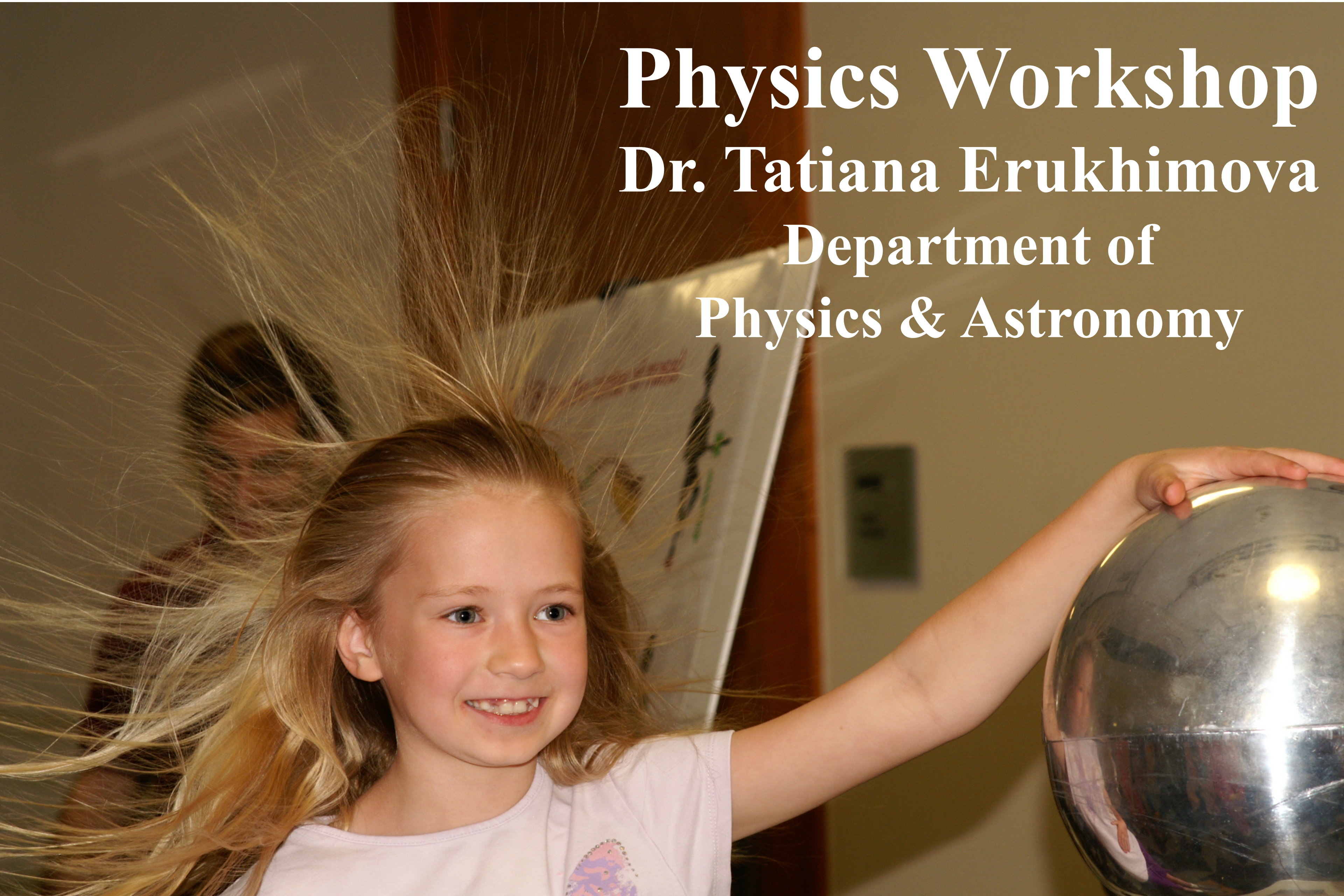
TEXAS A&M UNIVERSITY

Physics Workshop

Dr. Tatiana Erukhimova

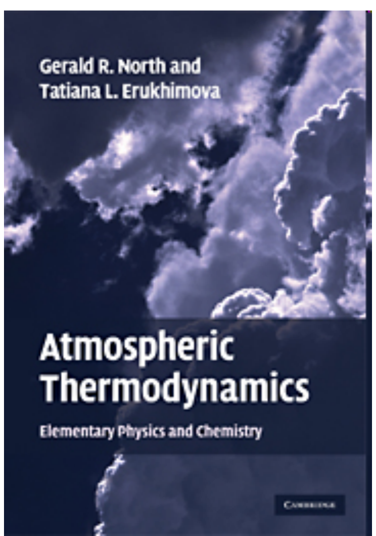
Department of Physics & Astronomy



Senior Lecturer & Outreach Coordinator
PhD in 1999 from Russian Academy of Sciences

Taught Physics classes for engineering and science majors since 2006

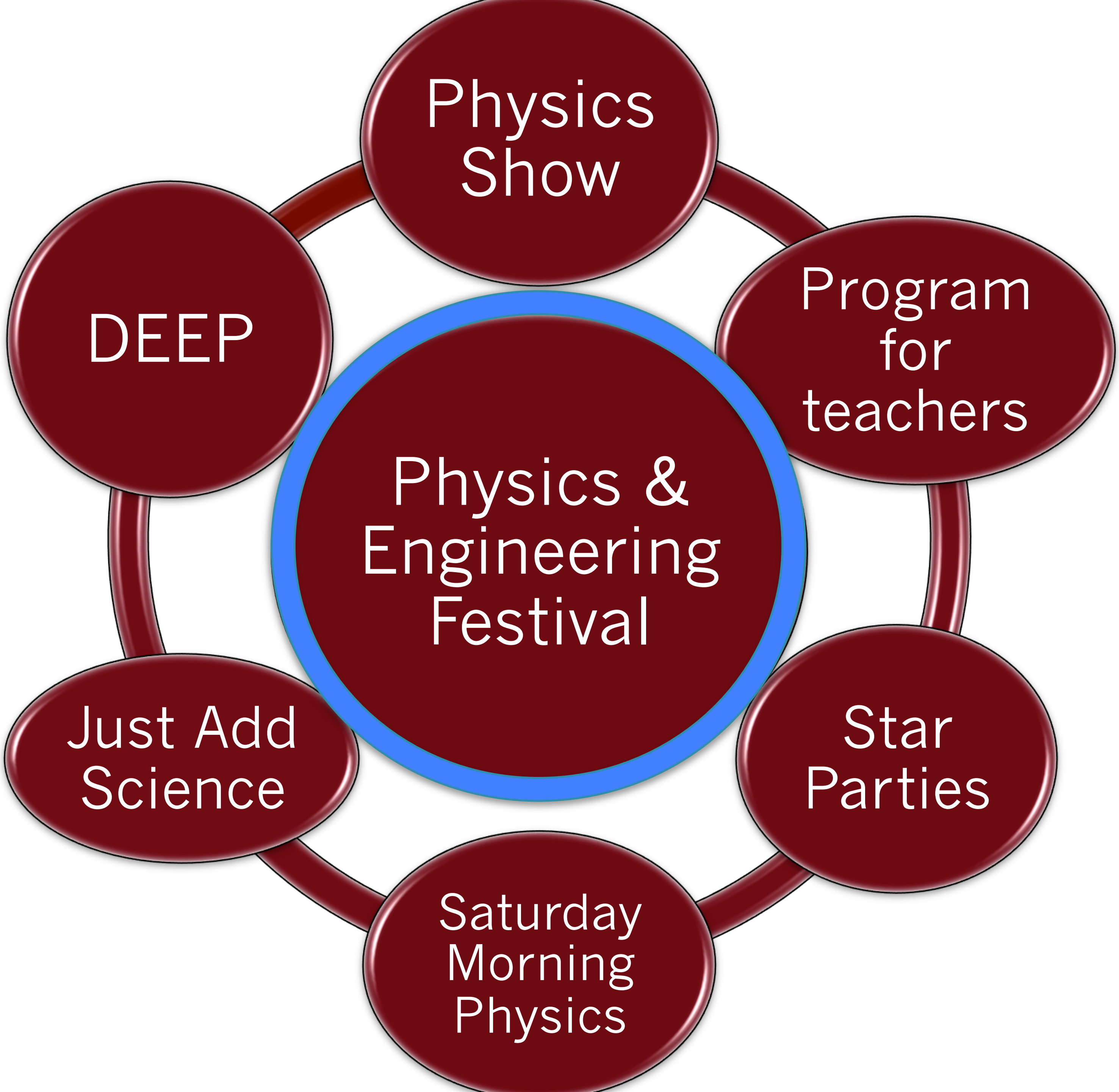
- 2014 *Sigma Xi's* Outstanding Science Communicator Award
- 2013 John E. Trott, Jr. Award in Student Recruiting
- 2012 Distinguished Achievement University-Level Award in Teaching
- 2015, 2009, Distinguished Achievement College-Level Award in Teaching
- SLATE awards: 2008, 2009, 2011



Atmospheric Thermodynamics
Elementary Physics and Chemistry

Gerald R. North
Tatiana L. Erukhimova

CAMBRIDGE UNIVERSITY PRESS


Physics Show
Program for teachers
Star Parties
Saturday Morning Physics
Just Add Science
DEEP
Physics & Engineering Festival

72 Faculty

2 Nobel Laureates

3 National Academy of Science

12 Distinguished Professors

Physics Faculty teach introductory physics classes P218 (Mechanics) and P208 (Electricity & Magnetism) to all engineering students

Today's demonstrations

- ***can be made with household materials***
- ***require little preparation***
- ***modest budget***
- ***can be easily shown in the classroom***

I can't help but see physics everywhere I go now. It's pretty neat.

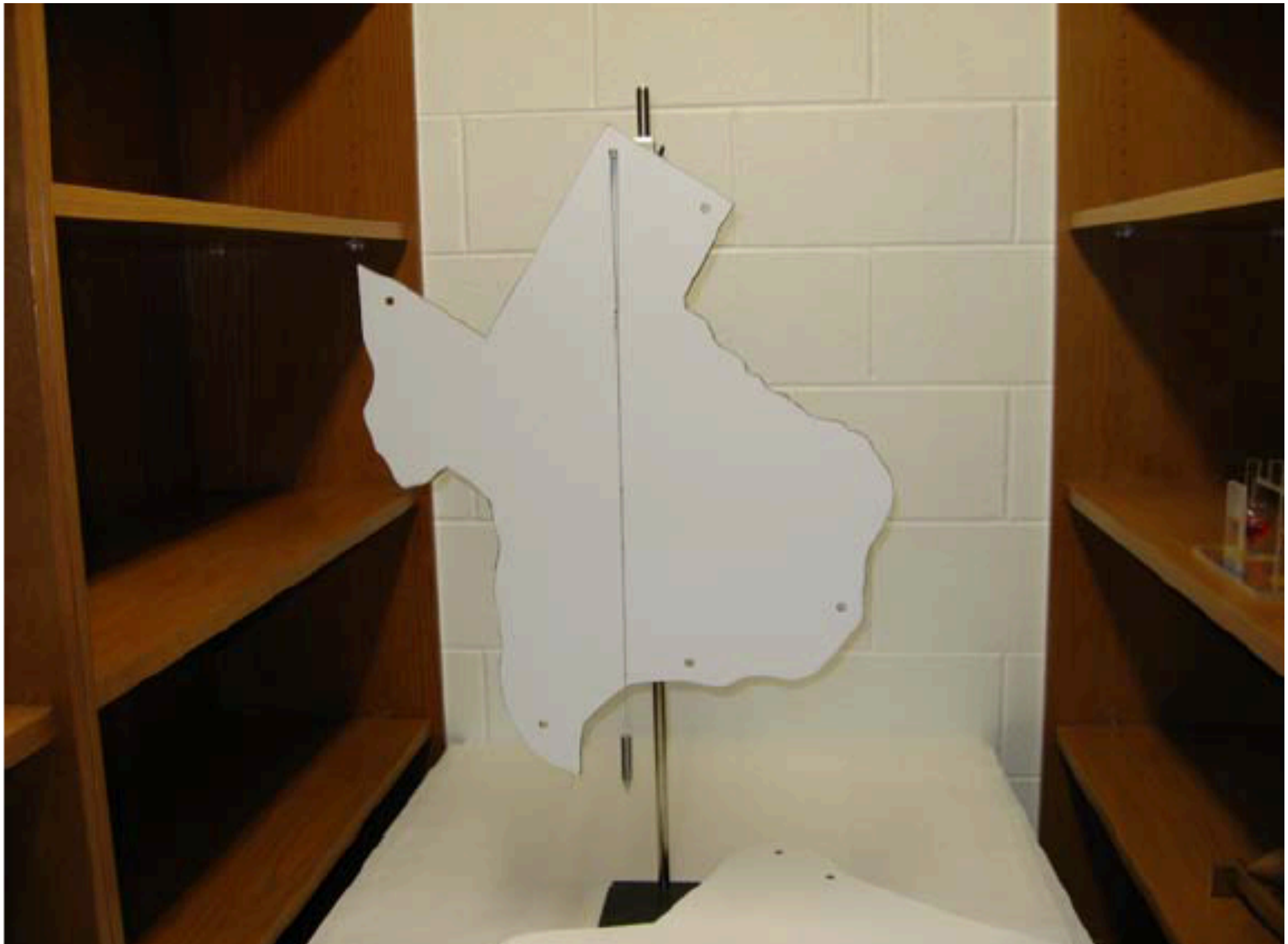
From Physics 218 (Mechanics) students' evaluations

Balance of Forces and Torques
Concept of Center of Mass

$$\sum \vec{F}_{ext} = 0 \quad \sum \vec{\tau}_{ext} = 0$$

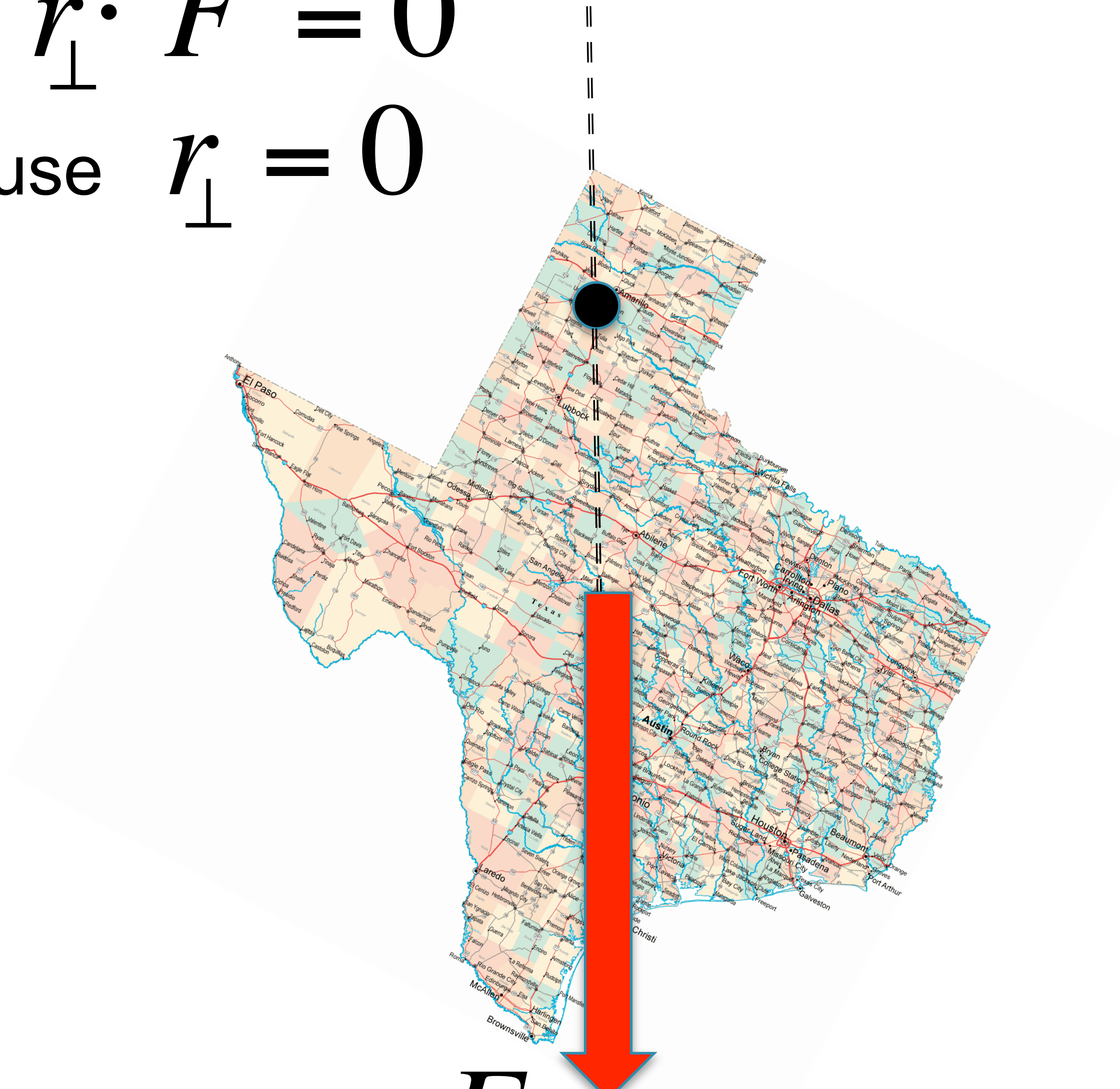
$$\vec{\tau} = \vec{r} \times \vec{F} \quad or \quad \tau = r_{\perp} \cdot F$$

Map of Texas



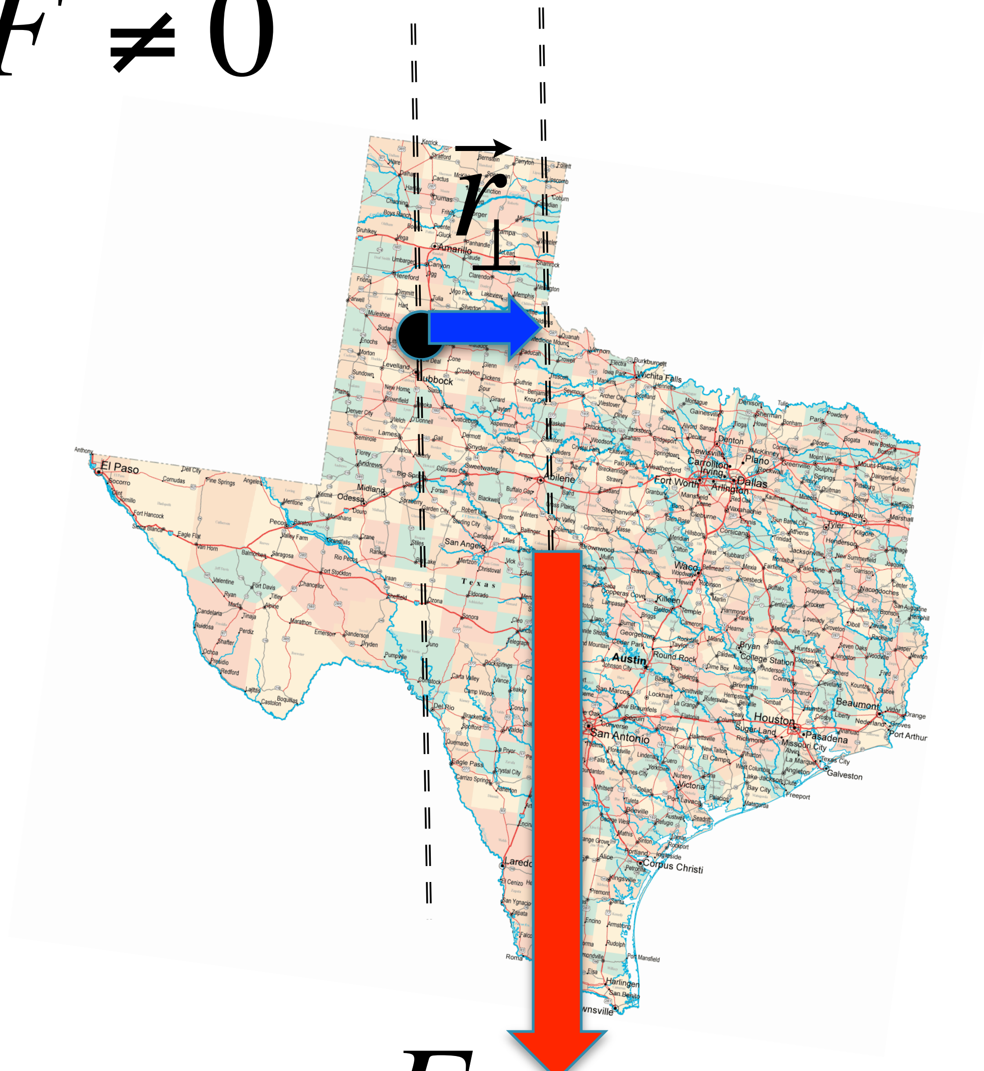
$$\tau = r_{\perp} \cdot F = 0$$

Because $r_{\perp} = 0$



$$F = mg$$

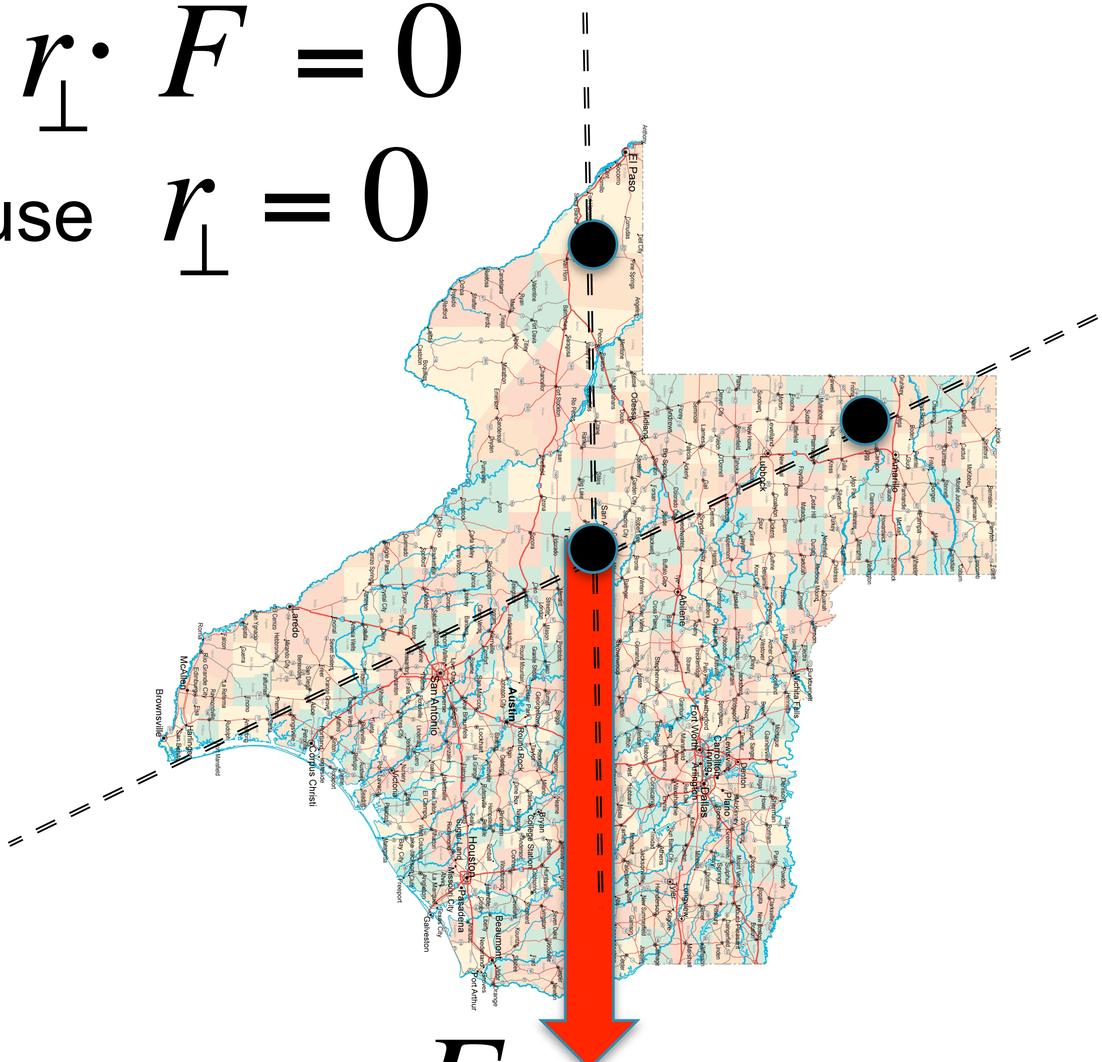
$$\tau = r_\perp \cdot F \neq 0$$



$$F = mg$$

$$\tau = r_{\perp} \cdot F = 0$$

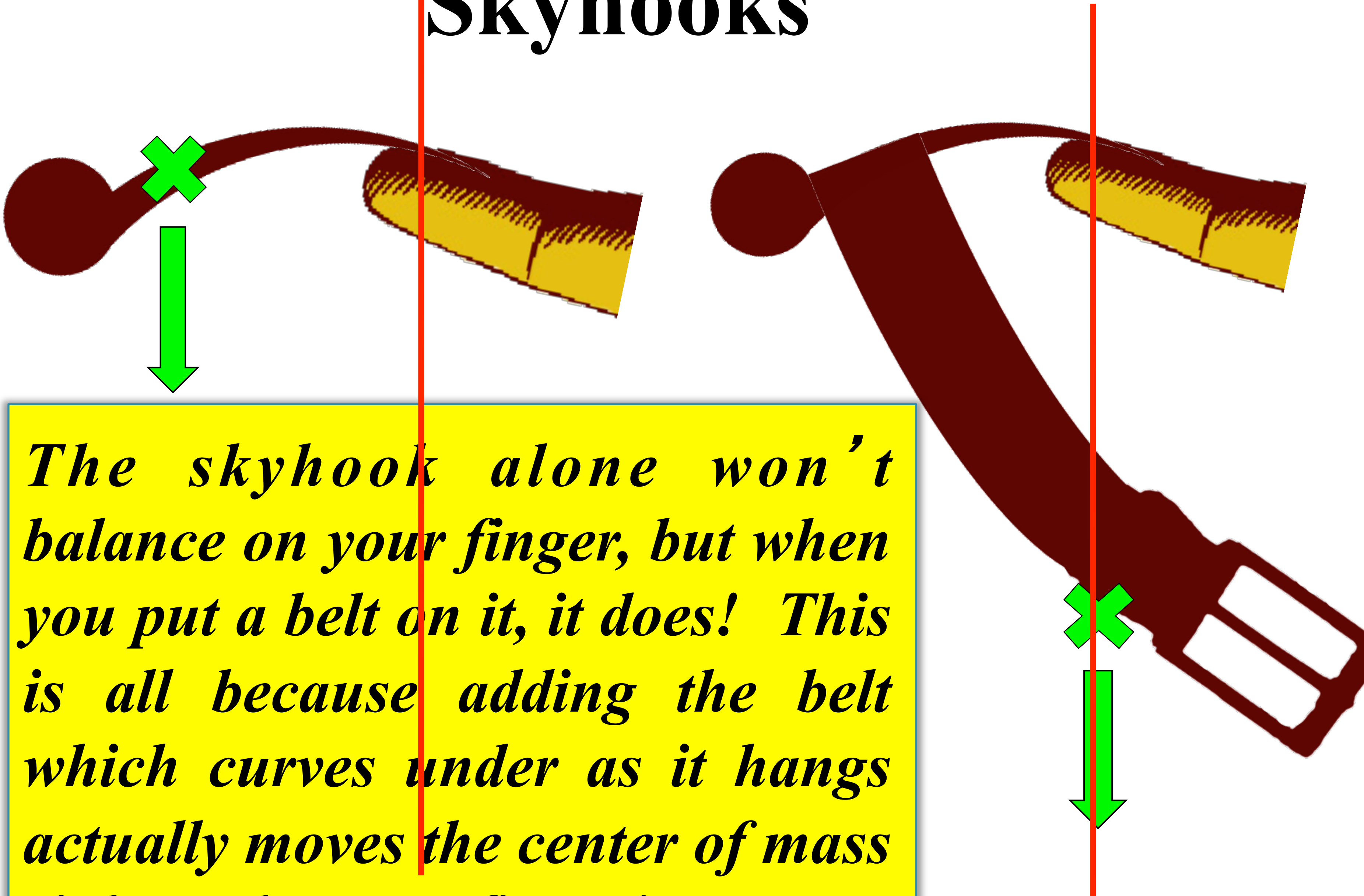
Because $r_{\perp} = 0$



$$F = mg$$

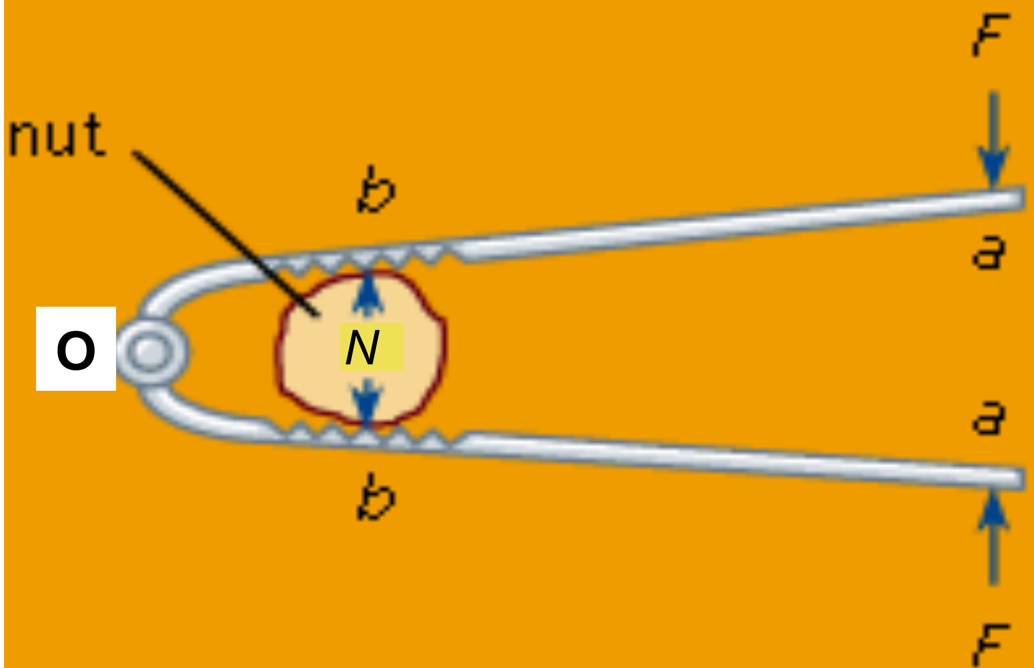

Brady, TX
Brady
Amarillo
Lubbock
Wichita Falls
Abilene
Midland
Odessa
San Angelo
Fort Worth
Dallas
Arlington
Plano
Denton
Waco
Killeen
Bryan
College Station
Austin
Round Rock
San Antonio
New Braunfels
Houston
Pasadena
Sugar Land
Beaumont
Galveston
Victoria
Corpus Christi
Tyler
Longview
Texas

Skyhooks



The skyhook alone won't balance on your finger, but when you put a belt on it, it does! This is all because adding the belt which curves under as it hangs actually moves the center of mass right under your finger!

Nutcracker



$$N = F\frac{a}{b}$$

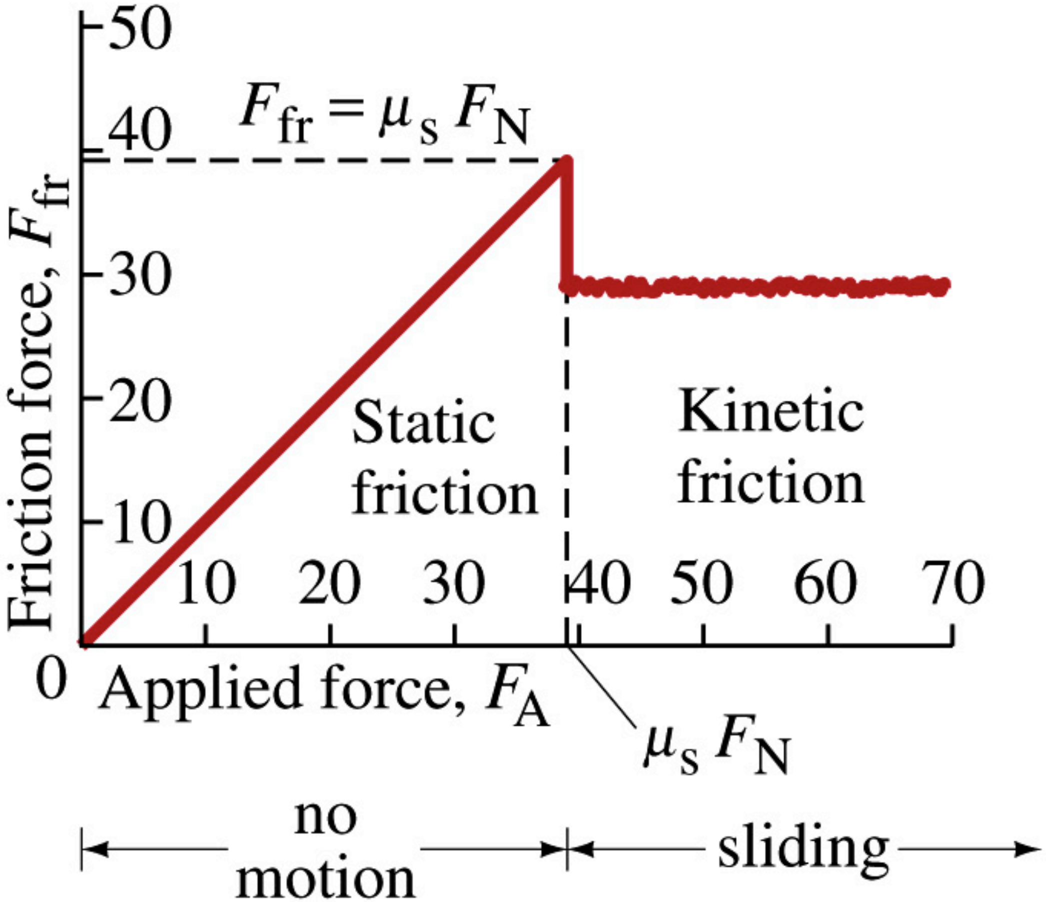
Inertia

If you pull the table cloth fast enough, the friction force between the cloth and the dinnerware will be very short-lived, so that the dinnerware will not have a chance to move before the force is gone.

Quantitatively, impulse $F\Delta t$ of the friction force must be small.

Atmospheric Pressure

Force of Friction with Phone Books



(*from Giancoli*)

Newton's Third Law with two spring scales

Equal and opposite force

Conservation of Momentum

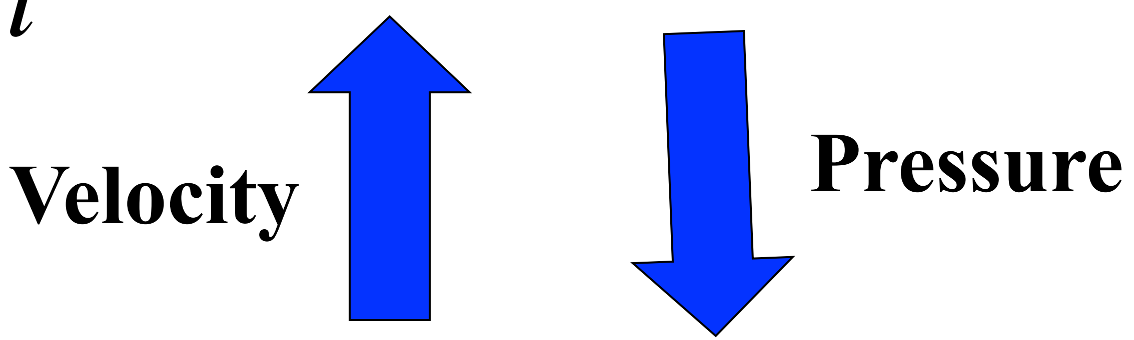
- Basketball and Racquetball
- Skateboard with Leaf Blower
- Rotating Platform with Leaf Blower (angular momentum)

More with a Leaf Blower!

Bernoulli's principle

$$p + \rho g h + \frac{1}{2}\rho v^2 = Const$$

$$h = Const$$



- **Leaf Blower and Flying Ball**
- **Leaf Blower, Broom, and Toilet Paper**

Eagle photo/Stuart Villanueva

The Frisbee as an Airfoil

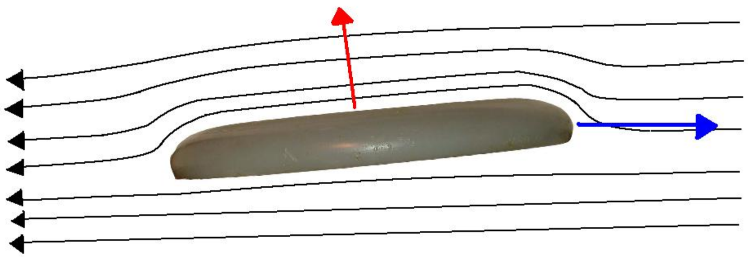
- According to Bernoulli's Eq,

  $p + \rho gh + ½\, \rho v^2 = \text{Constant}$

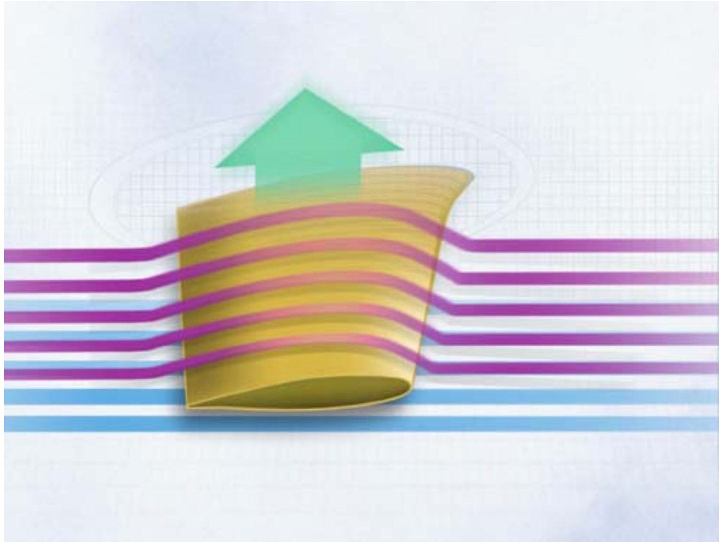
- The curved upper surface of the Frisbee forces the air above it to increase its velocity as compared with the air flowing underneath – much like an airplane wing

- Because ρgh is the same on the top and bottom of the Frisbee, the increased velocity of the air above the Frisbee must correspond to a lower air pressure

- The lower air pressure above the Frisbee provides a lift force that helps counteract gravity.



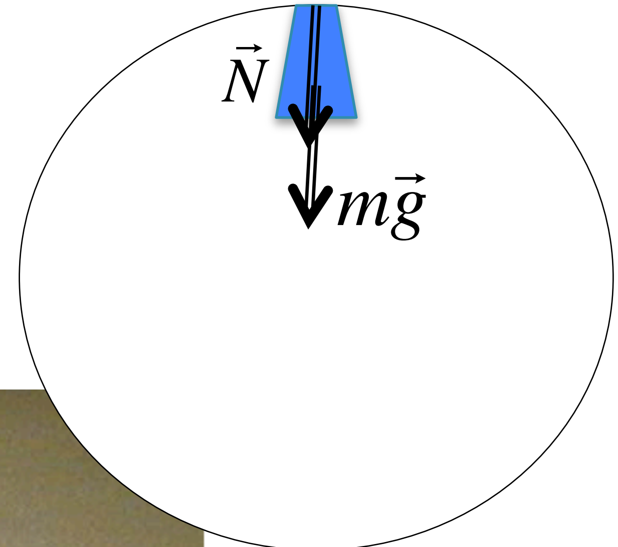
Frisbee



Airplane wing

Rotational Motion

Whirling Beaker of Water

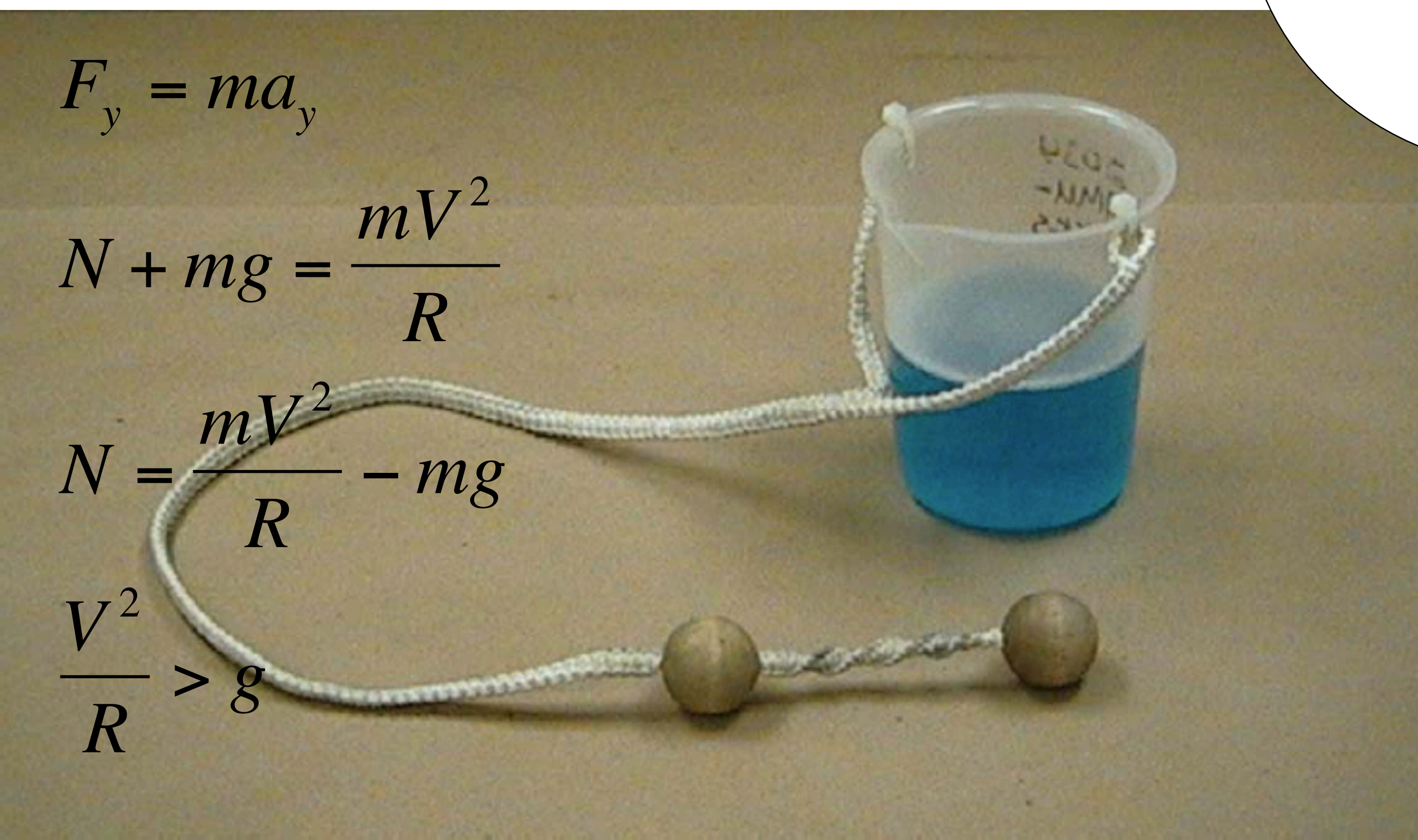


$$F_y = ma_y$$

$$N + mg = \frac{mV^2}{R}$$

$$N = \frac{mV^2}{R} - mg$$

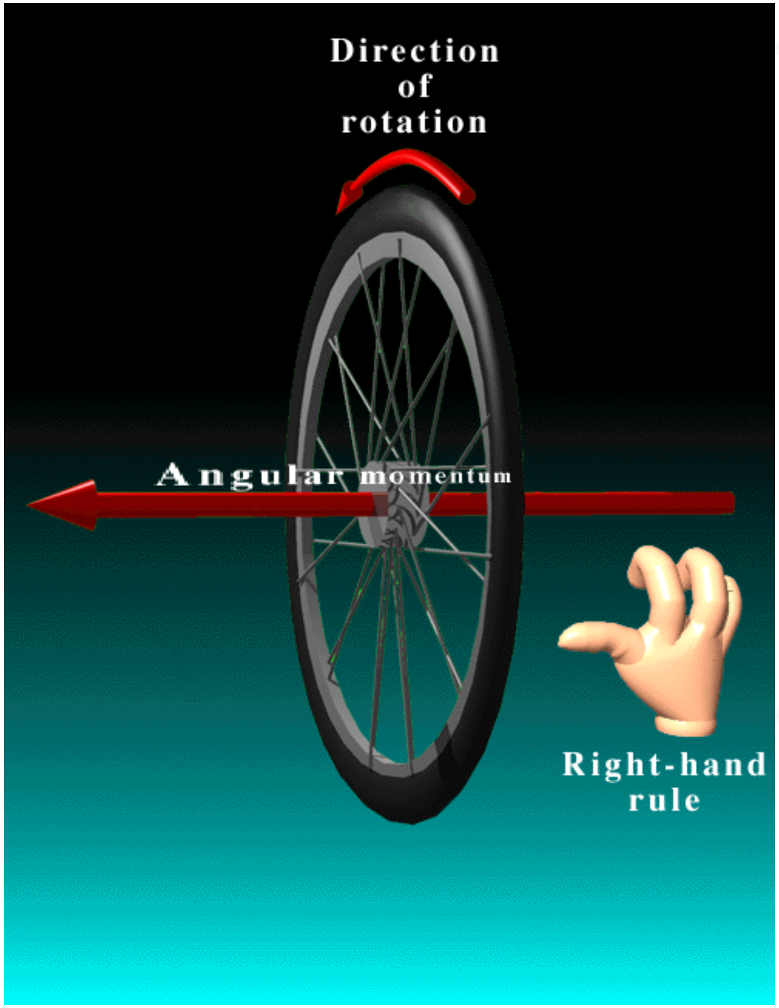
$$\frac{V^2}{R} > g$$



Rotation of Rigid Bodies

- **Cookie Cans with Magnets on Inclined Plane (moment of inertia)**
- **Rotating Platform with Weights and a Wheel (angular momentum)**
- **Eggs (hard-boiled and raw) on Inclined Plane**

Angular momentum



Moment of inertia

$$\vec{L} = I\vec{\omega}$$

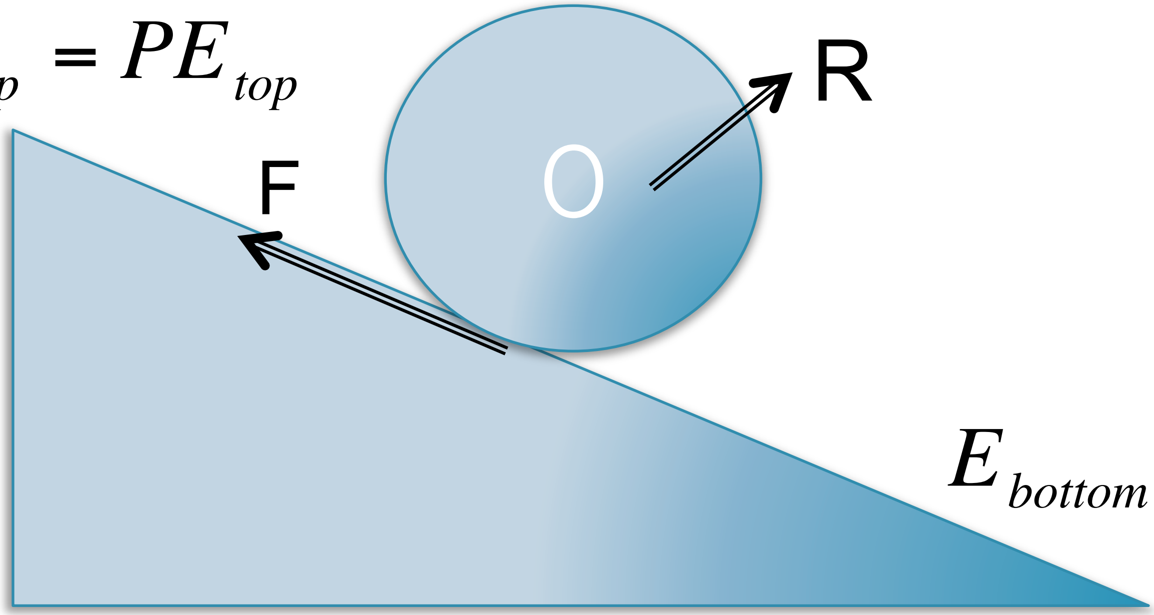
Angular velocity

Vector along axis of rotation

Compare with momentum:

$$\vec{P} = m\vec{V}$$

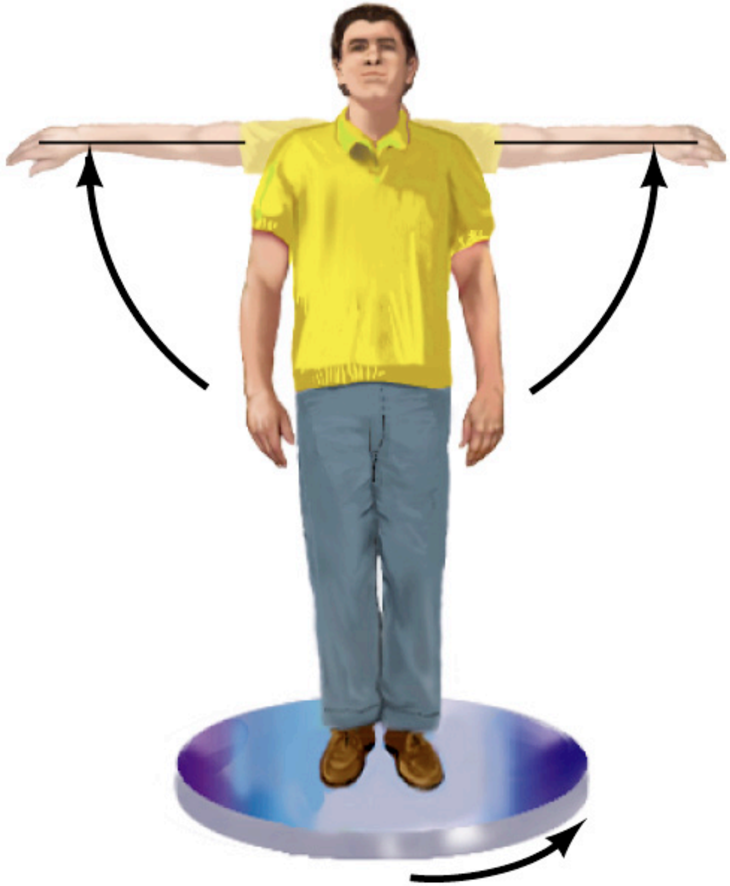
$$E_{top} = PE_{top}$$



$$E_{bottom} = KE_{bottom}$$

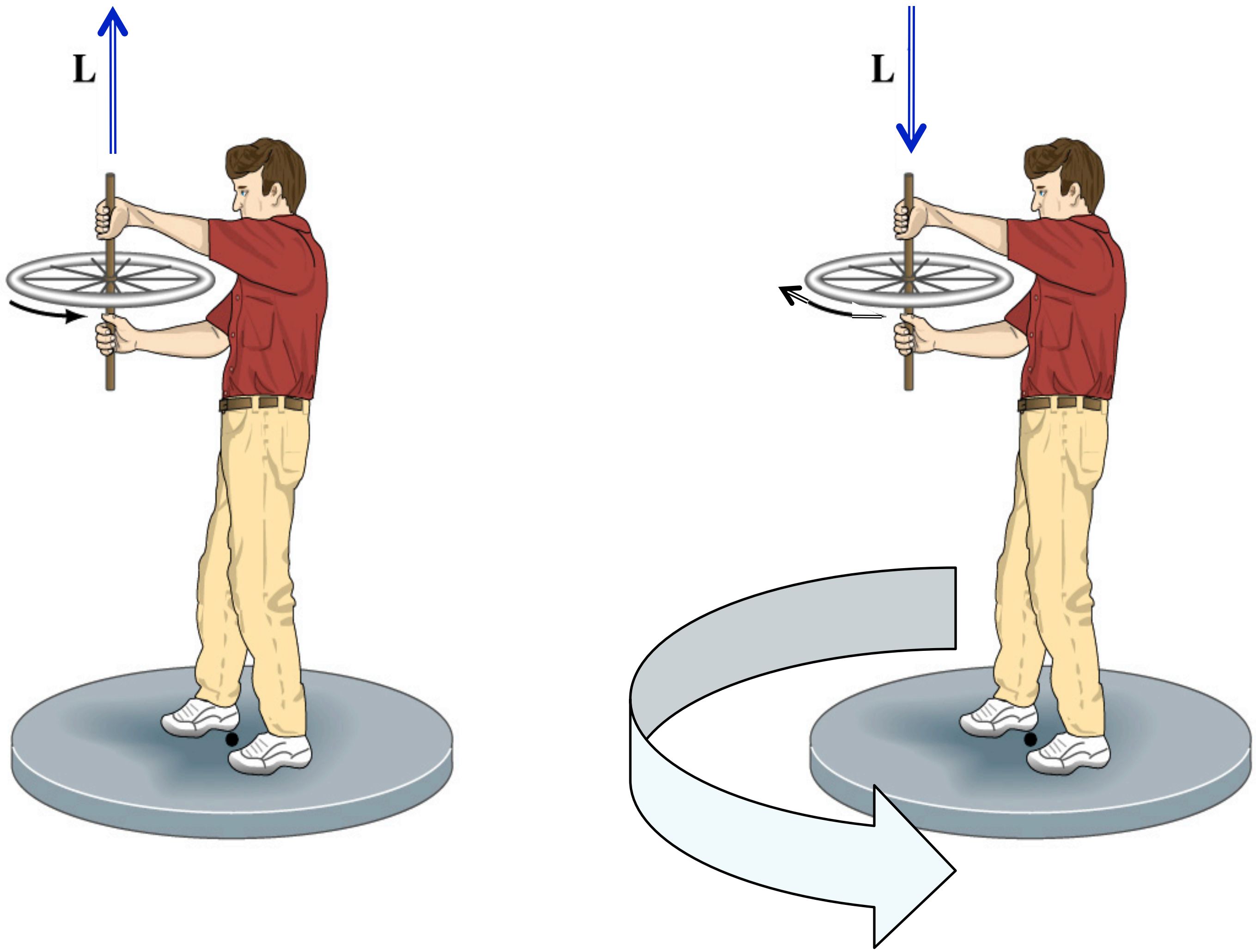
$$PE_{top} = KE_{bottom} \qquad KE_{bottom} = \frac{mV^2}{2} + \frac{I_0\omega^2}{2}$$

$$\omega = \frac{V}{R} \qquad KE_{bottom} = \left(m + \frac{I_0}{R^2}\right)\frac{V^2}{2}$$



L before = L after

$$I_a\omega_a = I_b\omega_b$$



$$L = I_{wheel}\omega$$

$$I_{wheel}\omega = -I_{wheel}\omega + (I_{man} + I_{platform})\omega_{new}$$

What do freshman students mostly struggle with when they enter physics class?

1. **Vectors, vectors, and vectors!** How to work with vectors by means of *components* - basic trigonometry is inevitable.

2. **Derive a solution in a symbolic form** rather than "plug and chug" approach

Projectile Motion

$$x(t) = v_x(0)t + x(0)$$

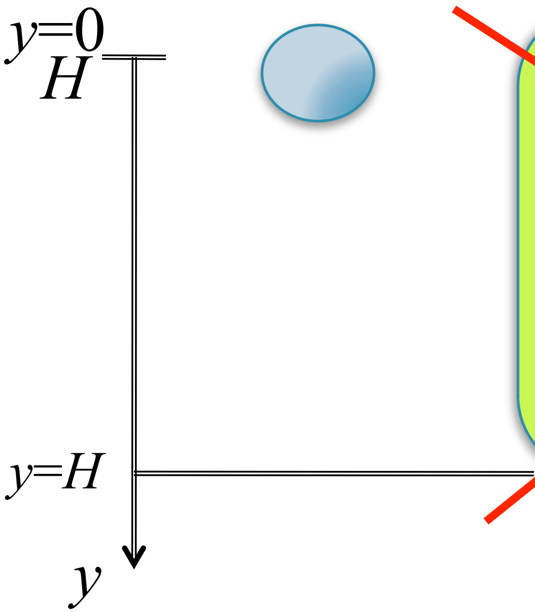
$$v_x(t) = v_x(0)$$

$$y(t) = \frac{1}{2}a_y t^2 + v_y(0)t + y(0)$$

$$v_y(t) = a_y t + v_y(0)$$

$$v_y^{\,2}(t_2) - v_y^{\,2}(t_1) = 2a_y\left(y(t_2) - y(t_1)\right)$$

How long does it take for the ball to reach the surface?



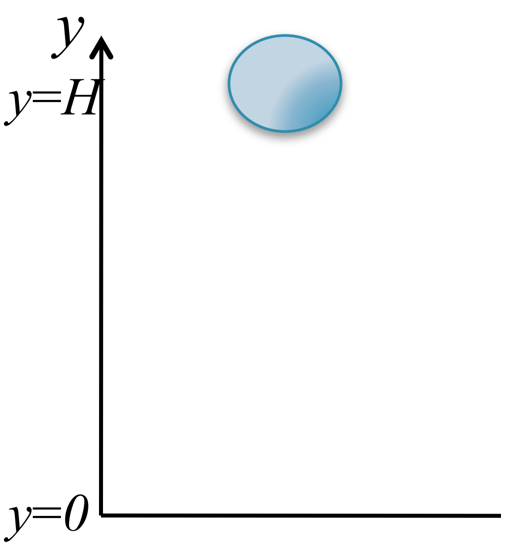
$$-\frac{1}{2}gt^2 = H$$

$$t = \sqrt{\frac{-2H}{g}}$$

$$a_y = +g; \quad y(t) = \frac{1}{2}gt^2$$

$$\frac{1}{2}gt^2 = H; \quad t = \sqrt{\frac{2H}{g}}$$

OR

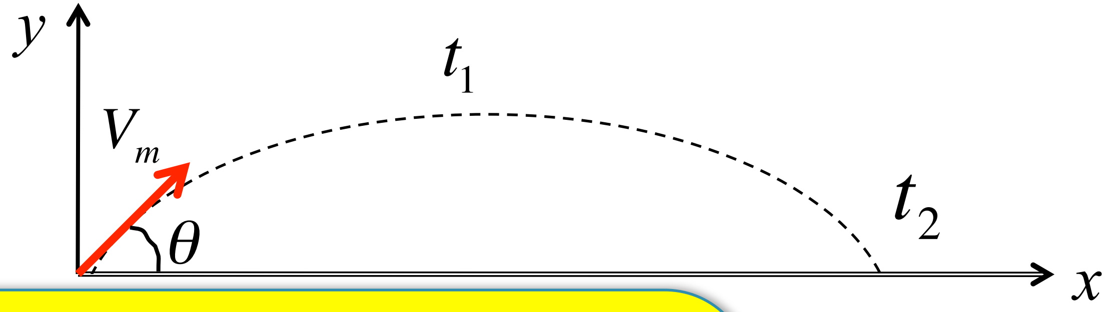


$$a_y = -g; \quad y(t) = -\frac{1}{2}gt^2 + H$$

$$-\frac{1}{2}gt^2 + H = 0; \quad t = \sqrt{\frac{2H}{g}}$$

Projectile Motion

A cannon at the origin points up at an angle θ with the x axis. A shell is fired which leaves the barrel with a velocity of magnitude V_{m}.
How long is the shell in the air before it lands?



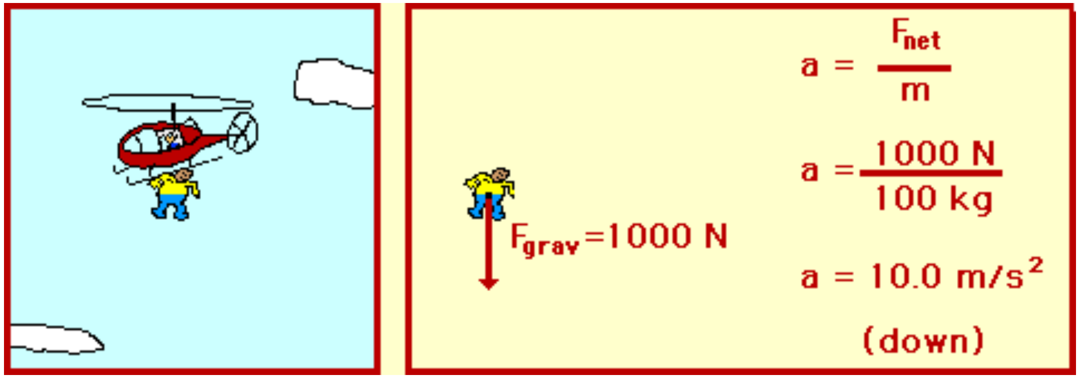
$$V_x(t) = V_m \cos\theta$$
$$V_y(t) = V_m \sin\theta$$
$$a_y = -g$$

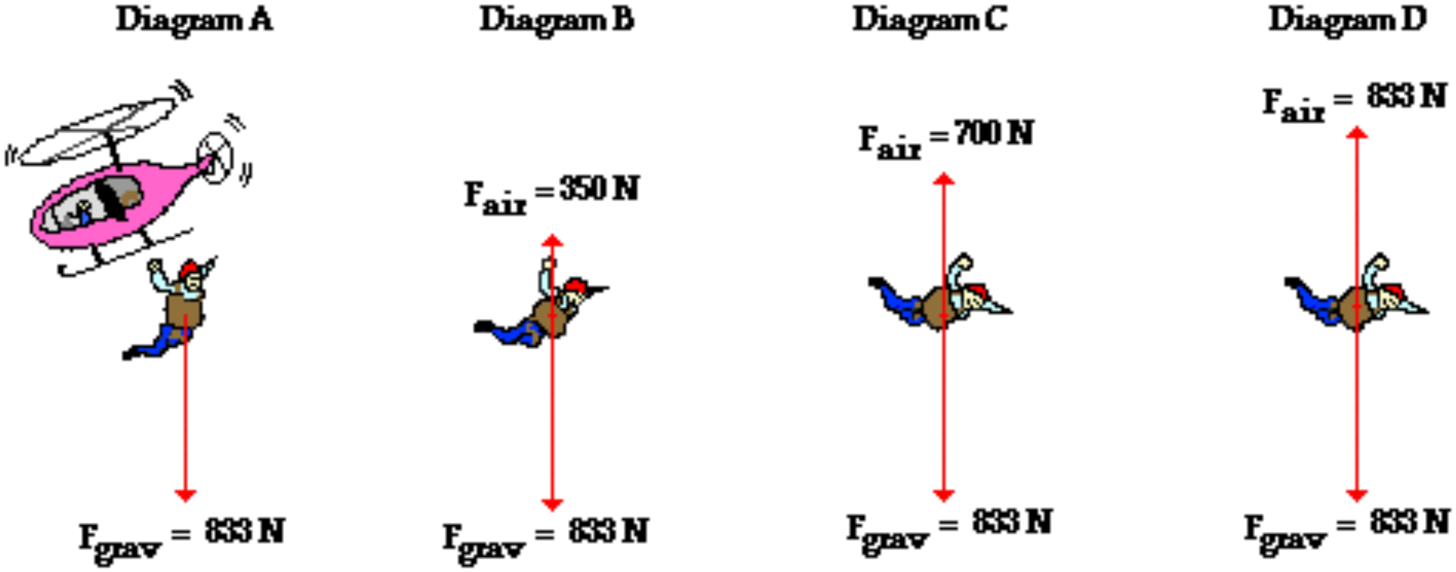
$$t_1 = ?$$
$$V_y(t) = -gt + V_m \sin\theta$$
$$V_y(t_1) = 0; \quad -gt_1 + V_m \sin\theta = 0$$
$$t_1 = \frac{V_m \sin\theta}{g}$$

$$t_2 = ? \quad y(t_2) = 0$$
$$y(t) = -\frac{1}{2}gt^2 + V_m \sin\theta\, t$$
$$-\frac{1}{2}gt_2^2 + V_m \sin\theta\, t_2 = 0;$$
$$t_2(-\frac{1}{2}gt_2 + V_m \sin\theta) = 0$$
$$t_2 = 2\frac{V_m \sin\theta}{g} = 2t_1$$

Falling with air resistance

$$a = \frac{dv}{dt} = g - kv^2$$





Terminal Velocity with Coffee Filters

$$mg - F_r = ma$$

where F_r is the resistance force.

$$a = g - \frac{F_r}{m}$$

1. A penny and a quarter dropped from a ladder land at the same time (air resistance is negligible).
2. A coin dropped in a coffee filter from a ladder lands later than a coin without coffee filter (the terminal velocity is smaller for larger cross-section area).
3. A quarter dropped in a coffee filter will land faster than a penny in a coffee filter (the terminal velocity is larger for larger mass)
4. Two identical coins dropped in coffee filters of different diameters land at different times (the terminal velocity is smaller for larger cross-section area).

Resistance force: $F_r = \gamma A v^2$

A – area of the projectile

For a spherical projectile in air at STP: $\gamma = 0.25\ \mathrm{N} \times \mathrm{s}^2/\mathrm{m}^4$

Terminal velocity:

$$a = g - \frac{F_r}{m} = 0$$

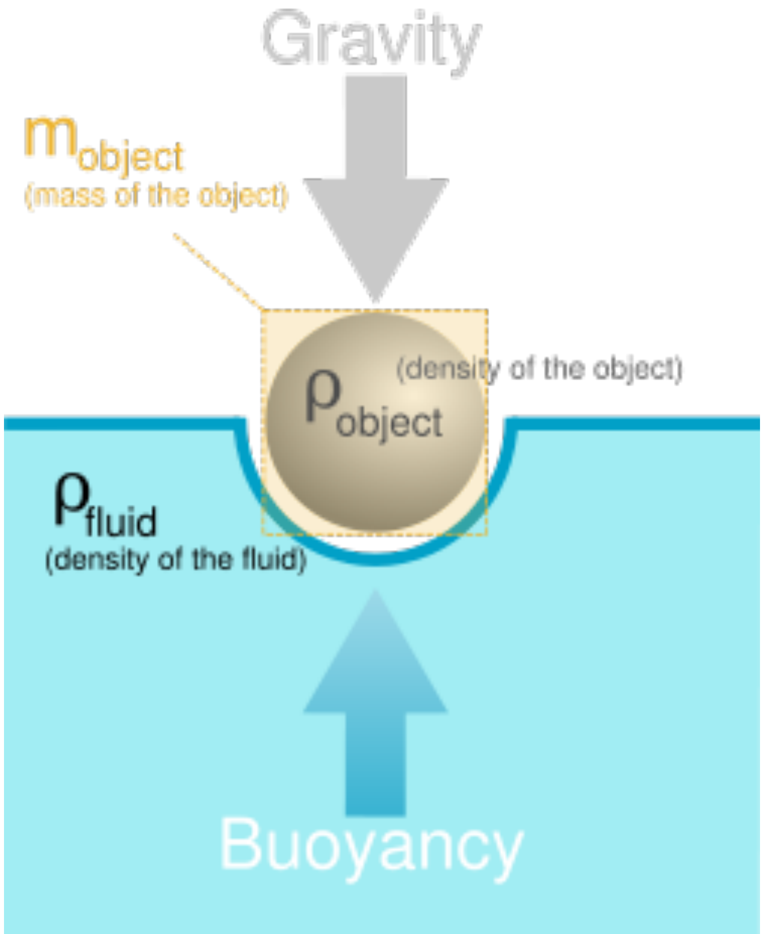
$$F_r = mg$$

$$\gamma A v^2 = mg$$

$$\boxed{v_T = \sqrt{\frac{mg}{\gamma A}}}$$

A 70-kg man with a parachute: $v_T \sim 5$ m/s
A 70-kg man without a parachute: $v_T \sim 70$ m/s

Buoyancy
(Magic Bubbles)



$$F = (\rho_{fluid} - \rho_{object})Vg$$

$$F = (\rho_{surrounding\ gas} - \rho_{object})Vg$$

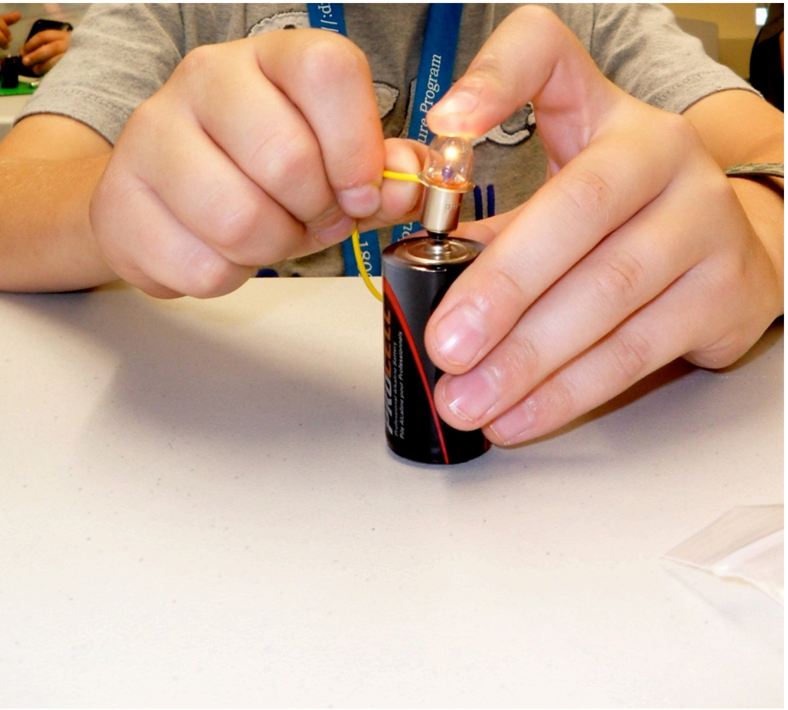
When a body is completely or partially immersed in a fluid, the fluid exerts an upward force on the body equal to the weight of the fluid displaced by the body.

Photo taken by Sam Craft

Static electricity

Can you make a light bulb work with a battery and a wire?

"Minds of Our Own"
by Dr. Matthew H. Schneps and Dr. Philip M. Sadler
Harvard-Smithsonian

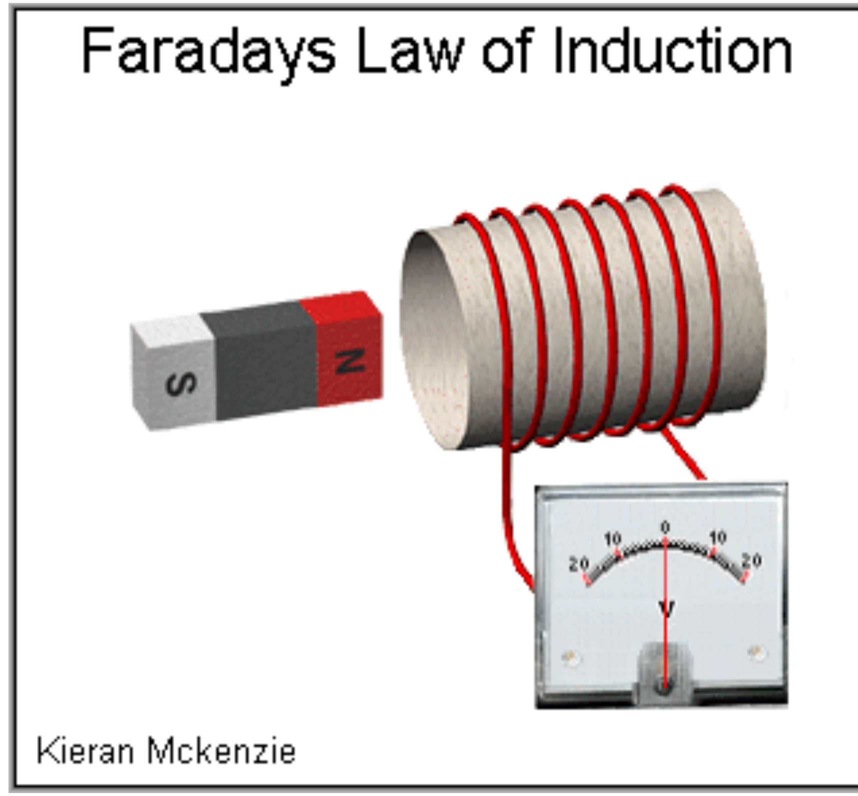


How can students graduate from prestigious schools like Harvard or MIT and not know even some of the most basic ideas in science taught in grade school?

Faraday's Law of Induction

•A time varying magnetic flux through a circuit will induce an EMF (voltage) in the circuit.

• Varying magnetic field is created as a bar magnet passes through the coil.



$$\oint \vec{E} \cdot d\vec{r} = -\frac{d\Phi_B}{dt}$$

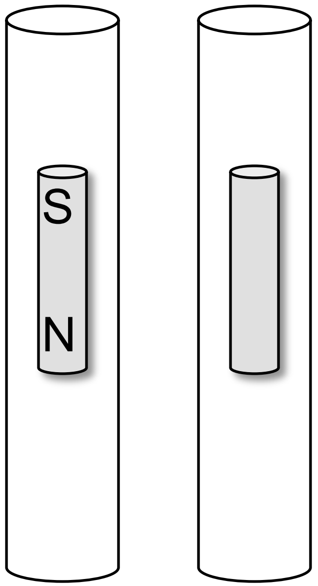
Lenz's Law

Which way will the current go?

Lenz's Law: if a current is induced by some change, the direction of the current is such that it opposes the change.

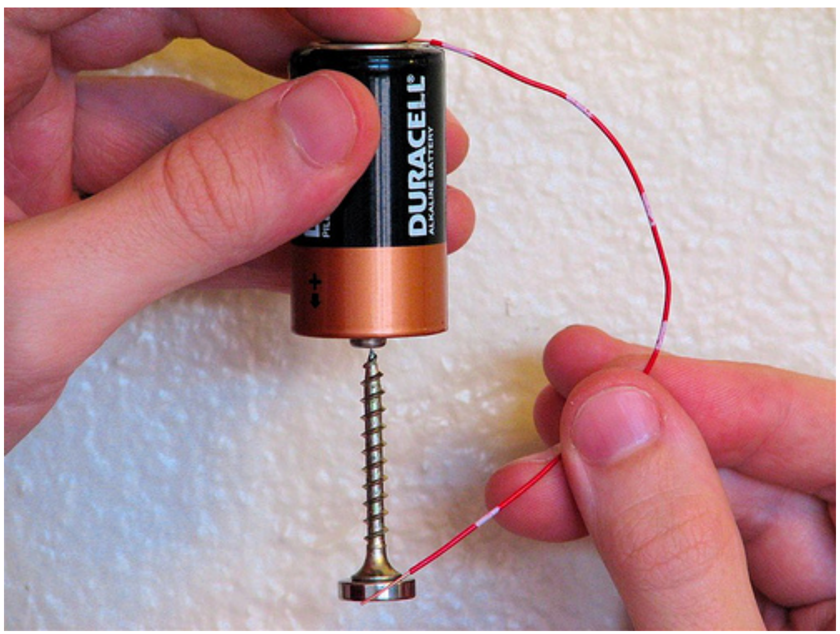
$$\oint \vec{E} \cdot d\vec{r} = -\frac{d\Phi_B}{dt}$$

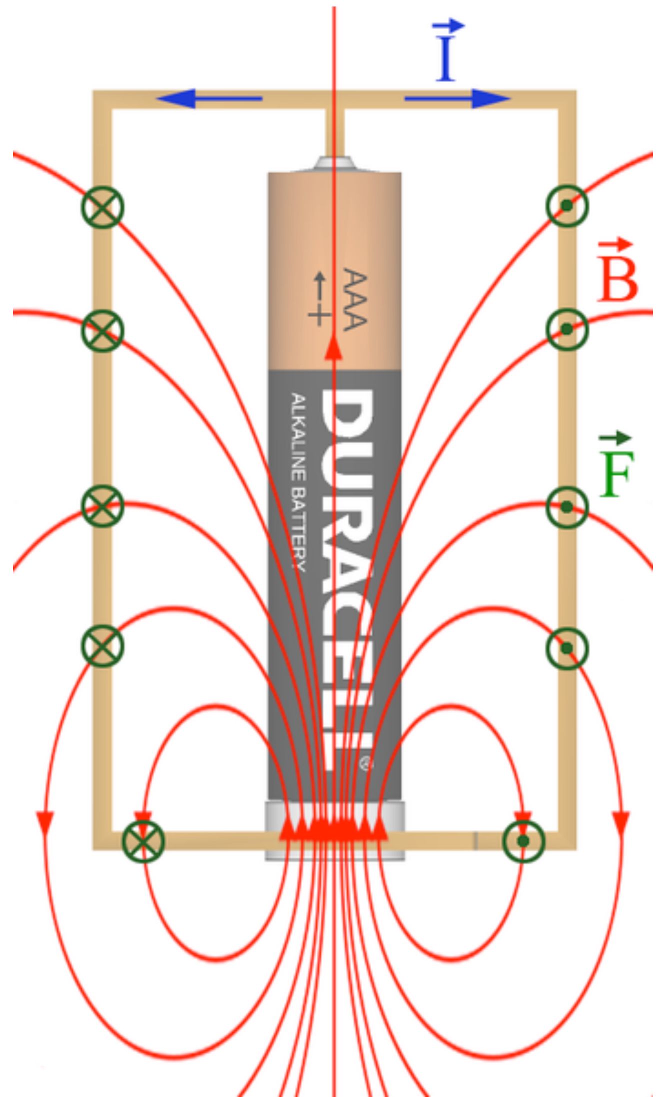
Experiment with a magnet falling in an aluminum pipe



Make your own MOTOR!

All you need is a battery, a nail, a small magnet, and a wire (foil works better)





http://en.wikipedia.org/wiki/Homopolar_motor

Physics & Engineering Festival
April 8 - 9

http://physicsfestival.tamu.edu/

See you there!