Title: 12/13 PSI - Student Presentations 2B

Date: Aug 17, 2012 03:00 PM

URL: http://www.pirsa.org/12080042

Abstract:

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Glass: is it a liquid or a solid?

Dax Koh

Physics in Nature Presentation
August 17, 2012

Some uses of glass

Some uses of glass

Canadian Clay and Glass Gallery

More uses of glass

Puzzles in the behavior of glass

- Dubbed "the Cinderella Problem of Condensed Matter Physics" by Anthony Leggett
- Puzzles in the behavior of glass can be divided into three main areas
  - Glass transition
  - Characteristic long-term memory effects
  - Near-equilibrium thermal, dielectric and transport properties

Is glass a liquid or a solid?

Solid

- Crystalline structure on microscopic scales
- Molecules are arranged in a regular lattice
- As it is heated, the molecules vibrate about their fixed positions in the lattice

Liquid

- Molecules are disordered
- Molecules are not rigidly bound
- Has viscosity

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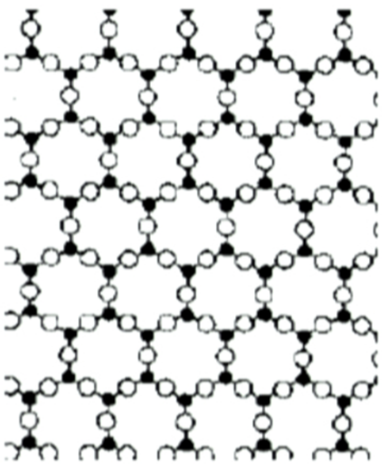
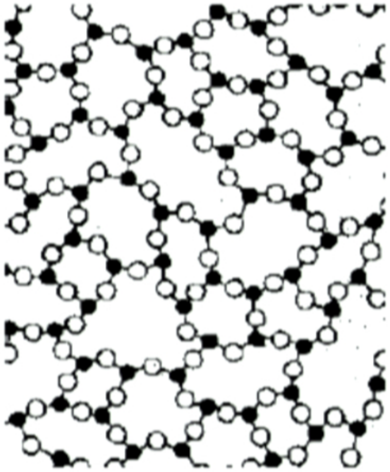
Is glass a liquid or a solid?

Crystalline solids	Ordered	Arranged in a regular lattice
Fluids	Disordered	Not rigidly bound
Glasses	Disordered	Are rigidly bound



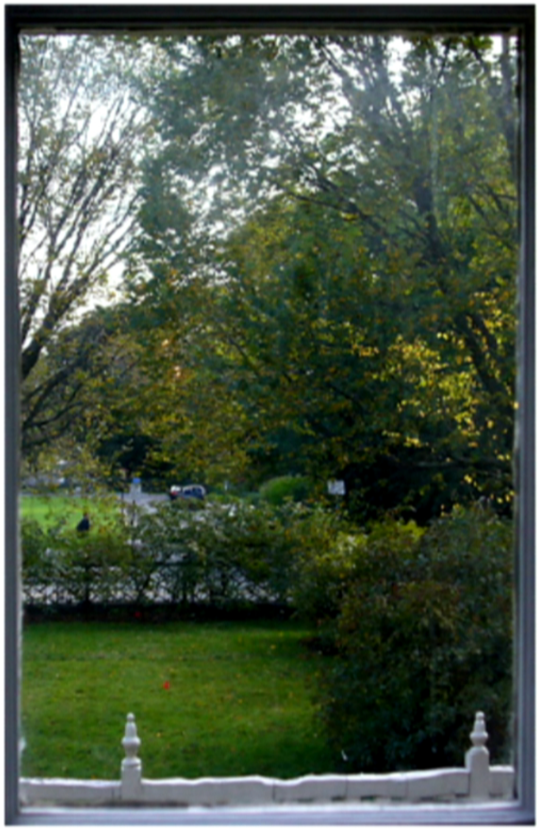
Crystal



Glass

Urban legends

- Antique window panes are thicker at the bottom, because glass has flowed to the bottom over time.
- Glass has no crystalline structure, and is therefore not a solid.
- Glass is a supercooled liquid that flows extremely slowly.



Antique window panes

- Could it be true that glass has flowed?
  - Closer inspection reveals that characteristic signs of flow, such as flowing around and out of the frame are not present
  - Deformations are more consistent with imperfections of methods used to make glass panes at the time.
  - Telescopic lenses made 150 years ago still maintain excellent optical properties.

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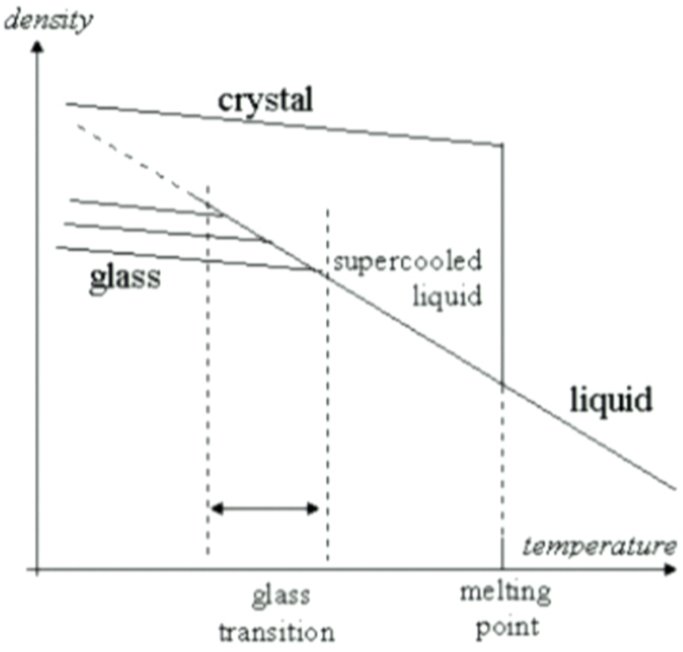
Antique window panes

- Why are panes of window glass thicker on the bottom than at the top?
  - Due to the glass manufacturing process, known as the crown glass process
  - A lump of molten glass was rolled, blown, expanded, flattened and finally spun into a disk before being cut into panes
  - The sheets were thicker toward the edge and were usually installed with the heavier side at the bottom.

Is glass a supercooled liquid?

- No
  - There is a second-order phase transition between the supercooled liquid state and the glass state.
  - Such a transition can be detected as a marked change in the thermal expansivity and heat capacity of the material



Glass

- An amorphous solid that exhibits a glass transition
  - Amorphous: non-crystalline, without the long-range characteristics of a crystal
  - Glass transition: reversible transition in amorphous materials from a molten or rubber-like state to a hard and relatively brittle state

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Liquid-crystal transition vs glass transition

- Liquid-to -crystal transition is a thermodynamic one, i.e. the crystal is energetically more favorable than the liquid when below the melting point
- Glass transition is purely kinetic: the disordered glassy state does not have enough kinetic energy to overcome the potential energy barriers required for movement of the molecules past each other.

Conclusions

- No clear answer to the question “Is glass liquid or solid”
- The difference is semantic.
- The term “supercooled liquid” still persists, but is considered by many to be an unfortunate misnomer that should be avoided
- Measurements of glass viscosities show that glass should not deform significantly even over many centuries

What is Canada's most famous structure?

Quantizing the CN Tower

Gabriel Magill

A "Walk in Nature" Presentation

Perimeter Institute - PSI Program

gmagill@perimeterinstitute.ca

August 17th, 2012

PERIMETER INSTITUTE FOR THEORETICAL PHYSICS

perimeter scholars international

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A Walk in Urban Nature

CN Tower

Motivation

Guinness World Records

- World's Tallest Free-Standing Structure (until 2007) - 553.33m
- World's highest and largest revolving restaurant
- World's highest wine cellar and bar
- Highest External Walk on a Building - EdgeWalk

Industrial Achievement

[3] http://www.cntower.ca/en-CA/Home.html

EdgeWalk - Living on the Edge

This walkway is located on top of the 360° revolving restaurant, 356m above the ground!

Quantizing the CN Tower

Origin of the Problem

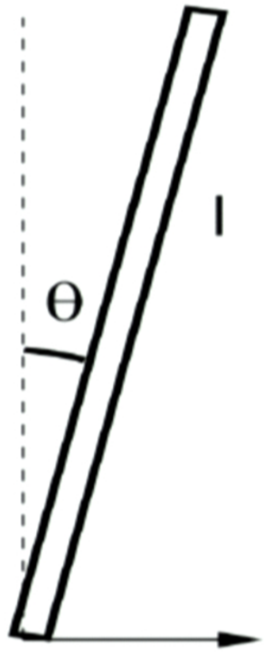
Variation of a problem proposed in 1960 by Dicke and Wittke
(*Introduction to Quantum Mechanics*)
Appeared in QT class [4]

Statement of the Problem

The CN tower is a free standing structure. Suppose gnomes ate the base until the tower stood on an infinitesimally sharp tip. Given the uncertainty principle, how long could the CN tower stay upright before toppling over?

Approaching the Problem

Step 1: Model the CN tower as an inverted physical pendulum



$$\mathcal{L} = T - V$$
$$= \frac{1}{2} I\omega^2 - mg\cos(\theta)\frac{L}{2}$$
$$\equiv \frac{1}{2} I\dot{\theta}^2 - mg\cos(\theta)\frac{L}{2}$$

$$I = \int_V \rho(\mathbf{r}) d(\mathbf{r})^2 dV(\mathbf{r})$$
$$= \frac{mL^2}{3}$$

[1][2][4]

Approaching the Problem

Step 3: Solve ODE using initial conditions

$$\theta(t=0) = \theta_0$$
$$\dot{\theta}(t=0) = \dot{\theta}_0$$

$$\Rightarrow \theta(t) = \left(\frac{\omega\theta_0 + \dot{\theta}_0}{2\omega}\right) e^{\omega t} + \left(\frac{\omega\theta_0 - \dot{\theta}_0}{2\omega}\right) e^{-\omega t}$$
$$\approx \left(\frac{\omega\theta_0 + \dot{\theta}_0}{2\omega}\right) e^{\omega t}$$

Note: We could have chosen to keep the $e^{-\omega t}$ term instead. We will discuss the implications of this later on.

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Approaching the Problem

Step 4: Invoke Uncertainty Principle

$$\hat{L} = r \times \hat{p}$$

$$\hat{x} = r\hat{\theta}$$

$$[\hat{x}, \hat{p}] = i\hbar \Leftrightarrow [\hat{\theta}, \hat{L}] = i\hbar$$

$$\Rightarrow \Delta\theta\Delta\dot{\theta} \geq \frac{\hbar}{2I}$$

In the limit of the uncertainty principle, we take:

$$\theta_0\dot{\theta}_0 \approx \frac{\hbar}{2I}$$

Yielding:

$$\theta(t) = \left(\frac{\theta_0}{2} + \frac{3\hbar}{4\theta_0 m\omega L^2}\right) e^{\omega t}$$

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Approaching the Problem

Maximal time the CN tower can stay upright, as dictated by QM

$$t = ln\left(\theta L\sqrt{\frac{2m}{3\hbar}\sqrt{\frac{3g}{2L}}}\right)\sqrt{\frac{2L}{3g}}$$

Where θ is the angle below which we consider our tower in equilibrium. Plugging in values (L=553.33m, m=117910000kg, $\theta = 0.1rad$), we get:

$$t = 315s$$

Calculating the Speed on Impact

Conservation of Energy for a Rod:

$$U = KE_{Rotational}$$

$$\frac{mgL}{2} = \frac{I\omega^2}{2}$$

$$= \frac{1}{2}\left(\frac{mL^2}{3}\right)\left(\frac{v_{tangential}}{L}\right)^2$$

Thus, on our Quantum CN Tower, someone walking on EdgeWalk would hit the ground at around 106km/h.

Discussion

Varying Parameters

- Effect of L and M
- Setting $\hbar = 0$

$$t = ln\left(\theta L\sqrt{\frac{2m}{3\hbar}\sqrt{\frac{3g}{2L}}}\right)\sqrt{\frac{2L}{3g}}$$

Discussion

Varying Parameters

- Effect of L and M
- Setting $\hbar = 0$

Disclaimer [1]

- Applying quantum principles to the macroscopic world
  - Infinitesimally sharp tip vs finite width
- Elimination of the negative exponential in the expression $\theta(t) = [\ldots]e^{\omega t} + [\ldots]e^{-\omega t}$
  - Considering the negative exponential would result in $t_{equilibrium} = \infty$

$$t = ln\left(\theta L\sqrt{\frac{2m}{3\hbar}\sqrt{\frac{3g}{2L}}}\right)\sqrt{\frac{2L}{3g}}$$

The Physics of Global Warming

John Selby

15/08/2012

perimeter scholars international

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The Sun

Black Body Radiation

1. Perfect emitter

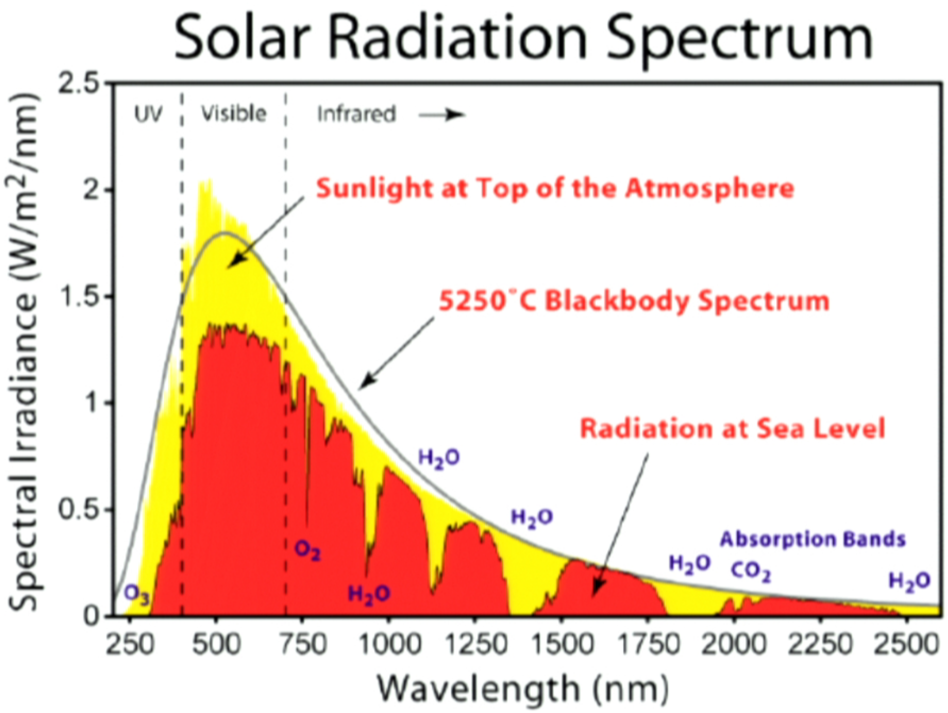
Black Body Radiation

1. Perfect emitter
2. Perfect absorber
3. Diffuse emitter

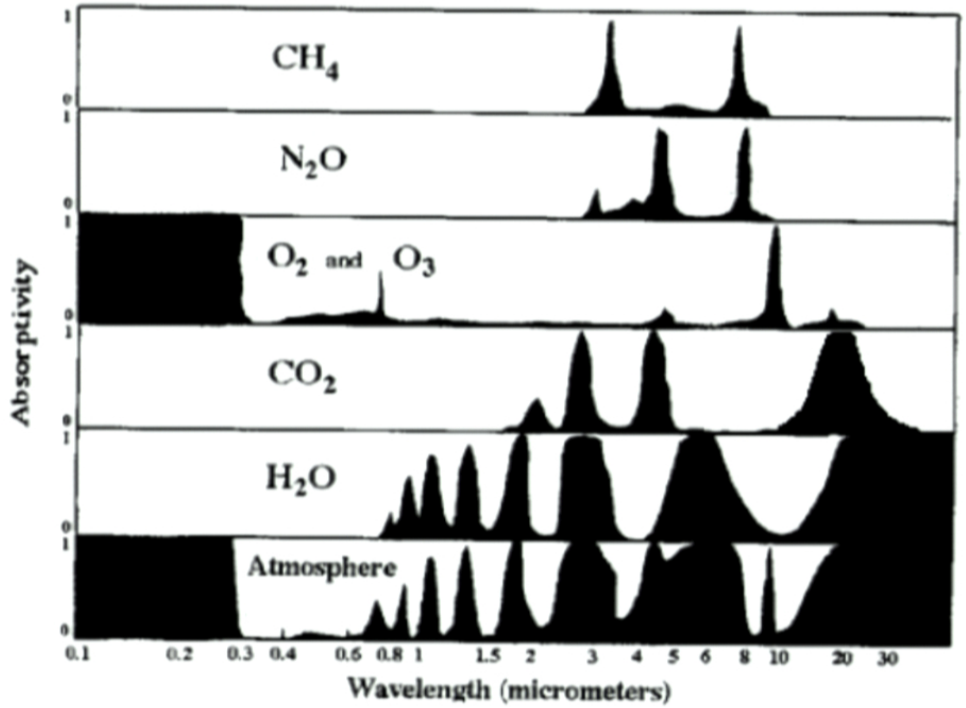
$$B_\nu(T) = \frac{2h\nu^3}{c^2}\frac{1}{e^{\frac{h\nu}{k_B T}}-1}$$

Where B is the spectral radiance.

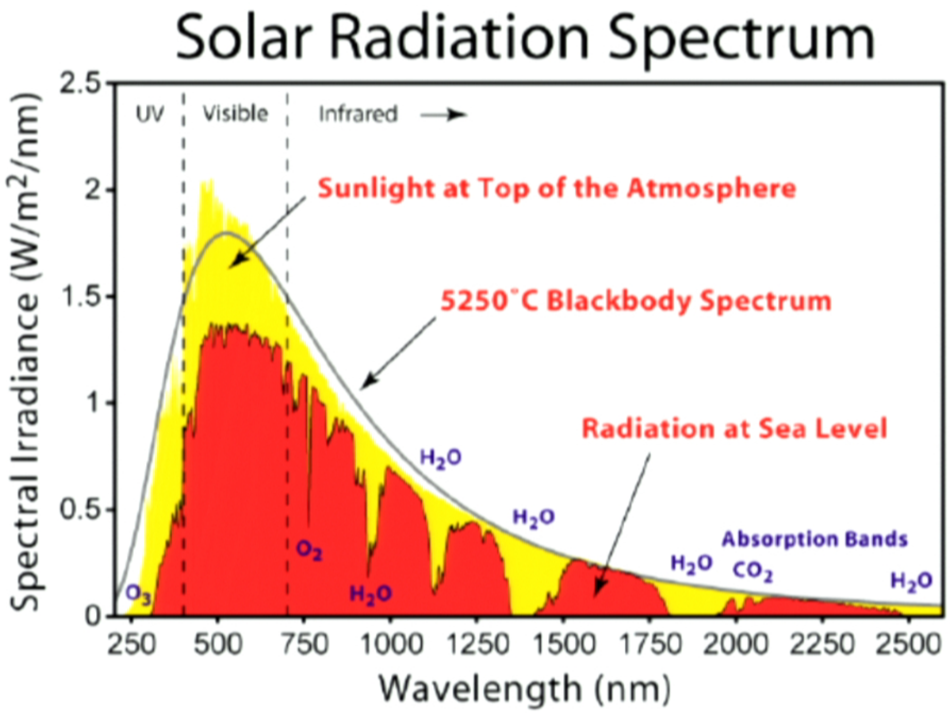
Absorption Spectrum



Absorption Spectrum



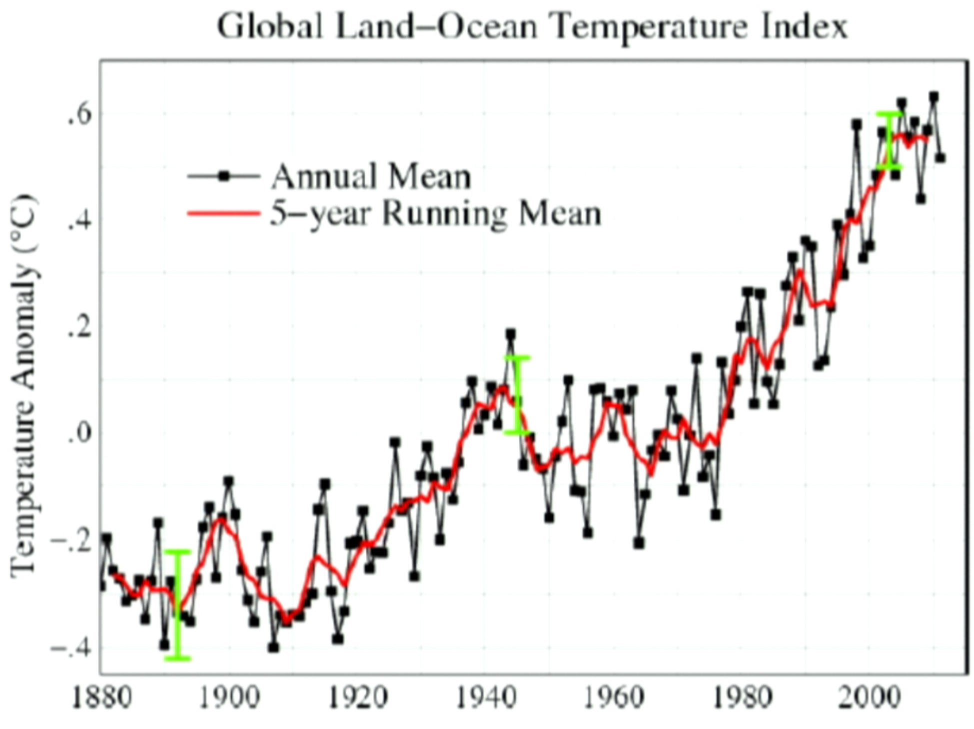
Absorption Spectrum



Snow

There is none!

Is the world warming up?



Requirements for Snow

1. Low temperatures $< 0^o C$
2. Precipitation

Solution 2: Move the earth away from the sun

Consequences:

1. Orbit around the sun is longer
2. Velocity is decreased
3. Orbit time is increased

Is it possible? Not easily in the available time.

Solution 3: Giant fridge

- Would be possible to cool down a region but...

Bend It Like Nadal

Andrei Catuneanu

August 17, 2012

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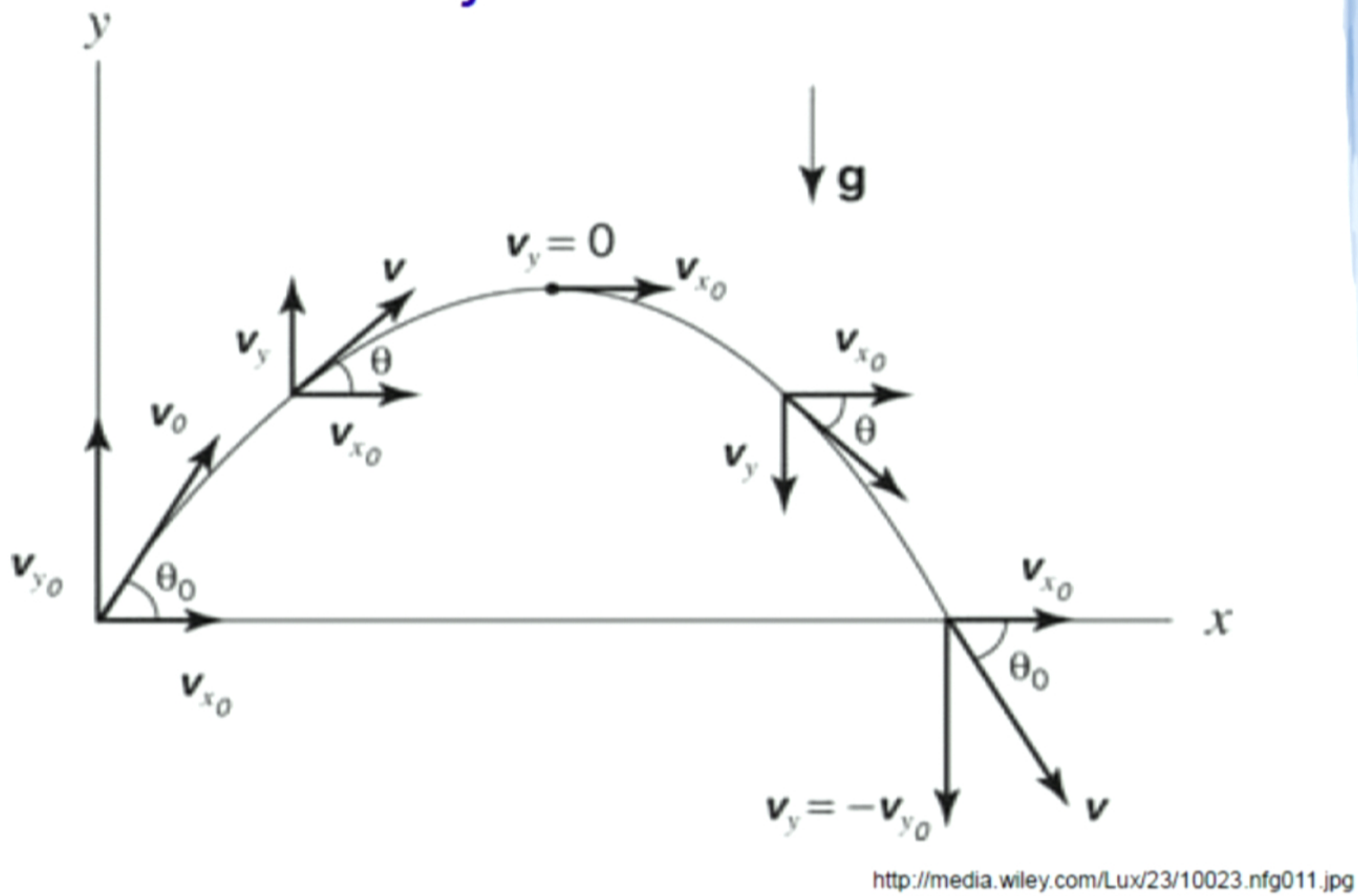
Photographic Inspiration

Projectile Motion



Torque

Where is the physics?

- Projectile motion
- Torque
- String tension

http://deepanjoshi.com/wp-content/uploads/2009/09/federer.jpg

String Tension and Ball Deformation

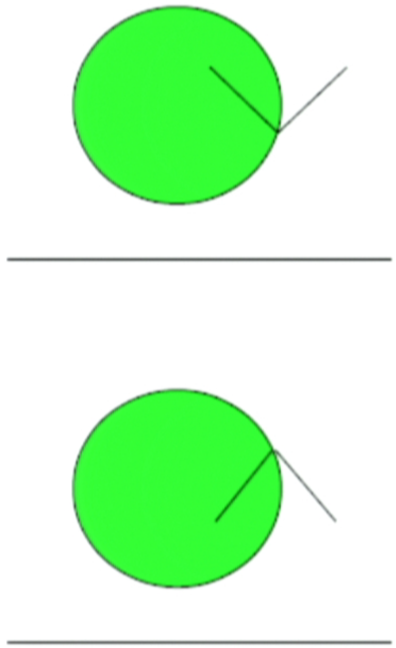
Where is the physics?

- Projectile motion
- Torque
- String tension
- Ball deformation
- Racquet material

http://deepanjoshi.com/wp-content/uploads/2009/09/federer.jpg

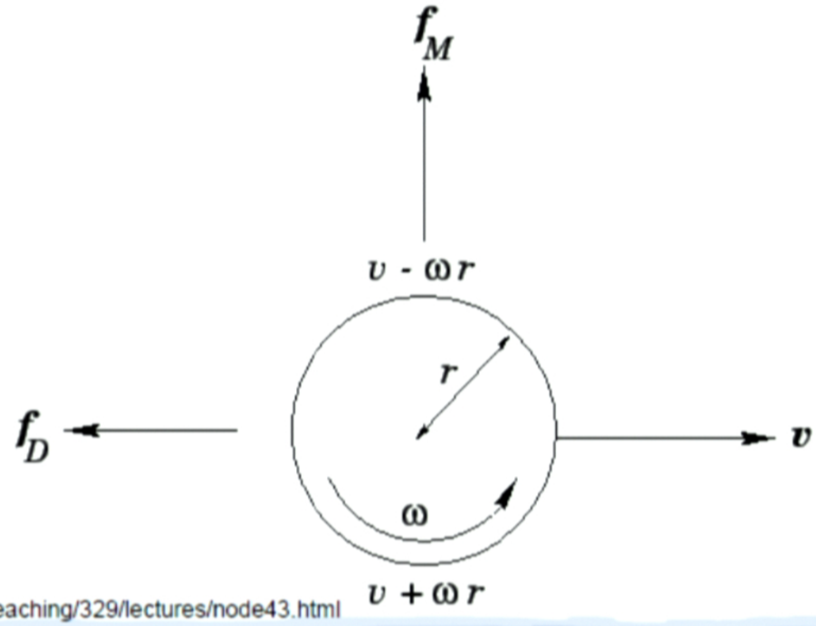
2+1 Main Spins

- Topspin
- Slice
- Flat



Spin Effects

- Does the ball's spin affect its trajectory?
  - Yes!



http://farside.ph.utexas.edu/teaching/329/lectures/node43.html

Naive Force Calculation

- Treat the ball as an airplane wing and apply Bernoulli's equation:

$$\rho v^2/2 + \rho g z + P = conserved$$

- Assumptions!

Naive Force Calculation

- Treat the ball as an airplane wing and apply Bernoulli's equation:

$$\rho v^2/2 + \rho g z + P = conserved$$

- Assumptions!
  - The pressure at the bottom and top of the ball is the same (very, very nearly)
  - Forget about drag and turbulence

The Result

$$F_m = \kappa r_0^3 \omega v$$

- Makes sense in the limits of
  - $\omega \to 0$

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The Result

$$F_m = \kappa r_0^3 \omega v$$

- Makes sense in the limits of
  - ω -> 0
  - v -> 0
  - r -> 0
- For a ball (radius 3.35cm) hit by Nadal (5000rpm at most) moving at 30m/s...
  - 4.5 N (80 m/s/s!!!)

Magnus Formula

$$F_m = S(v)(\omega \times v)$$

- The naive formula agrees with the cross-product (it's just a special case)
- Difference is in the coefficient!
  - v dependence
- Taking a value of S = 0.0001m, we find a force of just 0.3N – much better! (Adair+Giordano)

Physics in Tennis

- Rich in physics!
- The ball's spin affects trajectory in a way that is directly proportional to velocity and rate of spin
- Naive formula does not consider drag, but it's qualitatively reasonable

The "Fizzics" of Guinness: Why The Bubbles in a Pint of Guinness Sink

Speaker: Ciarán Lee

Outline

- Describe the basic physics of bubble formation and size in Guinness.

Speaker: Ciarán Lee

The "Fizzics" of Guinness: Why The Bubbles in a Pint of Guinness Sink

Outline

- Describe the basic physics of bubble formation and size in Guinness.
- Denomstrate the counter-intuitive phenomena of sinking bubbles in a pint of Guinness.

Foaming and Bubble Formation

- Guinness foams due to a combination of dissolved nitrogen and carbon dioxide.

Speaker: Ciarán Lee

The "Fizzics" of Guinness: Why The Bubbles in a Pint of Guinness Sink

Properties of the Bubbles

- We model Guinness by a liquid of density ρ_l and viscosity μ_l, with randomly distributed bubbles of gas with density ρ_g and viscosity μ_g.

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- To check whether the bubble shapes differ from spheres, we introduce the Bond number:

$$B_0 = \frac{\rho_l g d_b^2}{\sigma}.$$

- Where d_b is the bubbles characteristic length scale, σ is the surface tension and g is acceleration due to gravity.

Properties of Bubbles

- Inputting the values obtained for $\rho_l, \ldots$ etc. in "Why do bubbles in Guinness sink" by W.T Lee et al (see arXiv:1205.5233v1), we find that $B_0 \approx 0.002$.

Properties of the Bubbles

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Properties of Bubbles

- We can thus calculate the bubble velocity, v_b, using the Stokes formula for spheres,

$$v_b = \frac{(\rho_l - \rho_b) g d_b^2}{18\mu_l} \approx 3.96 mms^{-1}.$$

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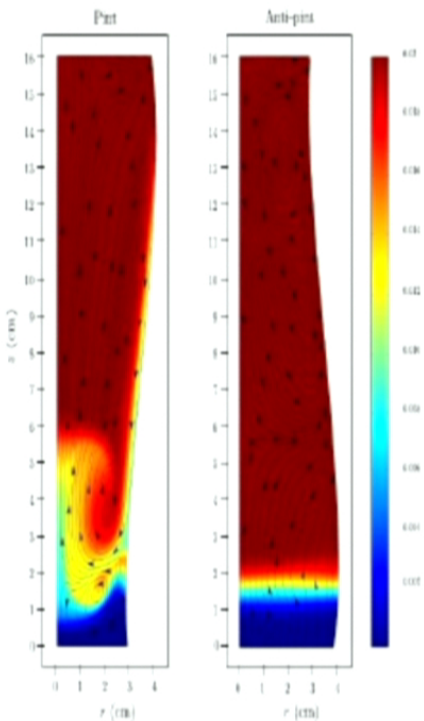
$$v_b = \frac{(\rho_l - \rho_b) g d_b^2}{18 \mu_l} \approx 3.96 mms^{-1}.$$

- The use of Stokes formula is also justified because the Reynolds number in this case is small ($Re \approx 0.24$).
- As v_b is much smaller than the speed of sound, the gas can be treated as incompressible.

Numerical Simulations

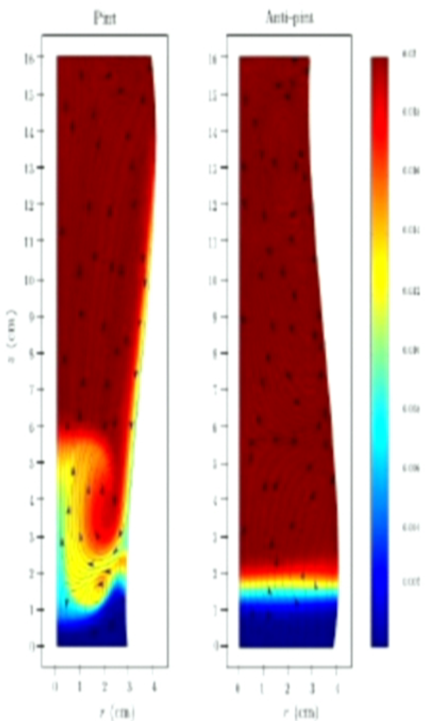


- Numerical simulations for the pint and anti-pint done in COMSOL by W.T. Lee et al (see arXiv:1205.5233v1).

Speaker: Ciarán Lee

The "Fizzics" of Guinness: Why The Bubbles in a Pint of Guinness Sink

Numerical Simulations



- Numerical simulations for the pint and anti-pint done in COMSOL by W.T. Lee et al (see arXiv:1205.5233v1).
- Curves show the streamlines of the bubbles.
- The scale gives the percent of the liquid gas mixture that is purely gas at a point.
- Red stands for high bubble concentration and blue stands for low concentration.

Numerical Simulations

- From the simulations we see that the bubbles flow down the glass and up the centre of the pint.

The Mechanism

- Note that whatever way the bubbles move, they exert a drag force on the surrounding liquid.

The Mechanism

- Note that whatever way the bubbles move, they exert a drag force on the surrounding liquid.
- If the bubbles (and hence, the drag force) are distributed uniformly, all liquid particles must move the same way.
- This effectively means they cannot move at all due to the liquids incompressibility and the fact that the container has a bottom.

Speaker: Ciarán Lee

The "Fizzics" of Guinness: Why The Bubbles in a Pint of Guinness Sink

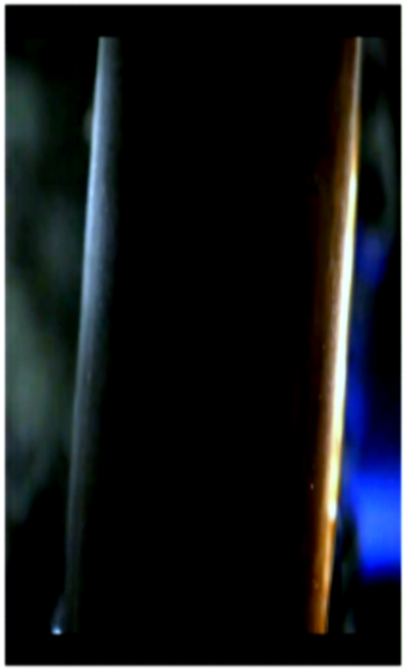
The Mechanism

- This leads us naturally to consider non-uniform distributions of the bubbles.
- Consider the case of low bubble density near to the containers wall.
- This would mean the drag force near the container's axis is larger than near the wall.
- This creates an imbalance and, thus, gives rise to a circulation: near the axis the liquid flows upward, near the wall, downward.

The Mechanism

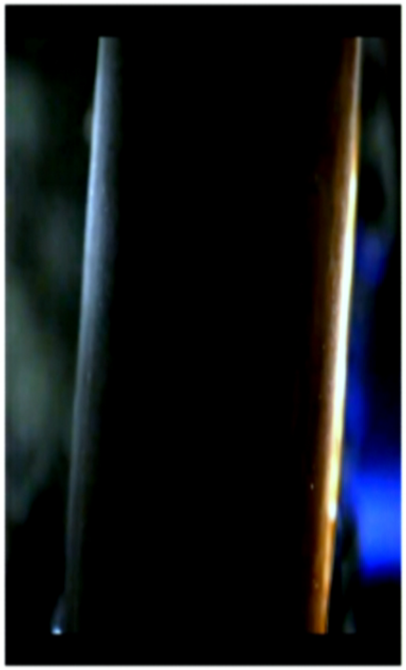
- If the velocity of the downward flow is larger than the velocity of the bubbles, v_b, then the bubbles will be observed to move downward.

Experiment



- Pour Guinness into a cylindrical container.

Experiment



- Pour Guinness into a cylindrical container.
- Tilt the cylinder like in the picture.


Why is the sky blue?
By Deanna Pineau
perimeter scholars
international

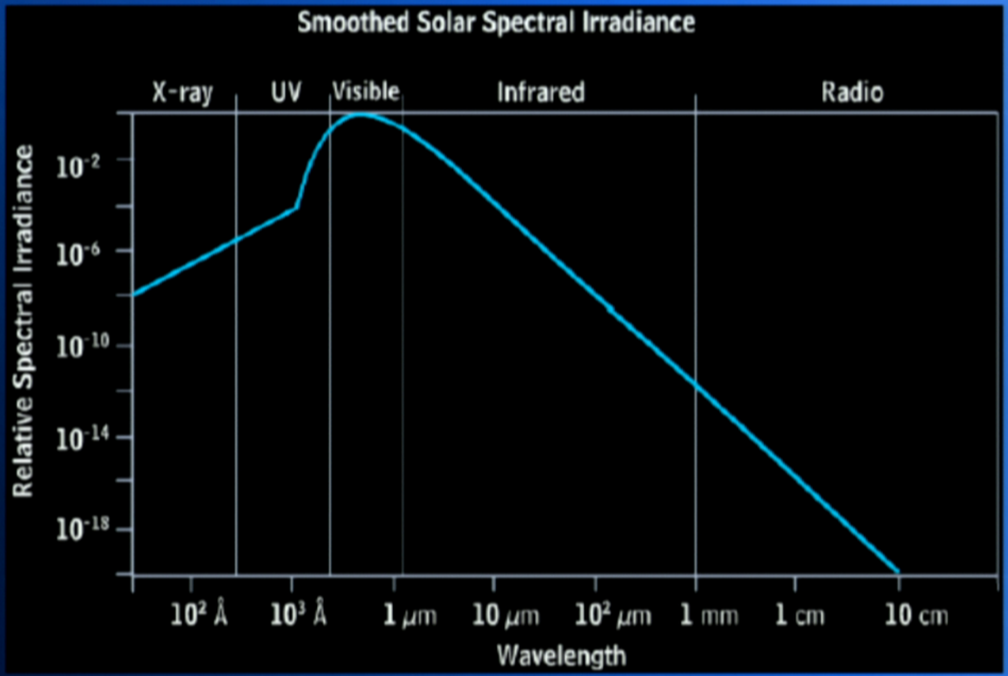
Outline

- Sunlight
- Earth's atmosphere

Sunlight

- Unpolarized

http://farside.ph.utexas.edu/teaching/em/lectures/node97.html



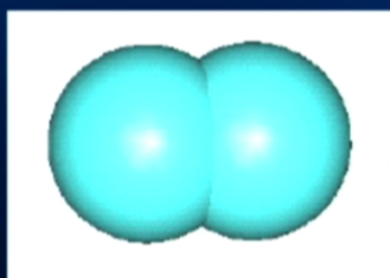
http://www.windows2universe.org/sun/spectrum/multispectral_sun_overview.html

Earth's atmosphere

- Scatters incident sunlight

  Van de Hulst, H.C. Light Scattering by Small Particles. 1981

  - Air molecules



http://www.nyu.edu/pages/mathmol/textbook/compounds.html

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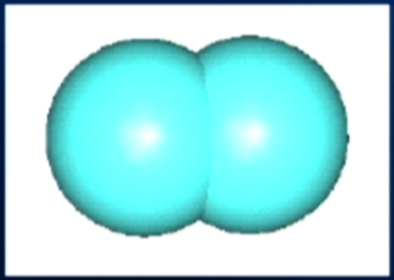


http://www.nyu.edu/pages/mathmol/textbook/compounds.html

  - Aerosol (haze and dust)

http://planetofthemonyets.blogspot.ca/2012/06/haze-lynas-and-anwar-to-rescue.html

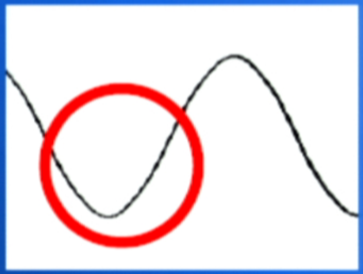
Rayleigh scattering

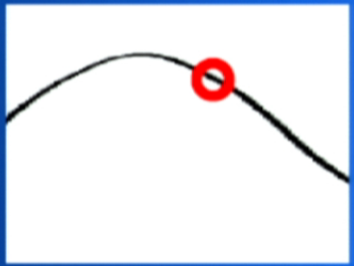
- d << λ

Info: Van de Hulst, H.C. Light Scattering by Small Particles. 1981

Rayleigh scattering

- d << λ
  - Applied electric field is homogeneous

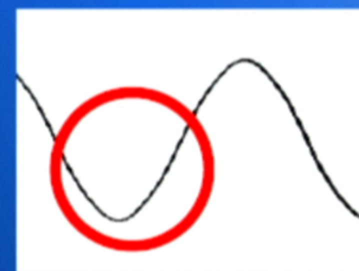




Info: Van de Hulst, H.C. Light Scattering by Small Particles. 1981

Rayleigh scattering

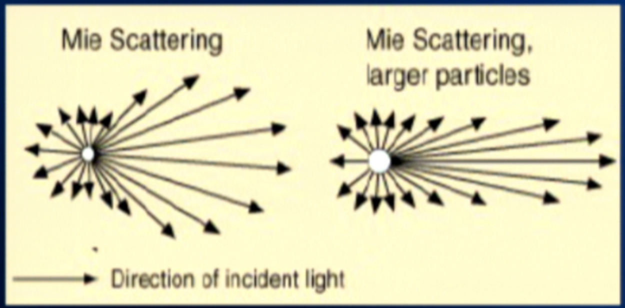
- $d << \lambda$
  - Applied electric field is homogeneous
- Dominant effect for small particles
- $I \propto 1 / \lambda^4$



Info: Van de Hulst, H.C. Light Scattering by Small Particles. 1981

White sky: Mie scattering

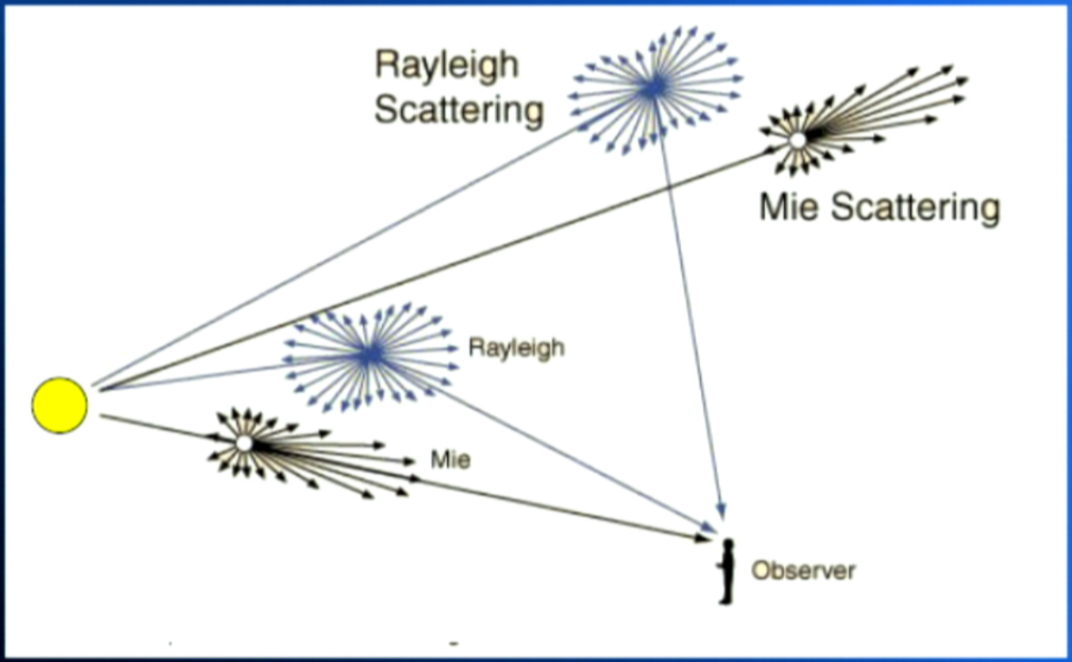
- d $\gtrapprox$ λ
- Dominant effect for large particles



http://hyperphysics.phy-astr.gsu.edu/Hbase/atmos/blusky.html

Info: Van de Hulst, H.C. Light Scattering by Small Particles. 1981

Mie and Rayleigh



http://hyperphysics.phy-astr.gsu.edu/Hbase/atmos/blusky.html

Conclusion

- Rayleigh scattering:
  - Blue sky
  - Small particles

Conclusion

- Rayleigh scattering:
  - Blue sky
  - Small particles

- Mie scattering:
  - White sky
  - Preferrentially forward-scattering
  - Large particles

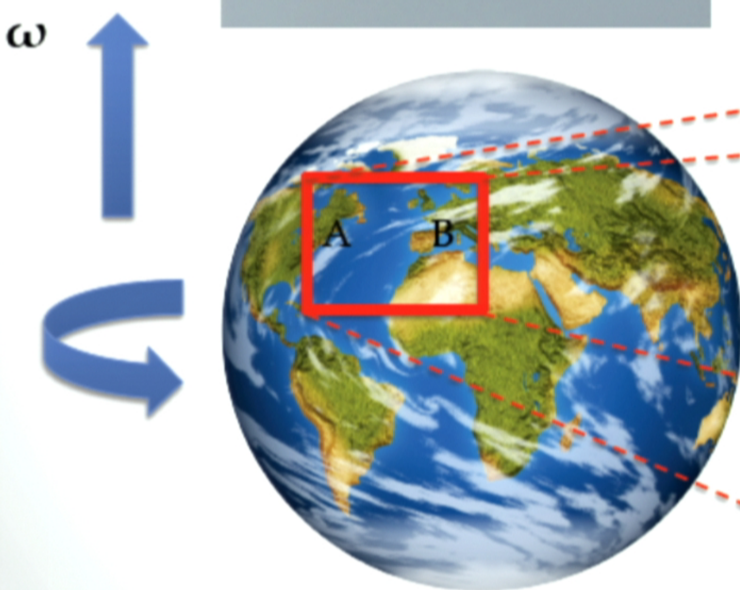
Reference Frames

Jun Yong Khoo

perimeter scholars international

Problem

Problem



Earth does not rotate:

X hours

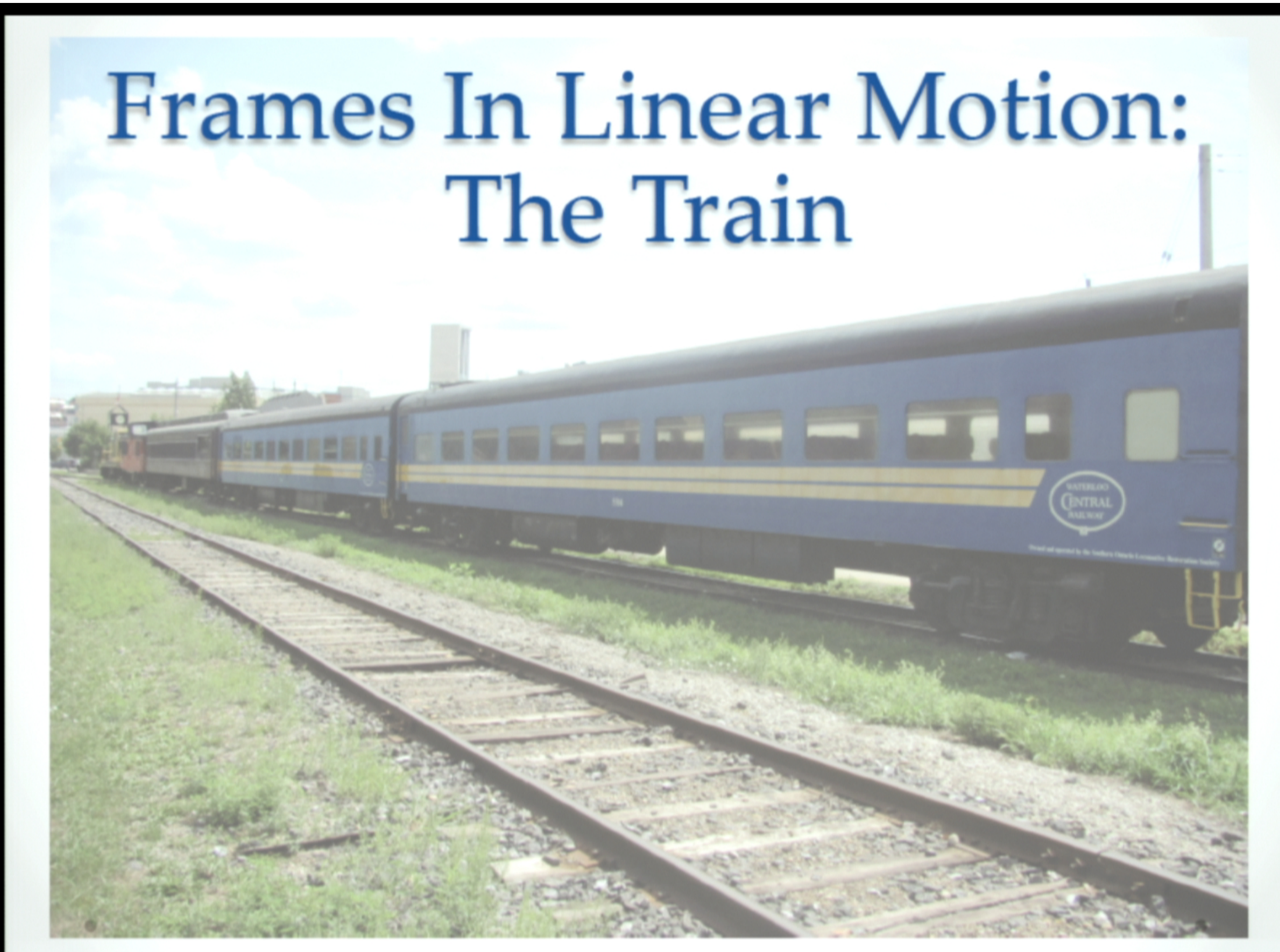
A ⟷ B

X + R hours?

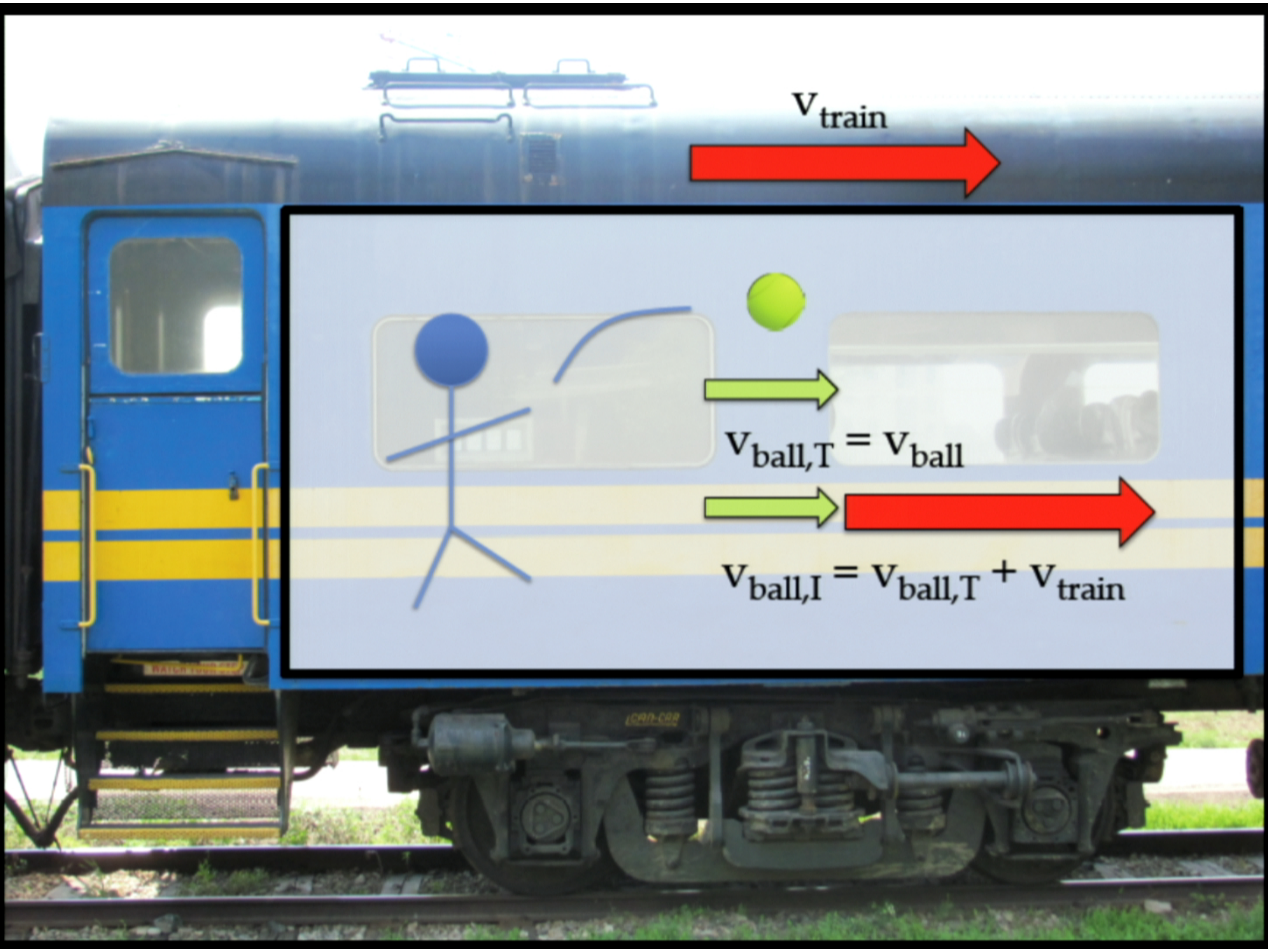
A → B

A ← B

X - R hours?


Frames In Linear Motion:
The Train

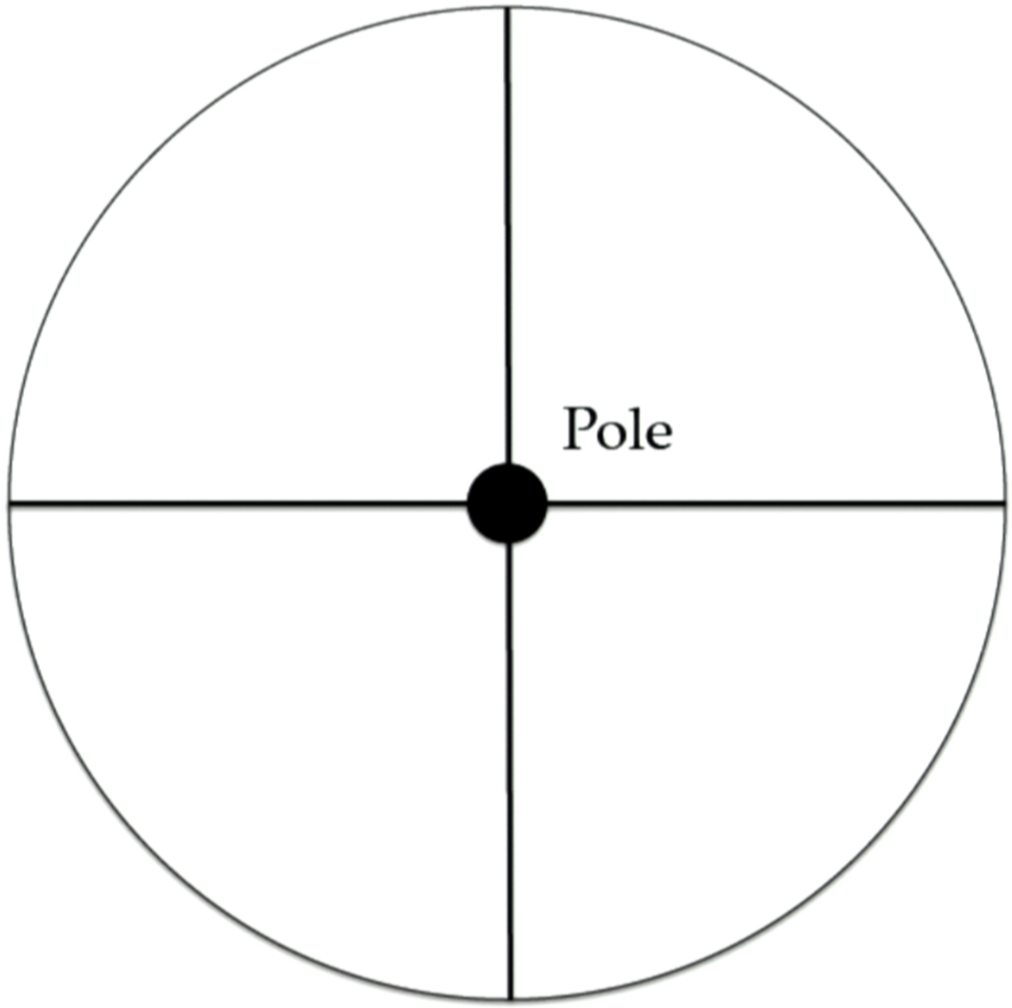

v_{train}

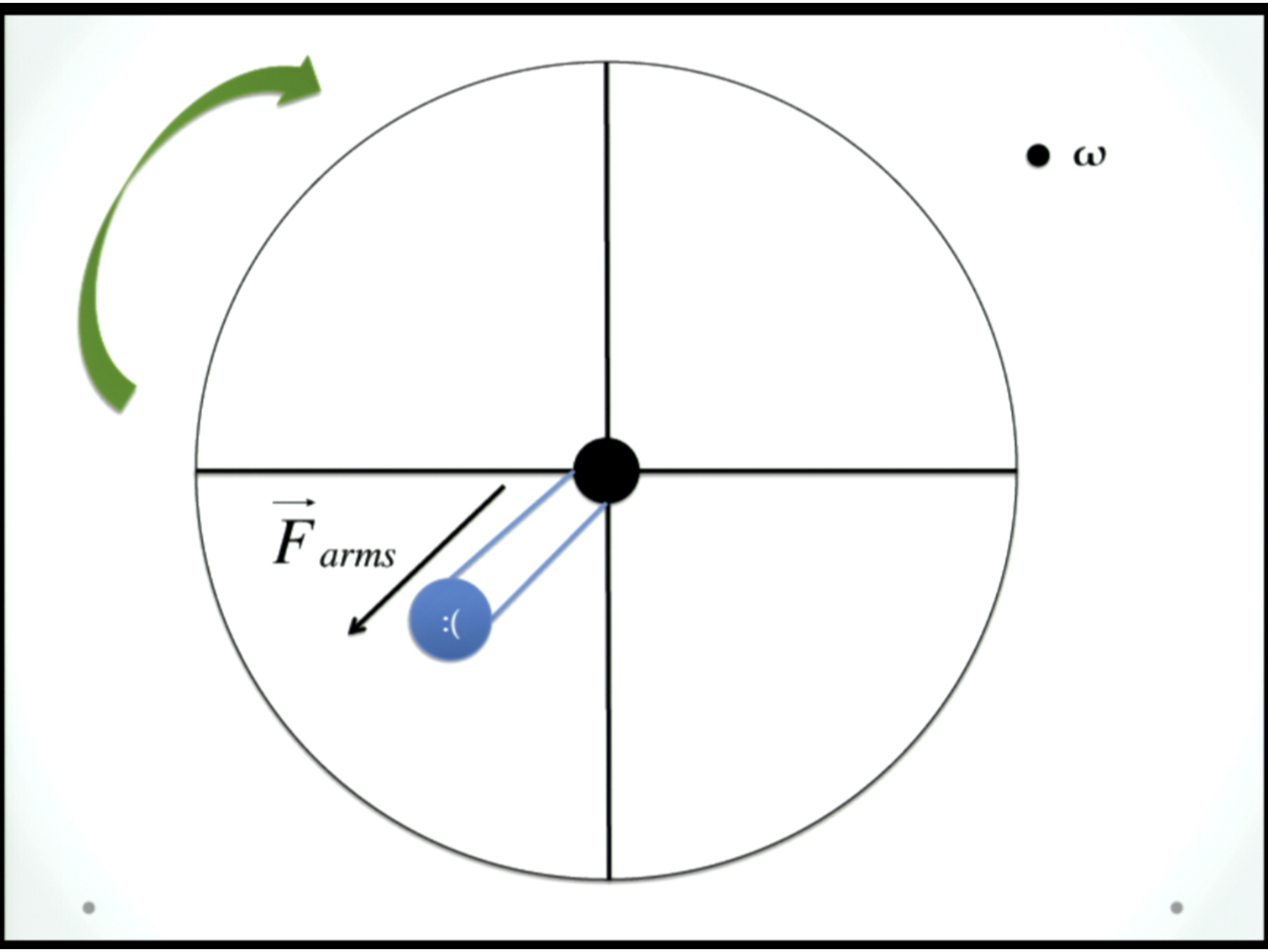


v_{train}
$v_{ball,T} = v_{ball}$
$v_{ball,I} = v_{ball,T} + v_{train}$

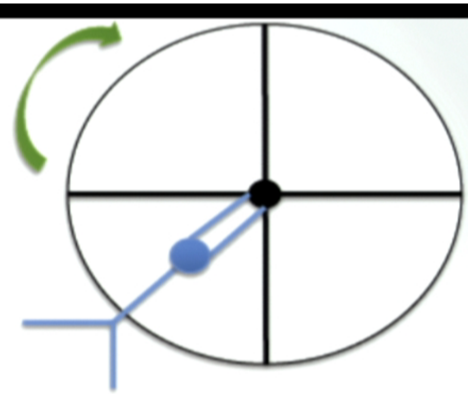
Rotating Frames: The Merry-Go-Round

http://www.ocmodshop.com/how-pc-fans-work/merry-go-round/

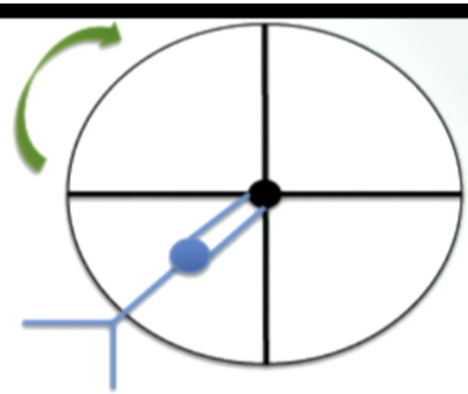

Pole


ω
$\vec{F}_{arms}$
:(

- How do <u>you</u> stay in the rotating frame?

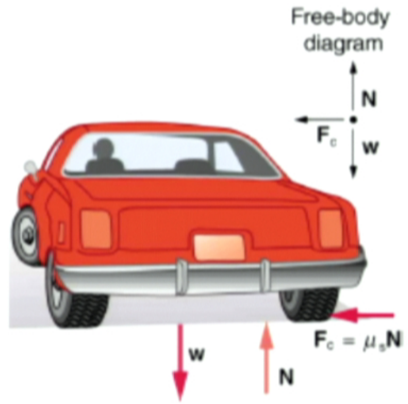


- How do you stay in the rotating frame?



- **…of a turning car?**

http://cnx.org/content/m42086/latest/?collection=col11406/latest



Rotating Frames: Equation of Motion

$$\vec{v}_{Inertial} = \vec{v}_{Rotating} + \left(\vec{\omega} \times \vec{r}\right); \qquad \vec{v}_a = \left.\frac{d\vec{r}}{dt}\right|_a$$

Rotating Frames: Equation of Motion

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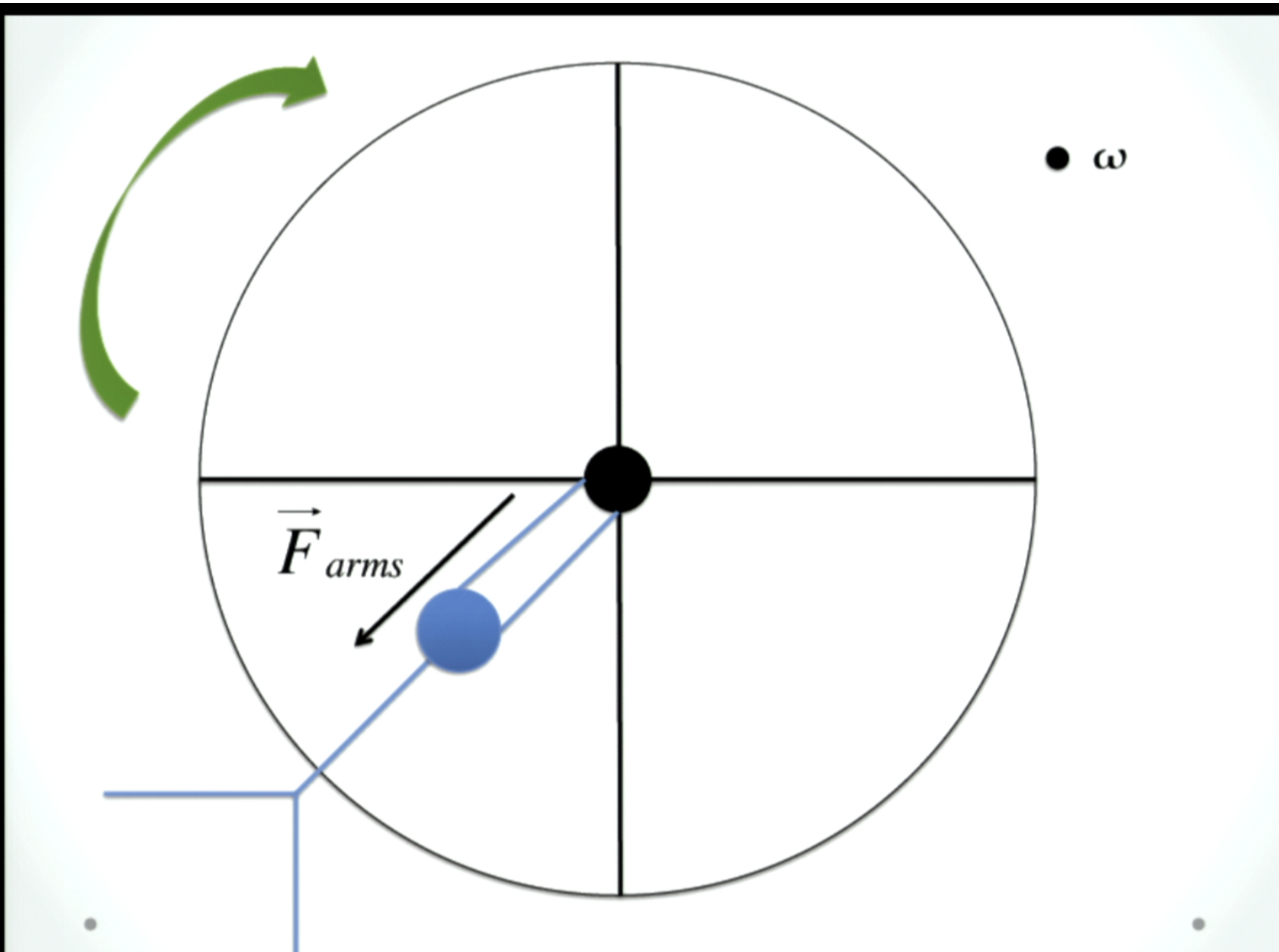
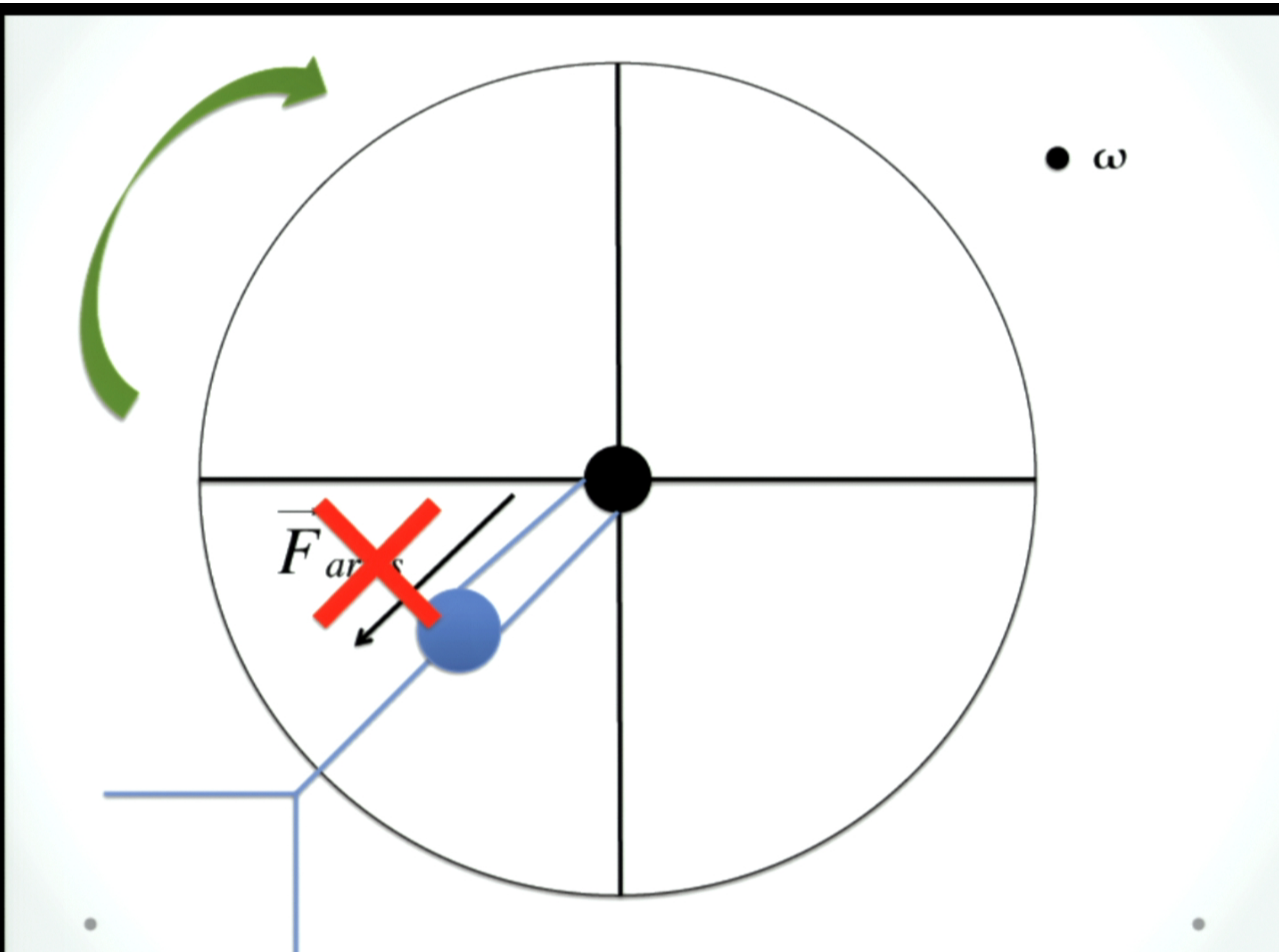
- It can be shown that in the rotating frame:

$$\vec{F}_R = m\left.\frac{d^2\vec{r}}{dt^2}\right|_R = \vec{F}_I - \underbrace{2m\left(\vec{\omega} \times \vec{v}_R\right)}_{\text{Coriolis Force}} - \underbrace{m\vec{\omega} \times \left(\vec{\omega} \times \vec{r}\right)}_{\text{Centrifugal Force}} \quad \text{(constant } \omega\text{)}$$


ω
$\vec{F}_{arms}$


ω

A Typical Online Response

- [http://wiki.answers.com/Q/Is_air_travel_time_the_same_whether_or_not_the_plane_is_flying_with_or_against_the_rotation_of_the_Earth]

"…Now instead of talking about boys on a moving train, lets talk about airplanes on a rotating earth. All the principles discussed above still apply. **The earth**, the mountains, people, animals, plants, **the atmosphere, clouds - *everything* - travels at the same speed**, just like the boys on the train. That is **assuming the winds are calm** - more about that in a moment. And since airplanes travel through air (that is what airspeed means) in calm winds it does not matter if you travel in the same direction as the earth's rotation, or in the opposite direction. Just like the boys tossing the ball back and forth on the train, the airplane takes the same time regardless of which direction it travels. Put simply, the earth's rotation does not affect the time it takes for an airplane to fly, regardless of whether it is flying East or West.

If that is so, you ask, then why does it take longer to fly from Paris to New York than from New York to Paris. The answer is the prevailing trade winds…"

Is It So Simple?

- A commonly overlooked point: $\vec{v}_{I,Plane}(t=0) \neq 0$

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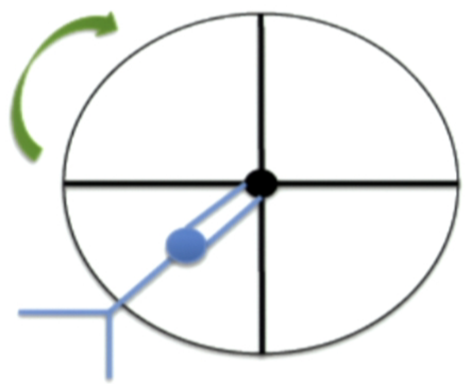
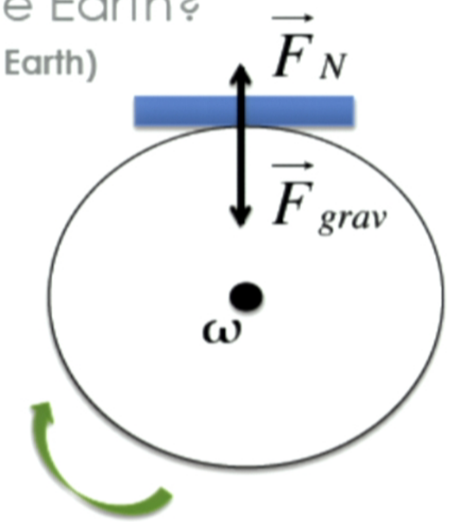
- However, when in the air, how does the plane stay in the rotating frame of the Earth?



Is It So Simple?

- A commonly overlooked point: $\vec{v}_{I,Plane}(t=0) \neq 0$
- However, when in the air, how does the plane stay in the rotating frame of the Earth?
  - Plane on the ground (rotating with Earth)



$$\vec{v}_{I,Plane}(t=0) = \vec{\omega} \times \vec{r}$$

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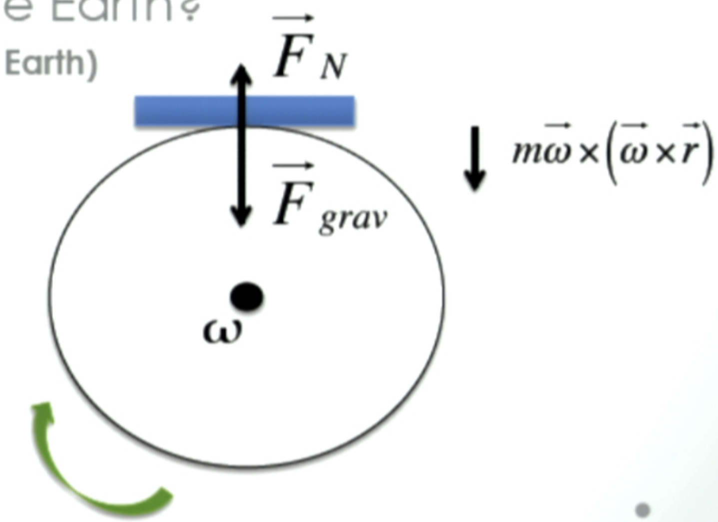
$$\vec{F}_{grav} - \vec{F}_N = m\vec{\omega} \times \left(\vec{\omega} \times \vec{r}\right)$$

$$\vec{v}_{I,Plane}(t=0) = \vec{\omega} \times \vec{r}$$



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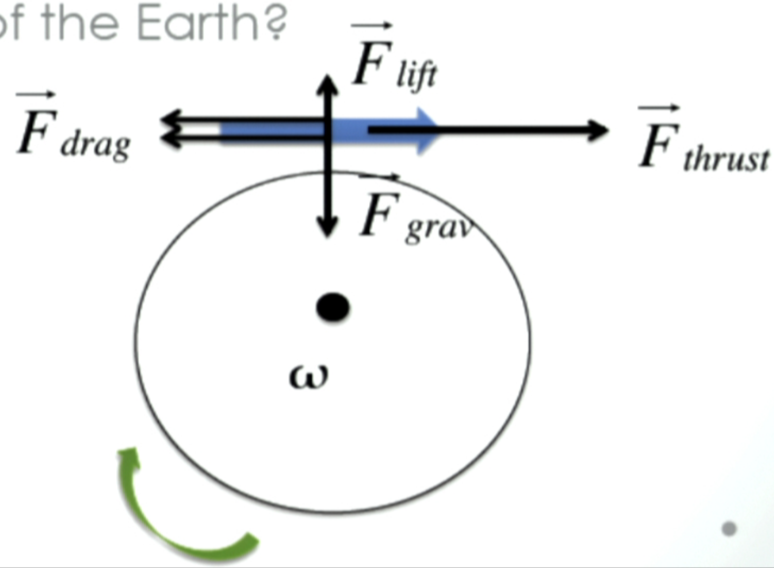
- A commonly overlooked point: $\vec{v}_{I,Plane}(t=0) \neq 0$
- However, when in the air, how does the plane stay in the rotating frame of the Earth?
  - Plane on the ground
  - **Plane in the air**



$$\vec{v}_{I,Plane}(t=0) \approx \vec{\omega} \times \vec{r}$$

Is It So Simple?

- A commonly overlooked point: $\vec{v}_{I,Plane}(t=0) \neq 0$
- However, when in the air, how does the plane stay in the rotating frame of the Earth?
  - Plane on the ground
  - **Plane in the air**

$$\sum \vec{F} = m \left. \frac{d^2 \vec{r}}{dt^2} \right|_I$$

$$\vec{v}_{I,Plane}(t=0) \approx \vec{\omega} \times \vec{r}$$

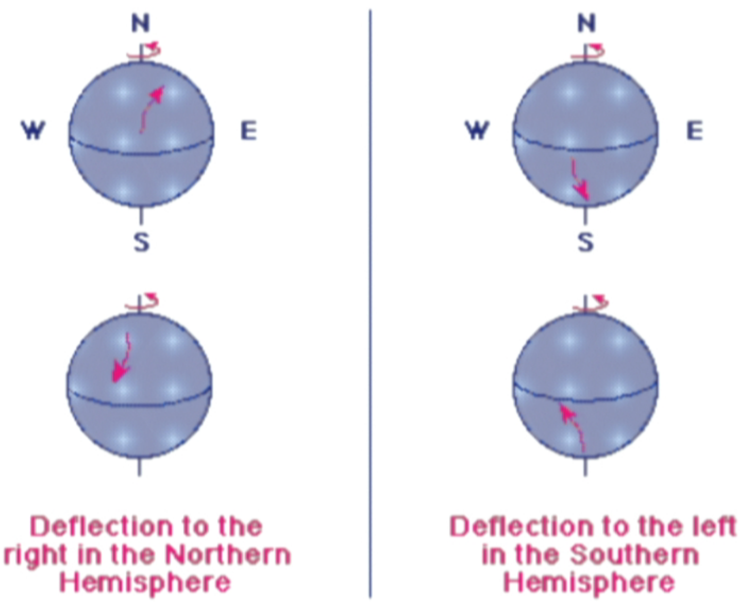
Is the plane still in the Earth's rotating frame?

More?

- "…If that is so, you ask, then **why does it take longer to fly from Paris to New York than from New York to Paris. The answer is the prevailing trade winds**…"

Coriolis Force

- Trade winds (~30km/h)

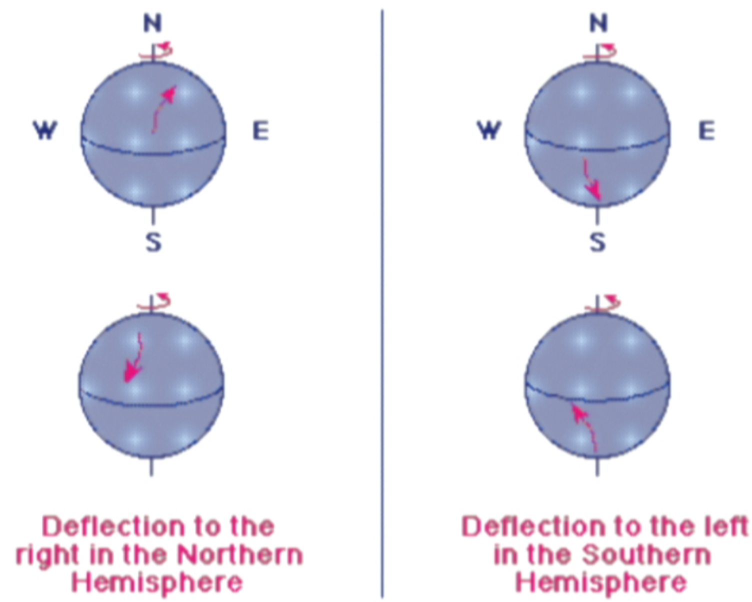


http://csep10.phys.ufk.edu/astr161/lect/earth/coriolis.html

The Coriolis force deflects to the right in the Northern hemisphere and to the left in the Southern hemisphere when viewed along the line of motion.

Coriolis Force

- Trade winds (~30km/h)



http://csep10.phys.utk.edu/astr161/lect/earth/coriolis.html

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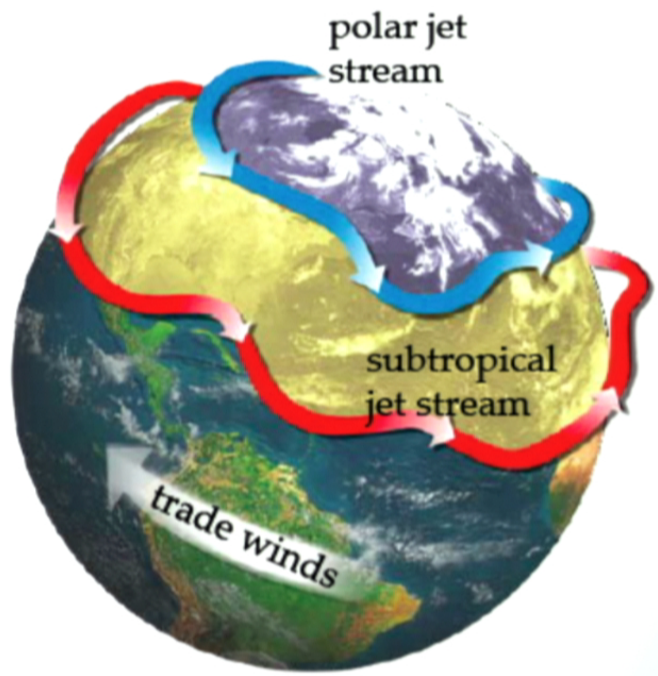
Coriolis Force

- Trade winds (~30km/h)
- **Deflection of flight path**

Coriolis Force

- Trade winds (~30km/h)
- Deflection of flight path
- **Jet streams (~200km/h)**

http://ww2010.atmos.uiuc.edu/(Gh)/guides/mtr/cyc/upa/jet.rxml



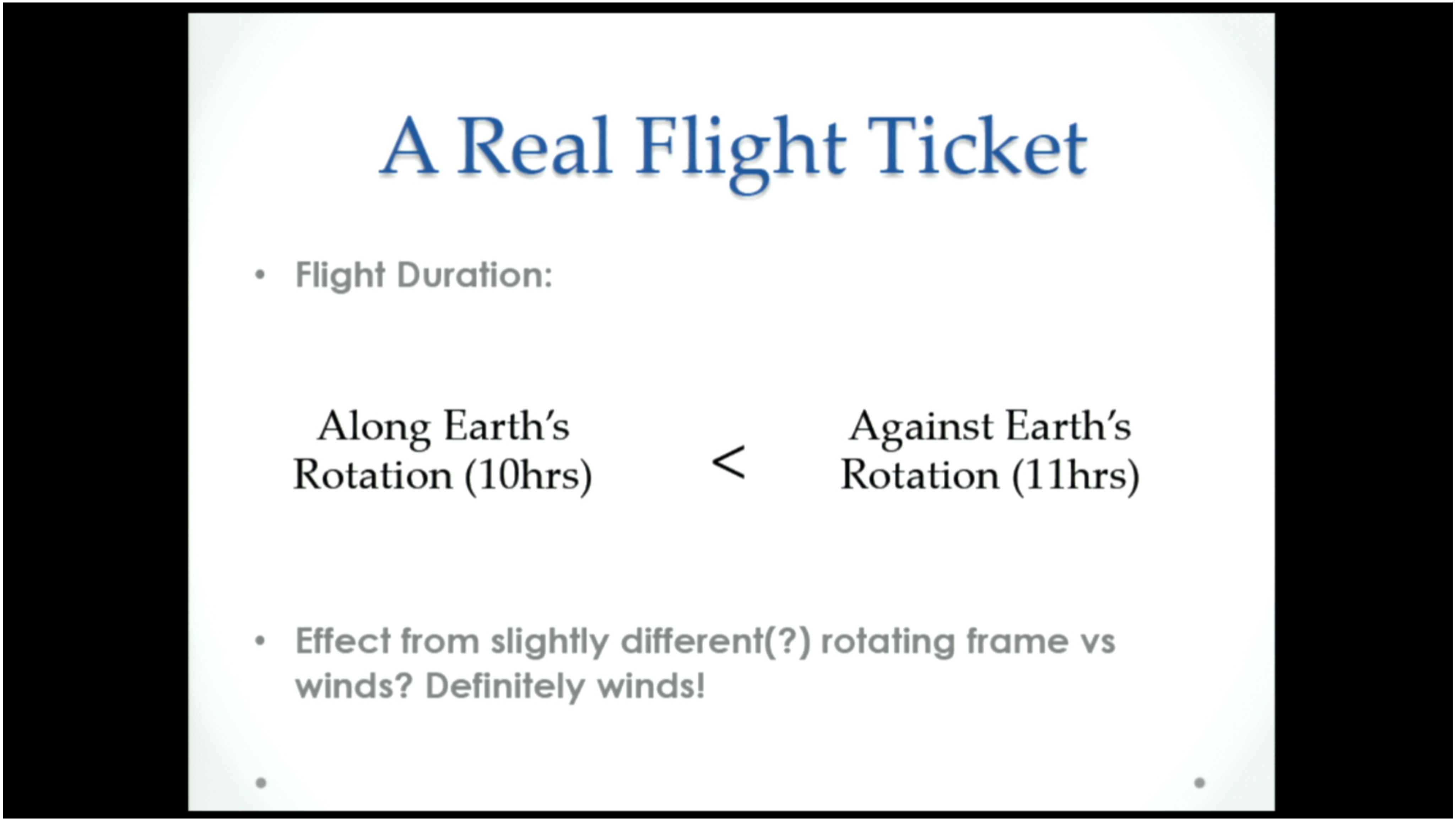
http://www.ops.org/ELEMENTARY/CATLIN/LinkClick.aspx?fileticket=6nh95iyGtm8%3D&tabid=227&mid=937

A Real Flight Ticket

- Flight Duration:

Along Earth's Rotation (10hrs) < Against Earth's Rotation (11hrs)

X + R hours? X - R hours?


A Real Flight Ticket
Flight Duration:
Along Earth's Rotation (10hrs)
<
Against Earth's Rotation (11hrs)
Effect from slightly different(?) rotating frame vs winds? Definitely winds!

Thank You!

??? Questions ???