related them with the notion that we have of motion
- introduced Newton's laws of motion and explained them with normal photos


The nature of movement and the movement of nature
CONCLUSIONS
Conclusions
We are not just surrounded by nature but also by Physics!


The nature of movement and the movement of nature
CONCLUSIONS
THANK YOU!


The Scale of Nature
The Scale of Nature
or: How Dangerous are Giant Mutated Ants?
Ruben Verresen
August 16, 2012
perimeter scholars
EN
11:57 AM

The Picture


The Scale of Nature
Poll of Intuition: Scale Invariance of Nature
Is the physics of the ant unchanged?
Is nature scale invariant in this example?

Poll of Intuition: Scale Invariance of Nature

Is the physics of the ant unchanged?
Is nature scale invariant in this example?

INTUITION SAYS YES

Poll of Intuition: Scale Invariance of Nature

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Is nature scale invariant in this example?

INTUITION SAYS YES

INTUITION SAYS NO

Poll of Intuition: Scale Invariance of Nature

Is the physics of the ant unchanged?
Is nature scale invariant in this example?

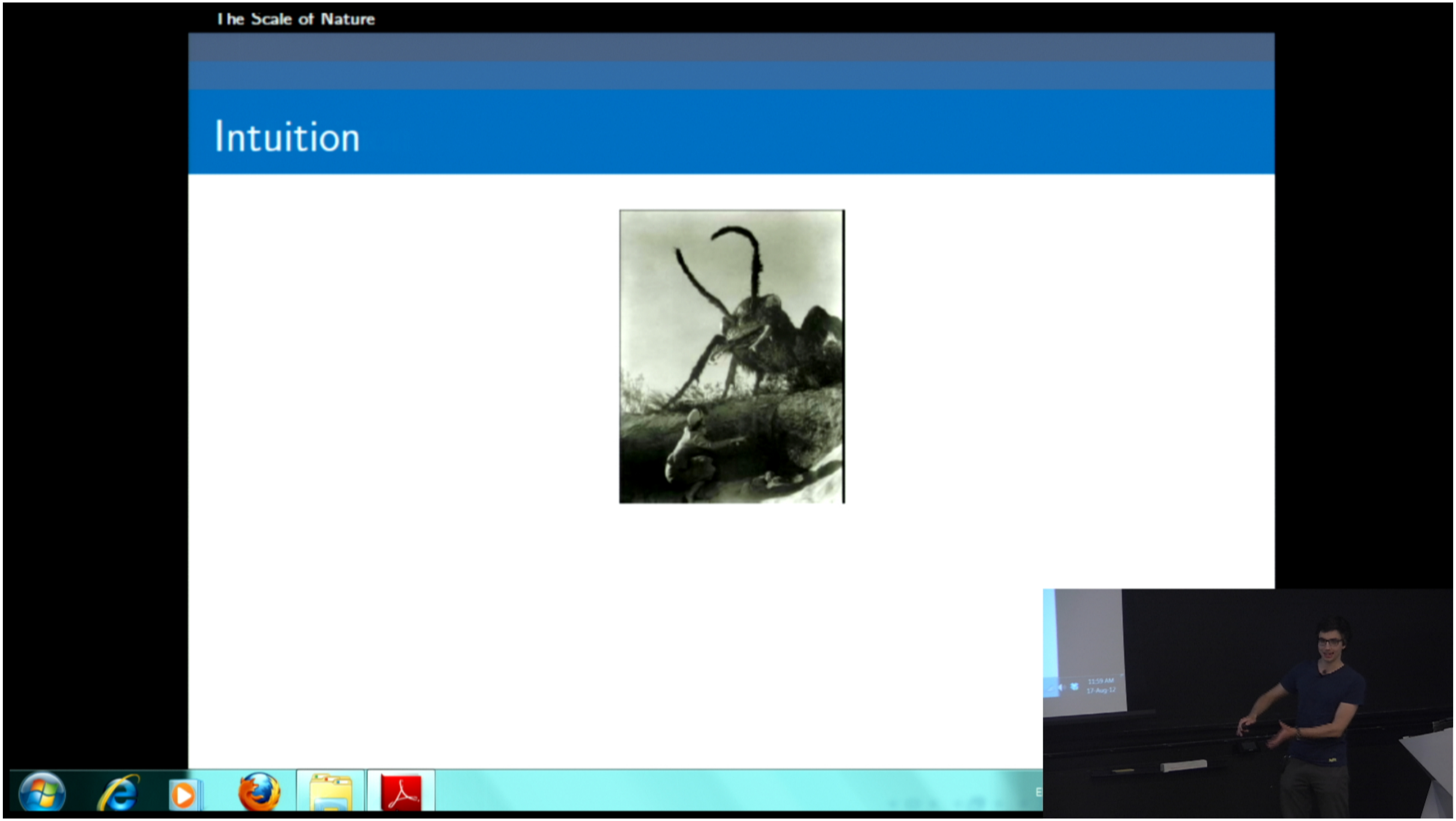
INTUITION SAYS YES

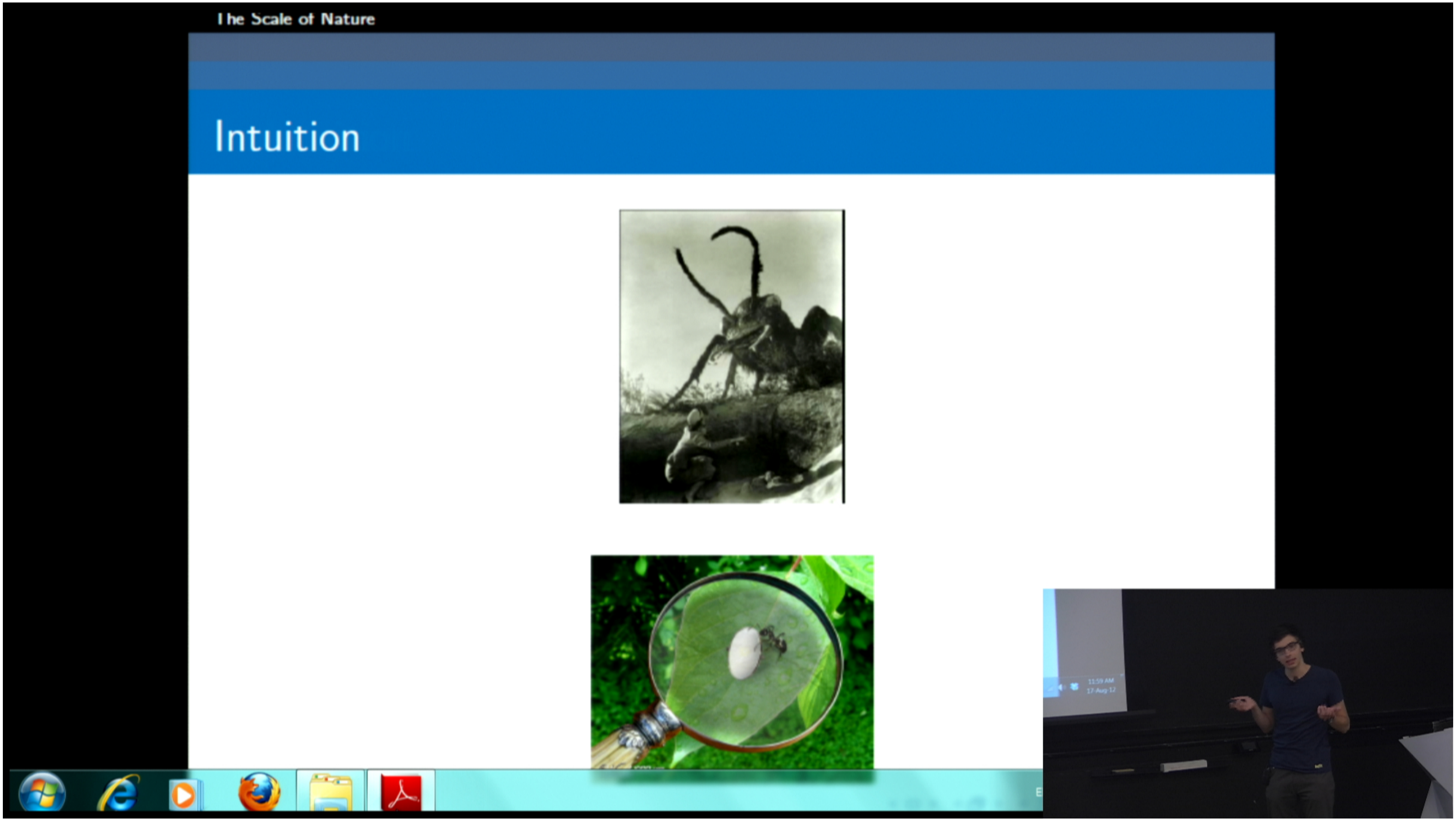
INTUITION SAYS NO

NO INTUITION

Overview

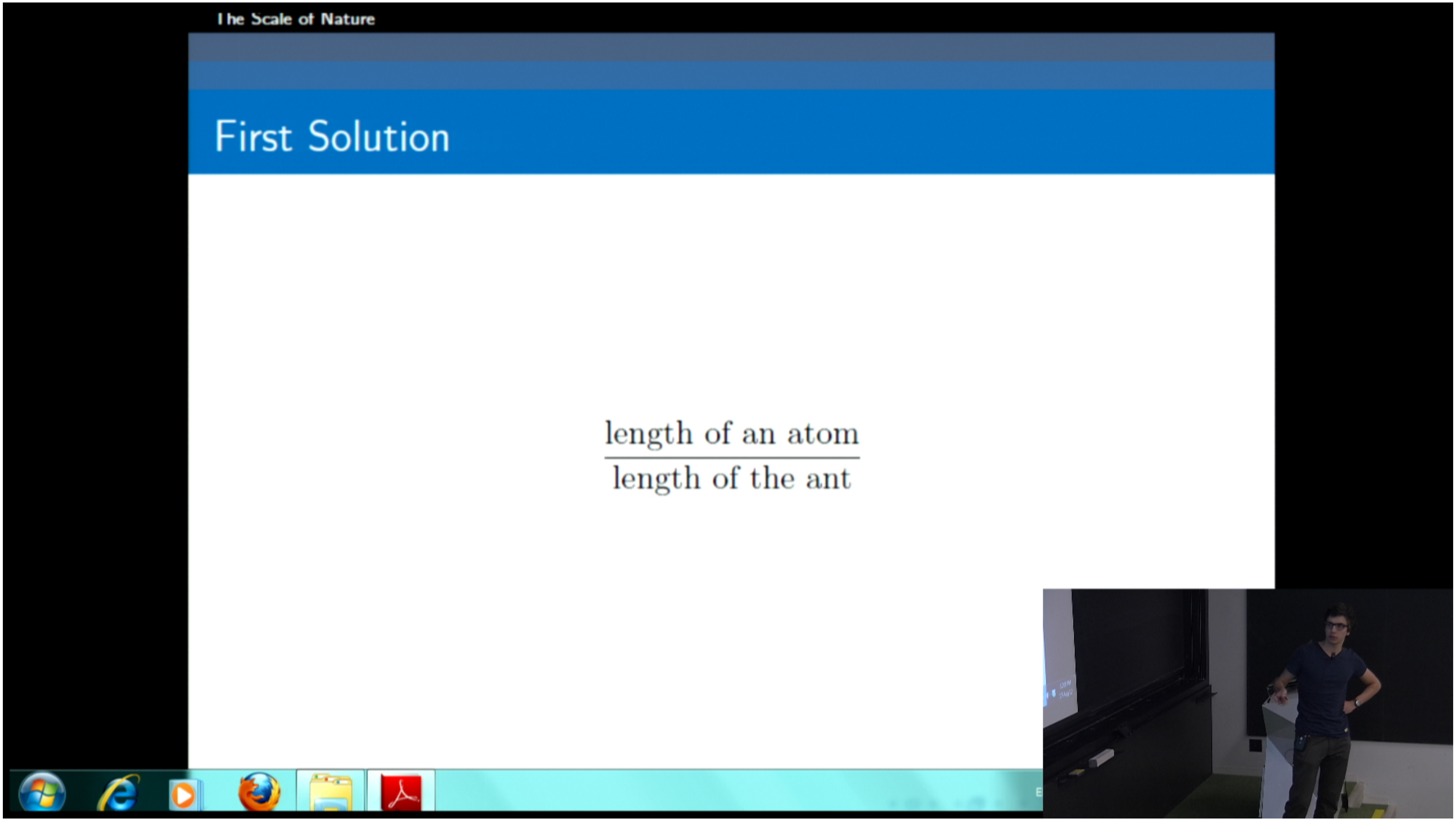
- Problem with intuition?
- A first solution
- Intermezzo: dimensionless constants
- Definite solution


The Scale of Nature
Intuition


The Scale of Nature
Intuition

First Solution

$$\frac{\text{length of an atom}}{\text{length of the ant}}$$


The Scale of Nature
First Solution
length of an atom / length of the ant

Dimensionful vs. dimensionless changes

Only a change in a dimensionless quantity is measurable.

Gamov, "Mr Tompkins in Wonderland"
= ill-defined

"Change c and keep other fundamental constants fixed"

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Only a change in a dimensionless quantity is measurable.

Gamov, “Mr Tompkins in Wonderland”
= ill-defined

“Change c and keep other fundamental constants fixed”
= impossible

Changing α, always measurable!

Final Solution

Dimensionless quantity that

- changes for the larger ant
- characterizes instability

MACROSCOPIC MICROSCOPIC

Final Solution

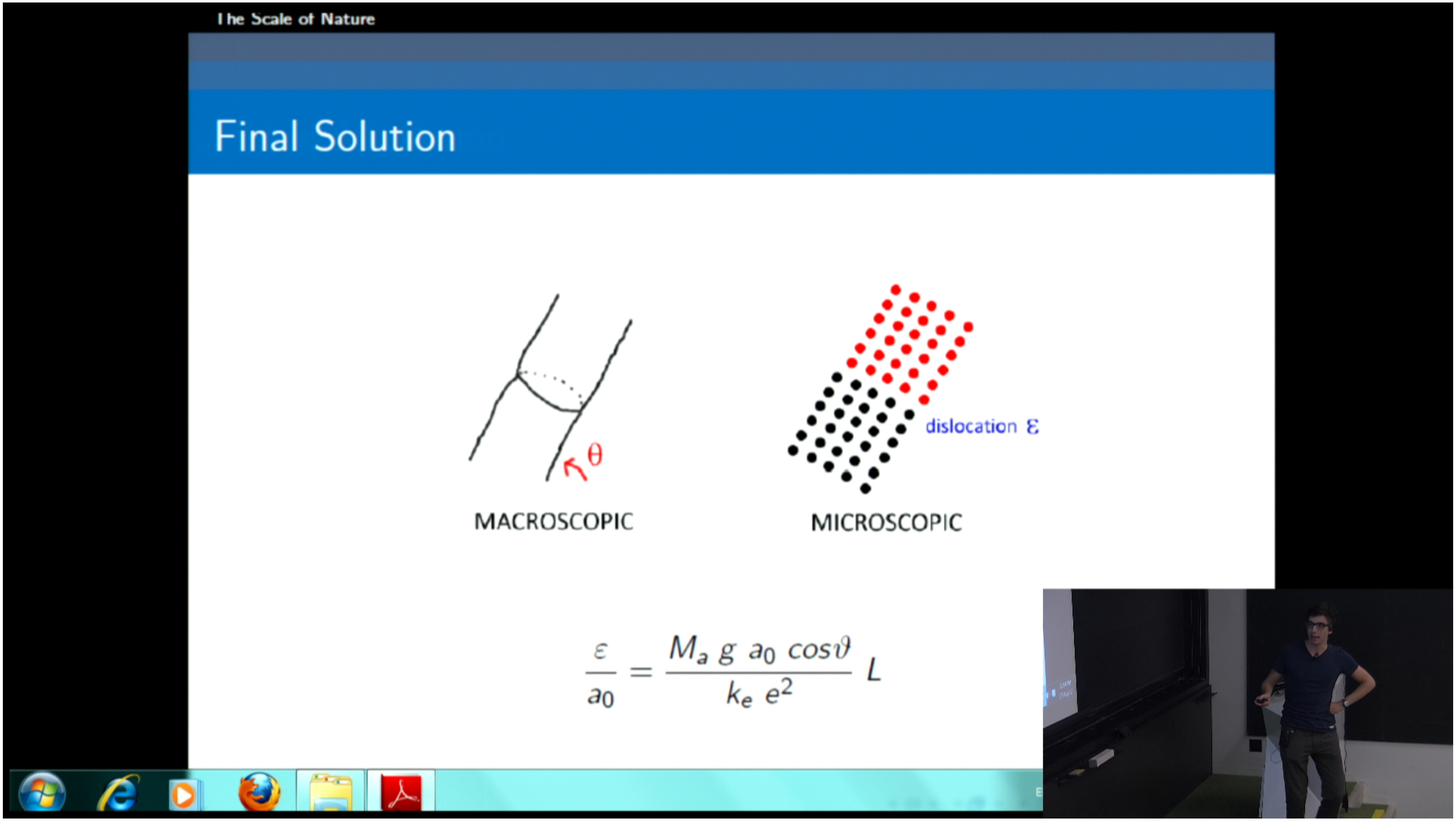
Dimensionless quantity that

- changes for the larger ant
- characterizes instability

MACROSCOPIC

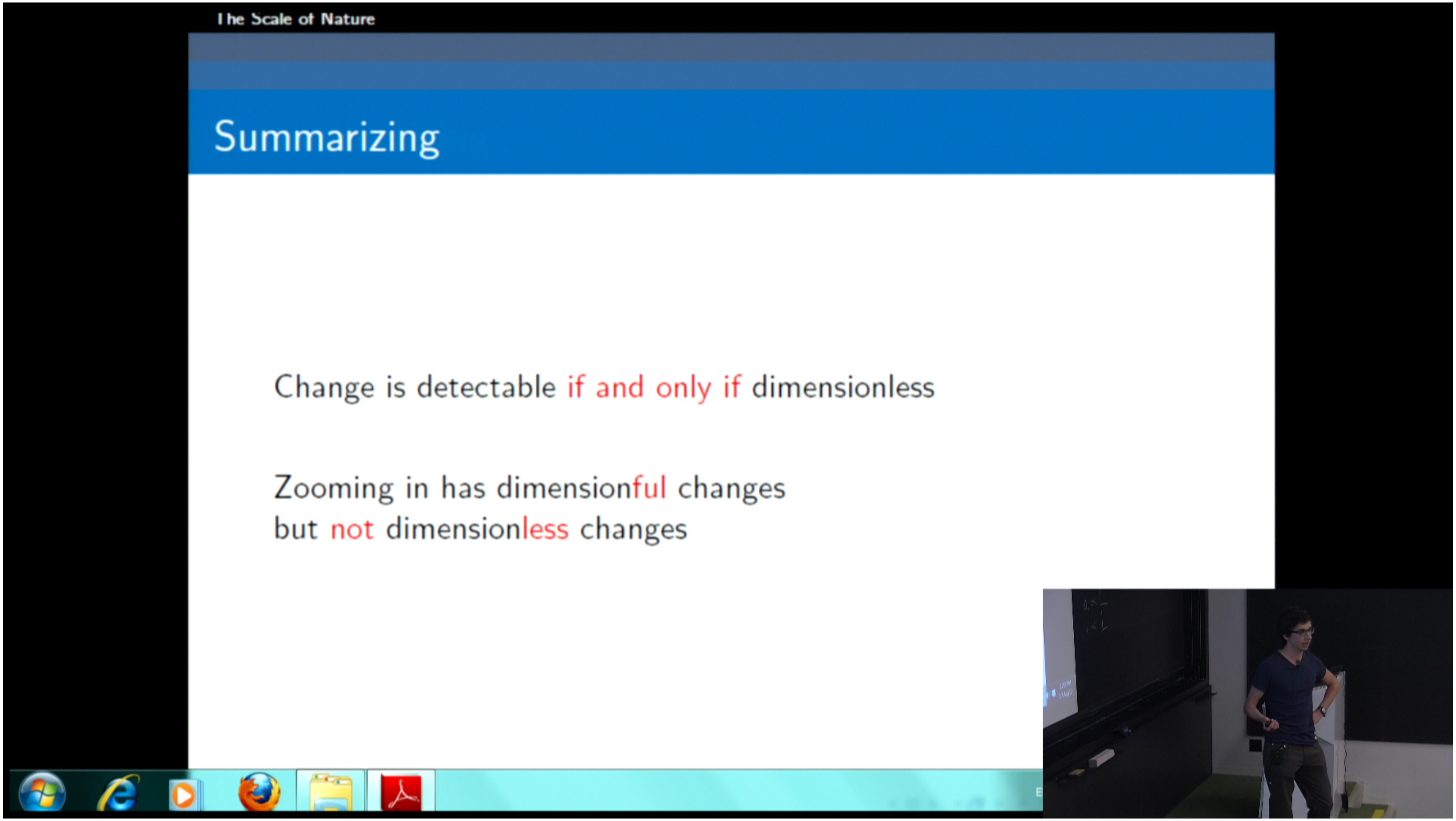
MICROSCOPIC

$$\text{dimensionless instability} = \frac{\varepsilon}{a_0}$$


The Scale of Nature
Final Solution
θ
MACROSCOPIC
dislocation ε
MICROSCOPIC
$\frac{\varepsilon}{a_0} = \frac{M_a\ g\ a_0\ \cos\vartheta}{k_e\ e^2}\ L$

Summarizing

Change is detectable if and only if dimensionless


The Scale of Nature
Summarizing
Change is detectable if and only if dimensionless
Zooming in has dimensionful changes
but not dimensionless changes

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Change is detectable if and only if dimensionless

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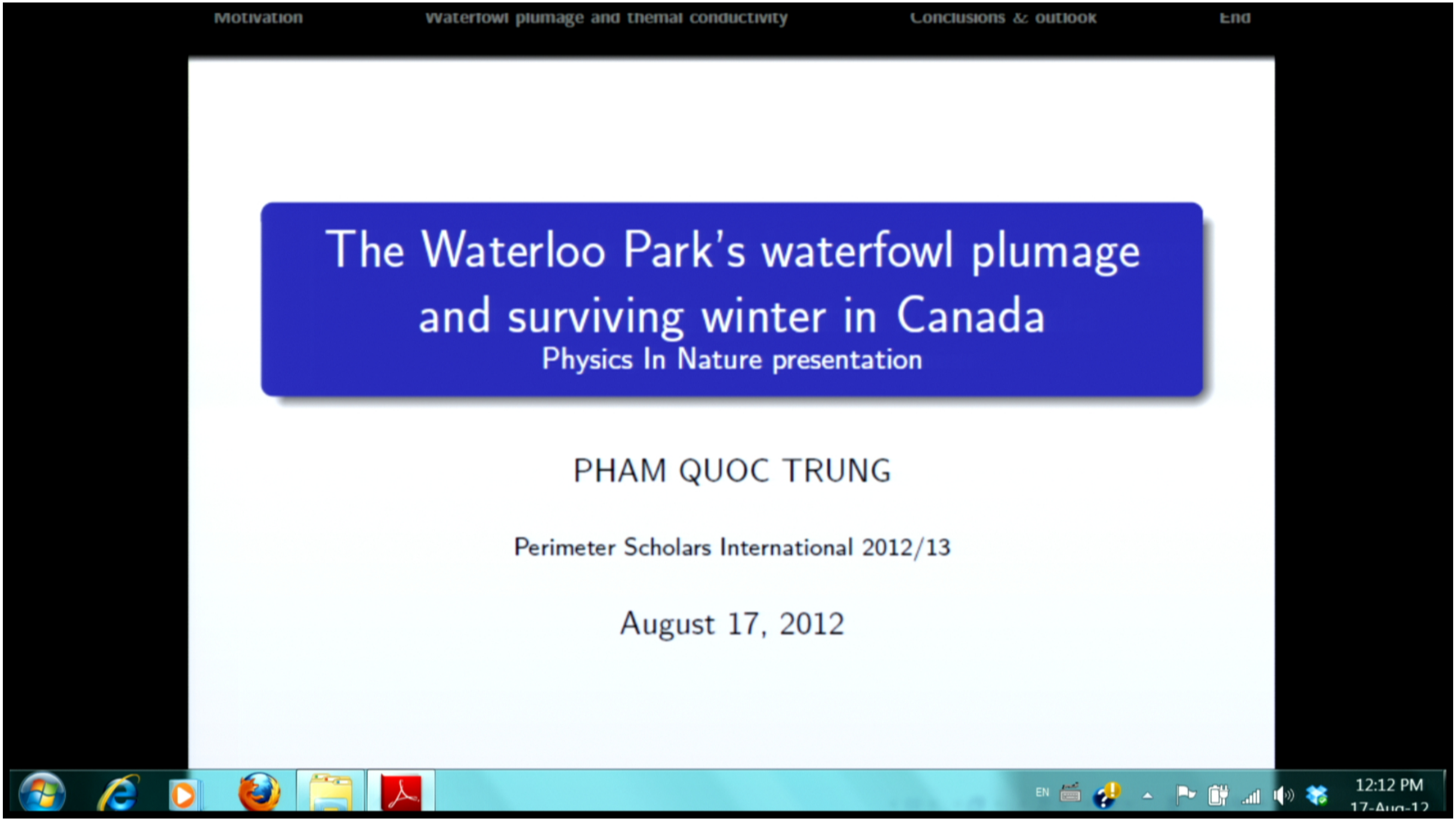
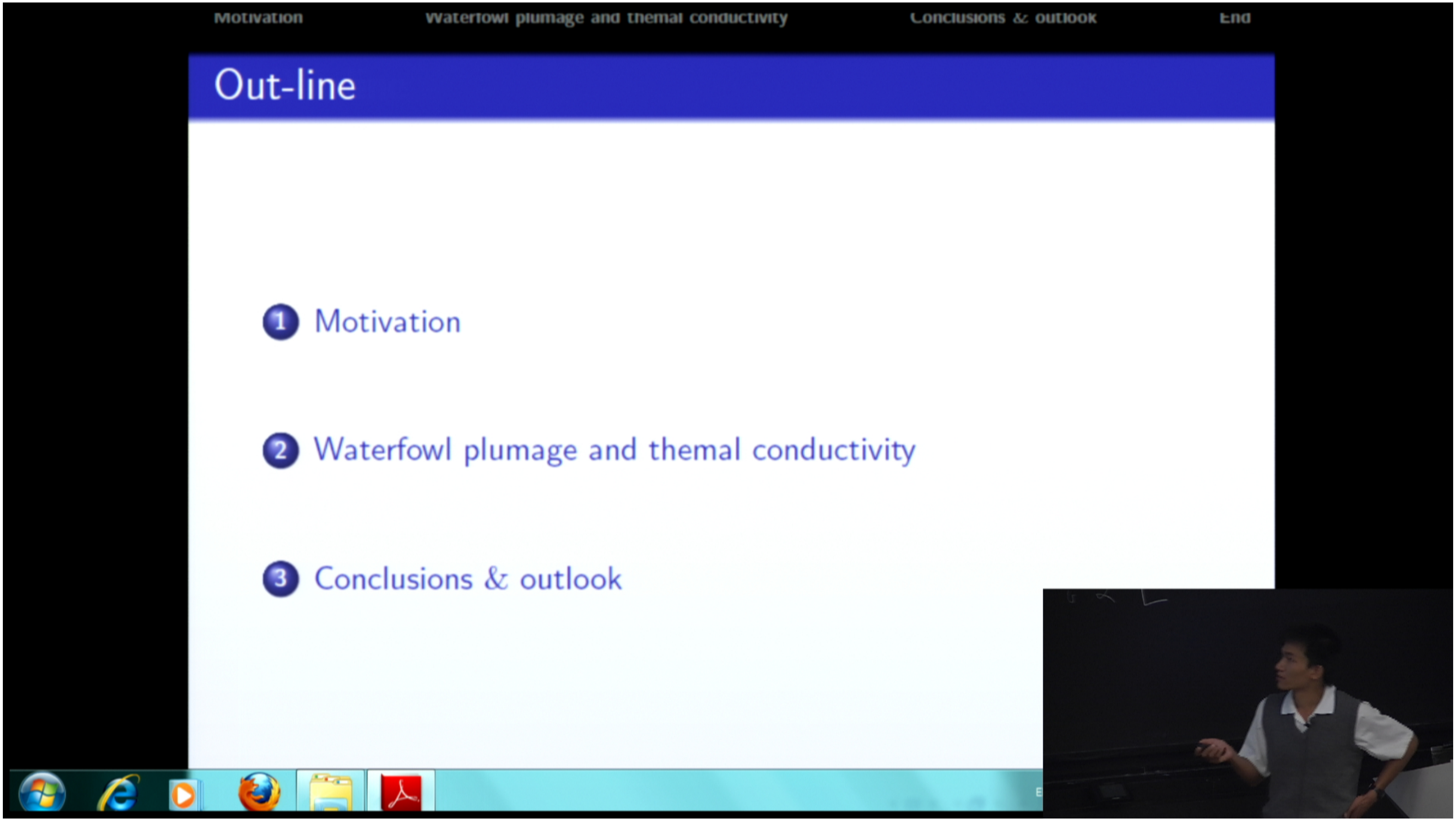

Motivation
Waterfowl plumage and themal conductivity
Conclusions & outlook
End
The Waterloo Park's waterfowl plumage and surviving winter in Canada
Physics In Nature presentation
PHAM QUOC TRUNG
Perimeter Scholars International 2012/13
August 17, 2012
12:12 PM


Motivation
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End
Out-line
1 Motivation
2 Waterfowl plumage and themal conductivity
3 Conclusions & outlook

Motivaion

- I have never experienced a winter in Canada before ⇒ have to get myself prepared to "survive" in Canada's severe winter weather.
- Hopefully, I can do this by asking ducks and geese at the Waterloo Park?

The cold weather and the ducks and geese's feather

- How come the duck and geese at the Waterloo Park can survive in such extreme cold weather of Canada?

The cold weather and the ducks and geese's feather

- How come the duck and geese at the Waterloo Park can survive in such extreme cold weather of Canada?
- Special plumage of waterfowl should play a very important role in protecting them from the elements.

Heat transfer through plumage

- Heat loss of ducks and geese mostly through their plumage.
- Heat transfer through plumage by several envanues[1]:
  1. conduction and free convection through air,
  2. conduction along solid elements of the feathers, and
  3. radiation.

[1] [illegible] G. E. 1988a. Heat flow through avian plumages: The relative [illegible] conduction, convection, and radiation. J. Therm. Biol. [illegible]

Heat transfer through plumage

- Feathers are composed of keratin, which has a considerably low conductivity[2].
- Only a small amount of heat lost is due to radiation (5% of total heat flow[3])

⇒ Waterfowl must prevent heat loss mostly from conduction and convection through air.

[2] S Baxter 1946 Proc. Phys. Soc. 58 105 doi:10.1088/0959-5309/58/1/310
[3] W[illegible] G. E. 1988a. Heat flow through avian plumages: The relative [illegible] conduction, convection, and radiation. J. Therm. Biol. [illegible]

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17-Aug-12

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Feathers of the ducks

- Ducks, geese (and other waterfowl) usually have three main types of feathers: contour, down and flight feathers(supporting bird during flight.).
  - Contour feathers: outermost feathers, which overlap each other to form a protective outer shell and impenetrable barrier to wind and moisture.

Figure: Contour feather

Feathers of the ducks

Figure: Down feather

- Afterfeathers: attached to the lower shaft of some contour feathers.
- Down feathers: no interlocking barbules, light and fluffy apperance.
- Semiplumes: has downy feather look, and found between contour feathers and down feathers.

$\Rightarrow$ Plumages of waterlowl are arranged into many layers of feathers

Feathers of the ducks

Figure: Down feather

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Waterfowl feather and thermal conductivity

- What does the feather pattern of waterfowl have anything to do with thermal conductivity?
  - The contour feathers trap some air and keep water and snow from penetrating into waterfowl's skin.
  - The fluffy barbules of down feathers also trap numerous tiny pockets of air in proximity to the skin.

$\Rightarrow$ These features provide a critical thermal buffer between the animal and its environment.

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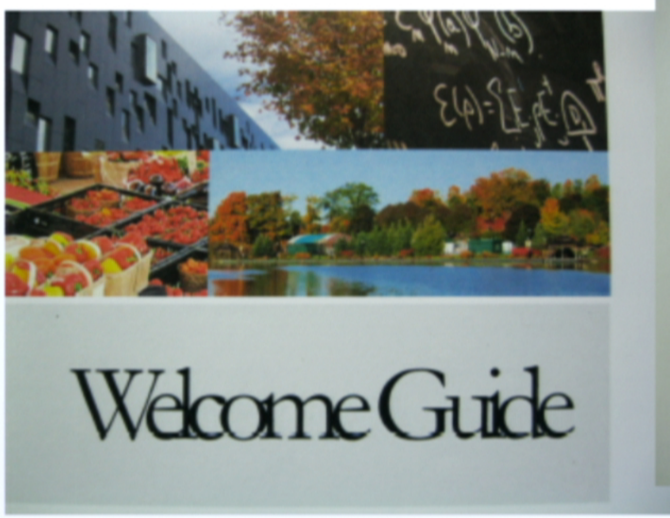
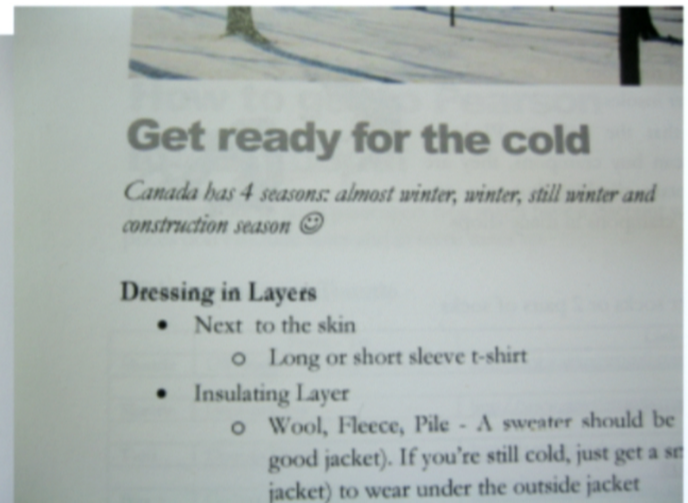
Conclusions & outlook

- answers my own question why Diana mentioned in the PSI's Wellcome Guide that PSI students should dress in many layers.





Get ready for the cold

Canada has 4 seasons: almost winter, winter, still winter and construction season ☺

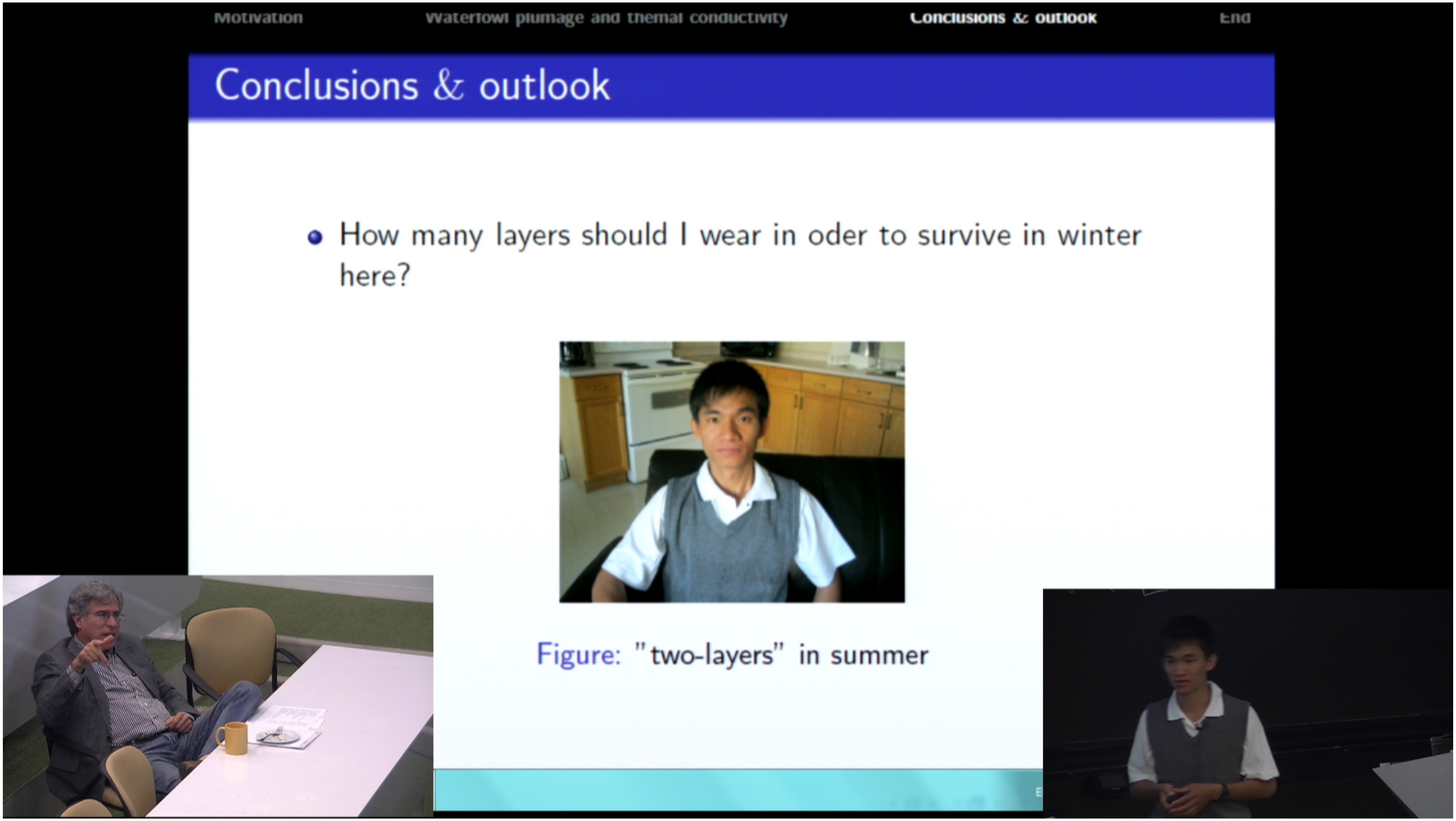
Dressing in Layers

- Next to the skin
  - Long or short sleeve t-shirt
- Insulating Layer
  - Wool, Fleece, Pile - A sweater should be good jacket). If you're still cold, just get a sr jacket) to wear under the outside jacket

Conclusions & outlook

- How many layers should I wear in oder to survive in winter here?

Figure: "two-layers" in summer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