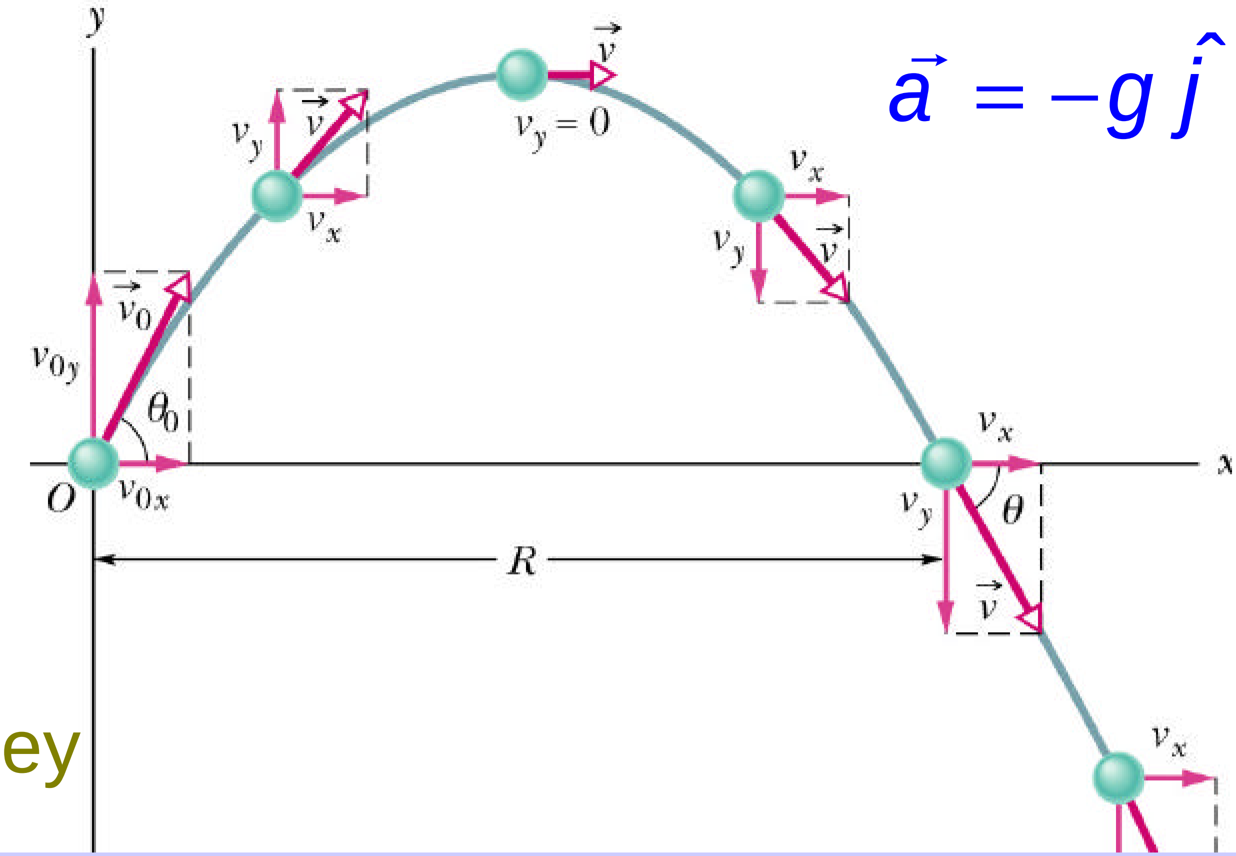
Review: Trajectory

- *x-comp of v is fixed*
- *y-comp of v is getting more negative at a fixed rate (g)*



$$\vec{a} = -g\,\hat{j}$$

Shoot the Monkey

$$y - y_0 = (\tan\theta_0)(x - x_0) - \frac{1}{2}\frac{g}{(v_0\cos\theta_0)^2}(x - x_0)^2$$

Flics to Illustrate

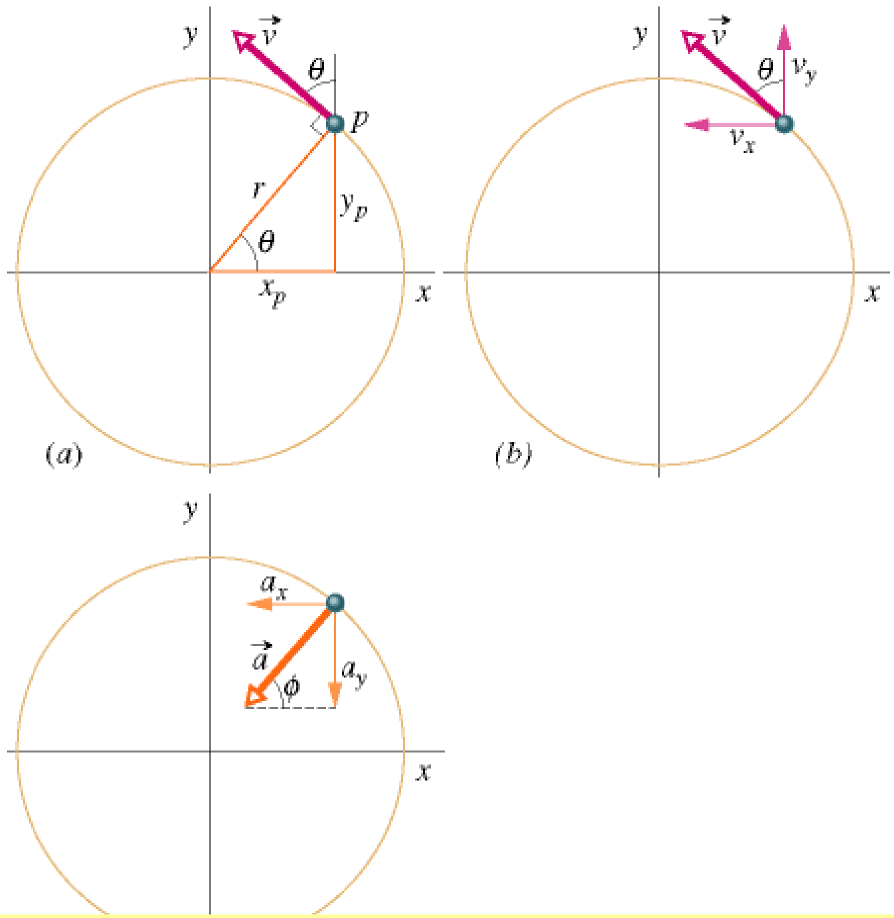
one ball-parabolic path.MOV

balls-traj eq.MOV

circ motion- v chg.MOV

3balls-parabolic.MOV

Review: Uniform Circular Motion



$$\sin\theta = \frac{y}{r} \qquad \cos\theta = \frac{x}{r}$$

$$\vec{r} = r\left[(\cos\theta)\hat{i} + (\sin\theta)\hat{j}\right] = r\hat{r}$$

$$\vec{v} = (-v\sin\theta)\hat{i} + (v\cos\theta)\hat{j}$$

$$\vec{v} = (-v\frac{y}{r})\hat{i} + (v\frac{x}{r})\hat{j}$$

$$\frac{d\vec{v}}{dt} = \left(-\frac{v}{r}\frac{dy}{dt}\right)\hat{i} + \left(\frac{v}{r}\frac{dx}{dt}\right)\hat{j}$$

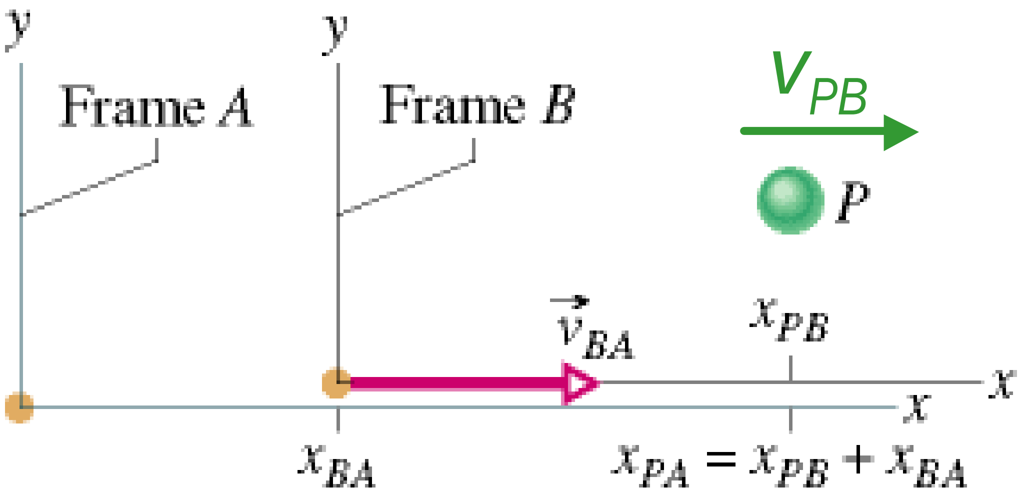
$$= \left(-\frac{v}{r}v\cos\theta\right)\hat{i} + \left(-\frac{v}{r}v\sin\theta\right)\hat{j}$$

$$\vec{a} = -\frac{v^2}{r}\left[(\cos\theta)\hat{i} + (\sin\theta)\hat{j}\right]$$

$$= -\hat{r}\frac{v^2}{r}$$

Conclude $a = v^2/r$ and
directed to center of circle

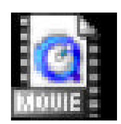
Relative Motion - 1D



$$V_{PA} = V_{PB} + V_{BA}$$

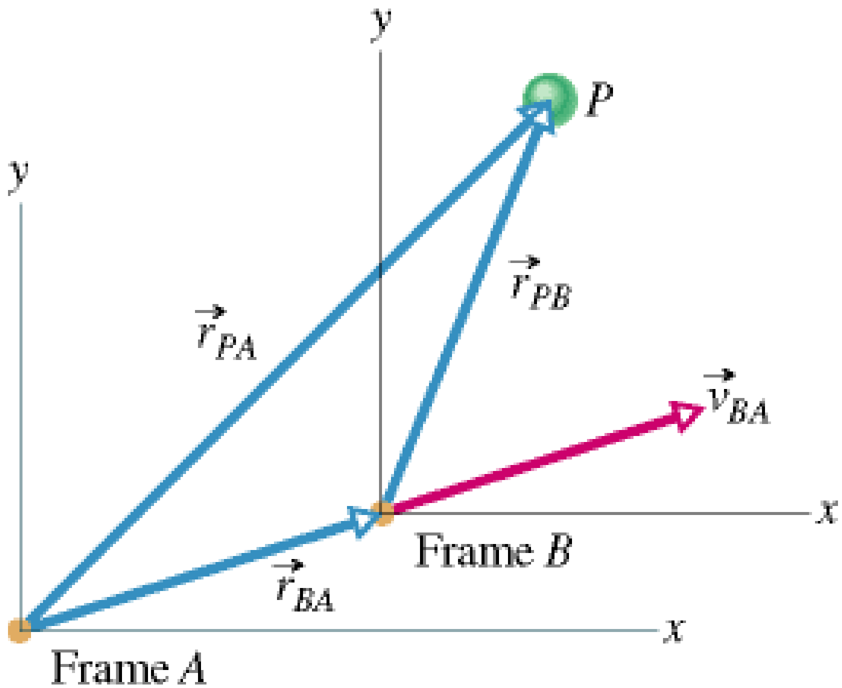
$$\vec{V}_{PA} = \vec{V}_{PB} + \vec{V}_{BA}$$

Intuitive concept: If I sit on a moving raft, and watch you walk, your speed is different than that seen by someone on the shore!



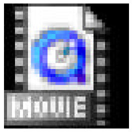
cars-rel motion 1D.MOV

Relative Motion 2D



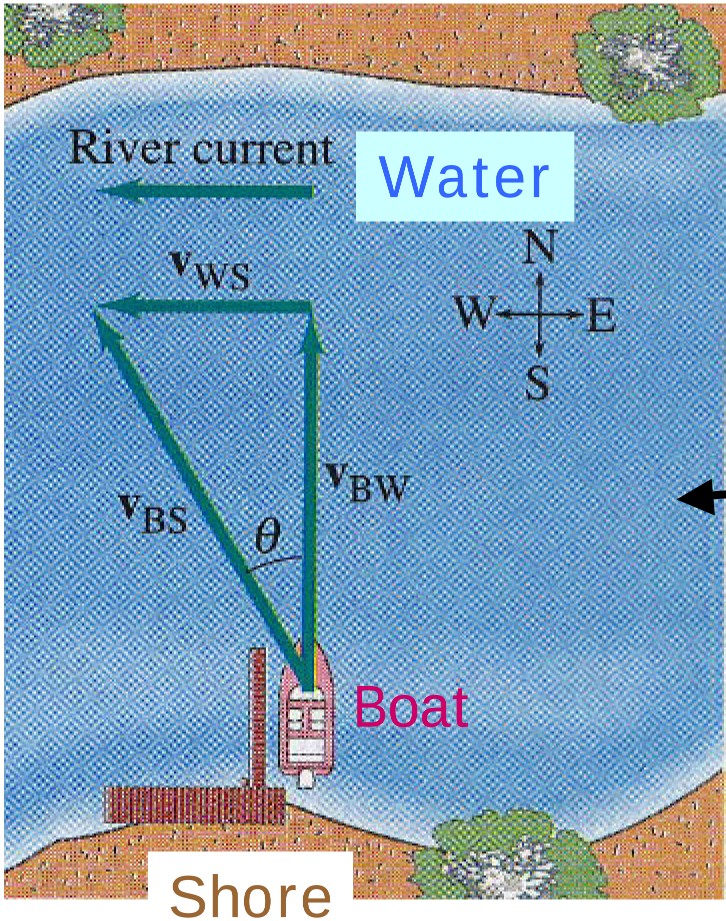
$$\vec{V}_{PA} = \vec{V}_{PB} + \vec{V}_{BA}$$

Intuitive concept:
Similar to 1D, but
requires more thought!



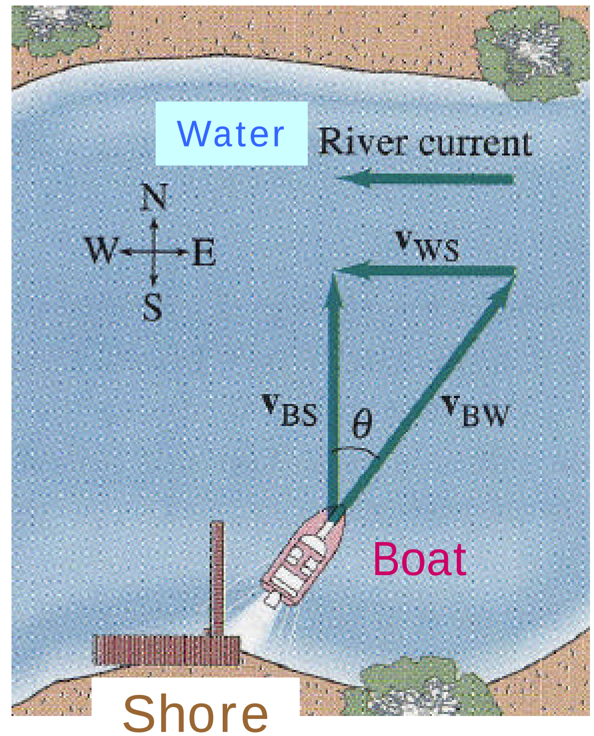
juggler-rel motion 2D.MOV

Simple Application



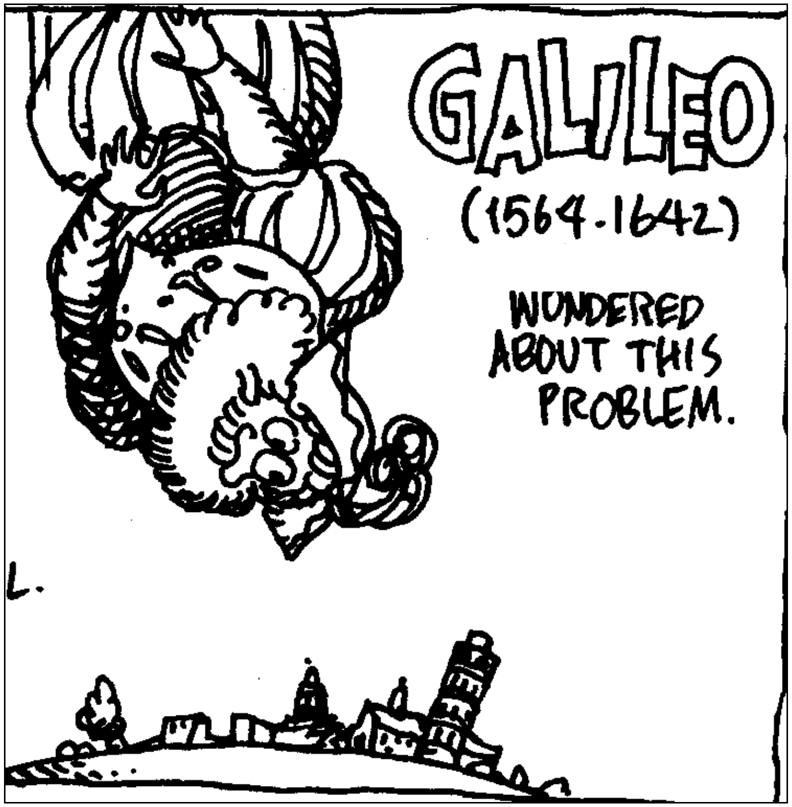
$$\vec{V}_{BS} = \vec{V}_{BW} + \vec{V}_{WS}$$

Heading North, relative to Water, makes boat move northwest



In order to head north relative to shore, boat must head northeast relative to shore

Review: Real World Motion (on Earth)



GOT IT RIGHT!

If all other forces (friction, air drag, …) are small and can be neglected, then

- **horizontal motion has zero acceleration**
- **vertical motion has a universal value of acceleration:**

$a=g=9.8\ m/s^2 = 32\ ft/s^2$ DOWN!

But Newton made the REALLY BIG STEP

Galileo Galilei

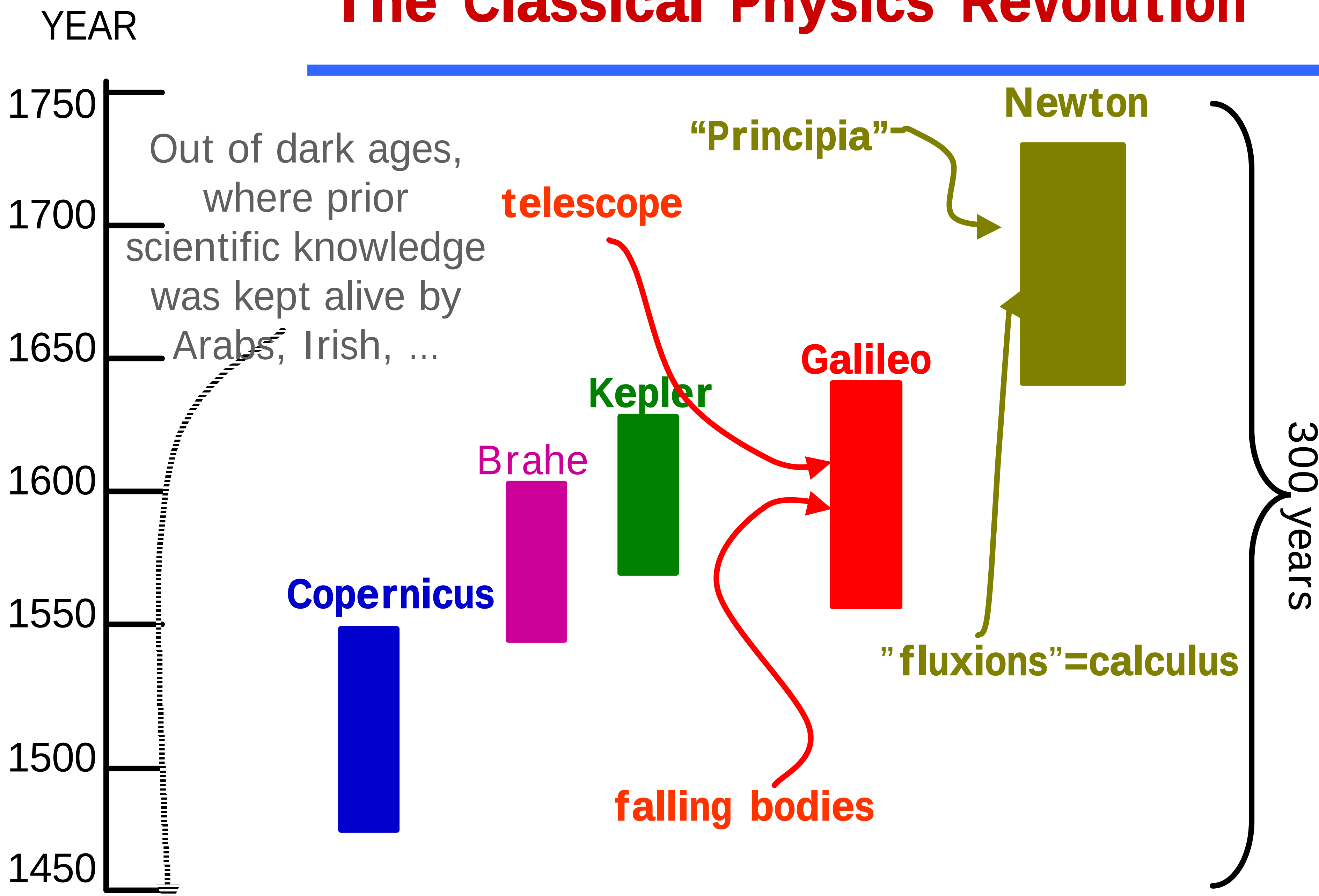
Sir Isaac Newton

- <u>Newton's Three Laws</u> (plus Gravitation) described (explained?) Galileo's discoveries from a more fundamental point of view
- But ALSO "explained" the mathematical description of the solar system built on
  - Copernicus
  - Tycho Brahe
  - Kepler
  - Galileo

We return to this later

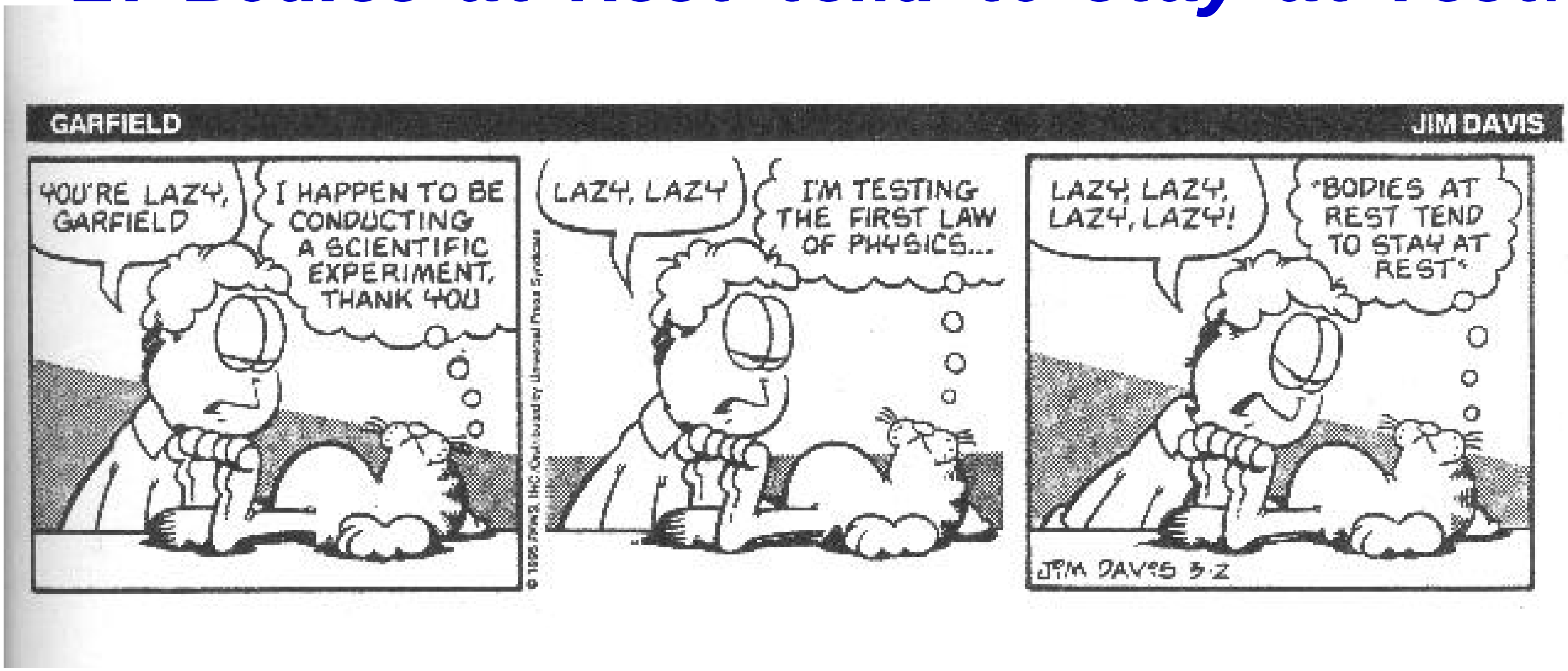
(we need to wait until Chapter 13!)

The Classical Physics Revolution



First Law

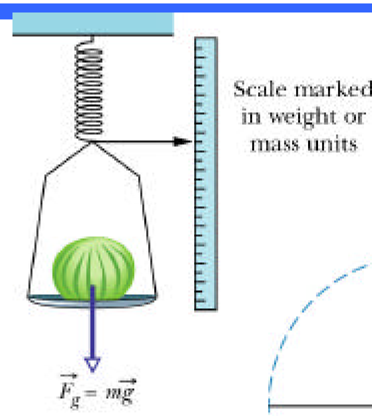
1. Bodies at Rest tend to stay at rest!



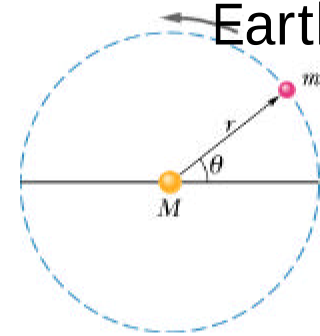
Not complete as above! Stays at constant velocity unless acted on by outside force!

A few illustrative forces

- **Fundamental Force**
  - **Gravity (see approximate version now; Newton's more basic version later – weight on Earth and more!)**



Sun and Earth



- **Familiar (but not fundamental)**
  - **Spring forces – will be more important than you think!**
  - **Contact forces between two surfaces:**
    - **Normal force**
    - **Friction force**
  - **Tension force exerted by string, cable, support column, …**

Fundamental explanation is in the interatomic forces between macroscopic pieces of matter <u>in contact!</u>

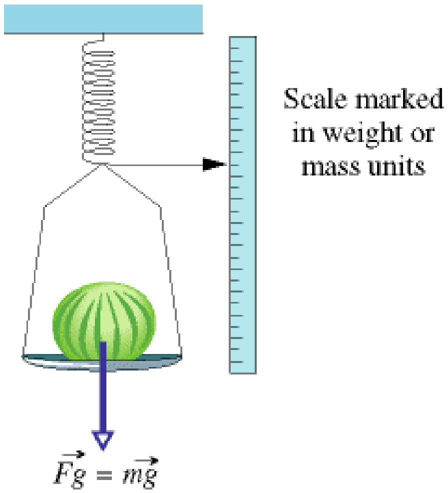
General Properties

- **Units** Int'l System English
  - Acceleration: m/s^2 and ft/sec^2
  - Mass: kilograms (1000 grams) and slugs …
  - Force: Newtons ………………………..and pounds (lbs)

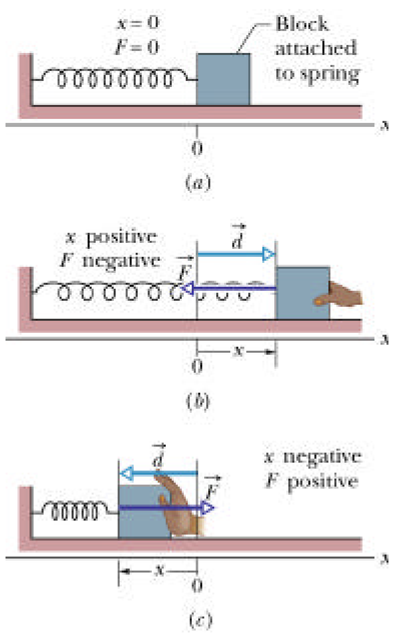
$$\vec{F} = m\vec{a}$$

- **Properties of Force**
  - Vector
    - Since mass is scalar property intrinsic to a body
    - Acceleration is a vector
  - Typically, there are many forces on a body
  - If the vector sum of all forces is zero, body does not accelerate
  - And *vice versa*

Illustrative Forces 1



- WEIGHT (gravitational force)
- Gravity pulls everything down, but is resisted by any contact with a surface
- If we let it go: *a=g , so it follows that the grav force must be F_g=mg*



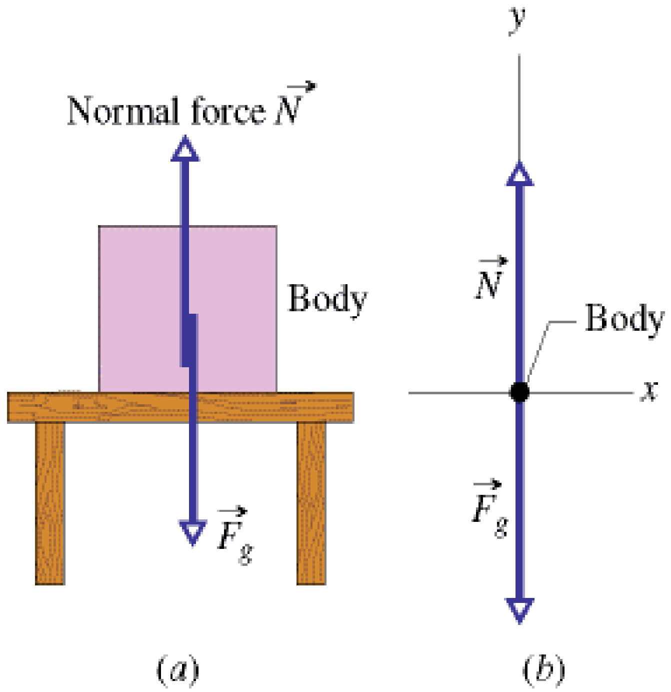
- **Spring Force:** force produced by spring (or flexible material) opposing extension or compression

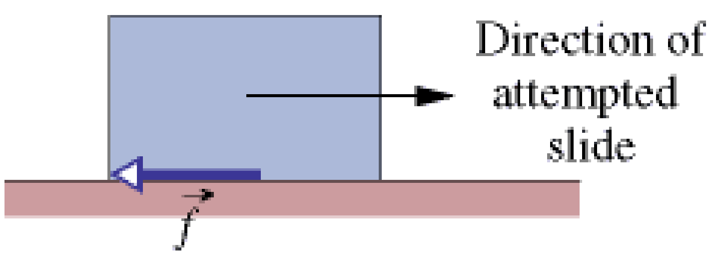
$$F_x = -kx$$

Illustrative Forces 2

- **Normal Force:** acts perpendicular to solid surfaces
  - prevents solid bodies from penetrating other solid bodies

If body is at rest, then $N = F_g = mg$



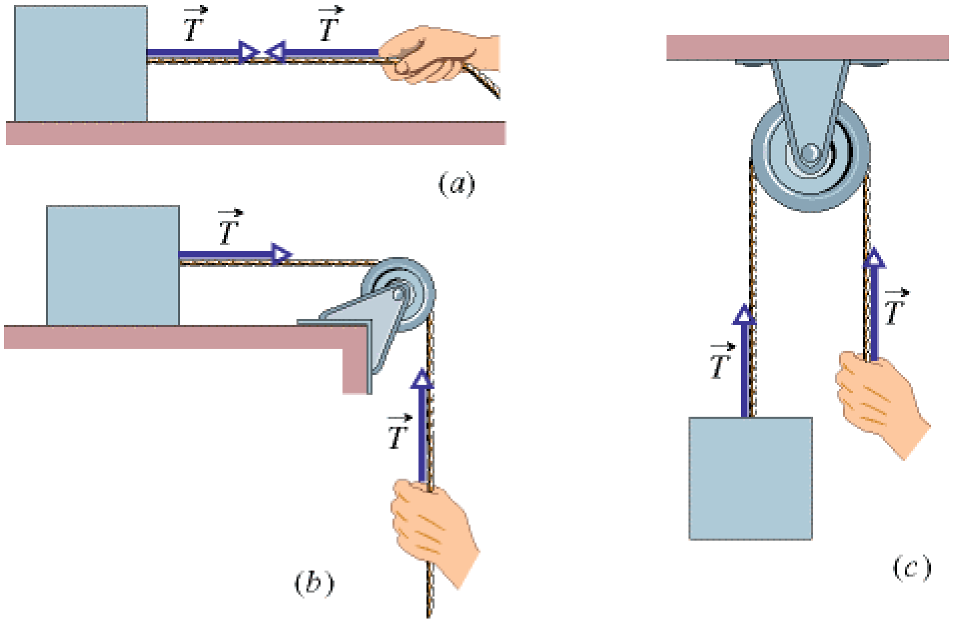


FRICTION

- **Friction**: HORIZONTAL force exerted by one surface on another
  - **varies with type of surface …there are even *frictionless* surfaces**
  - **can be static or kinetic**
  - **STAY TUNED!**

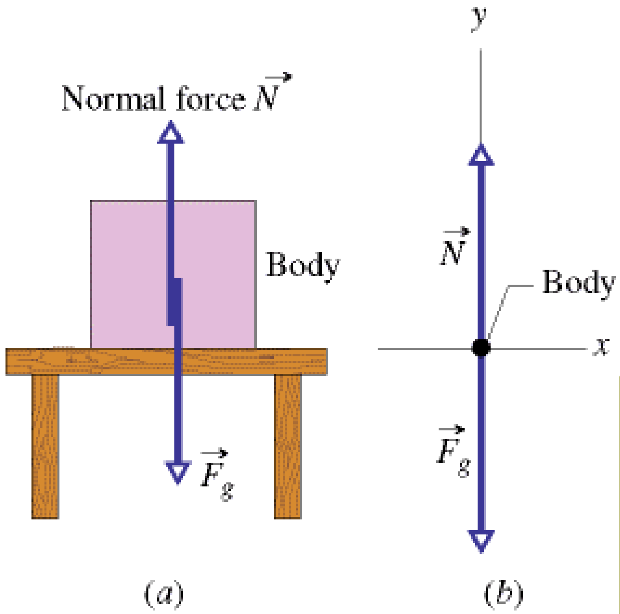
Illustrative Forces 3

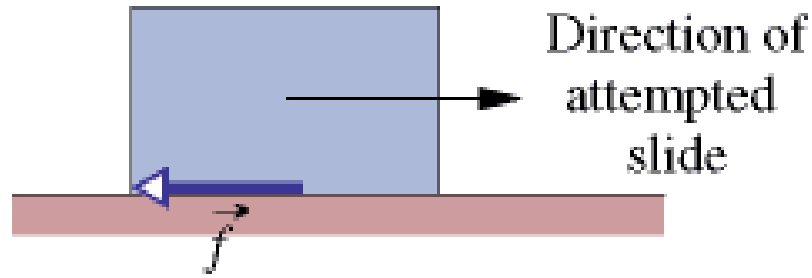
TENSION



- **Tension**: Force exerted by string, rope, cable, etc.
  - **typically the force is exerted by the cord on the body to which it is attached**
  - **the same force, in both directions, exists at all points in the cord**

Action and Reaction

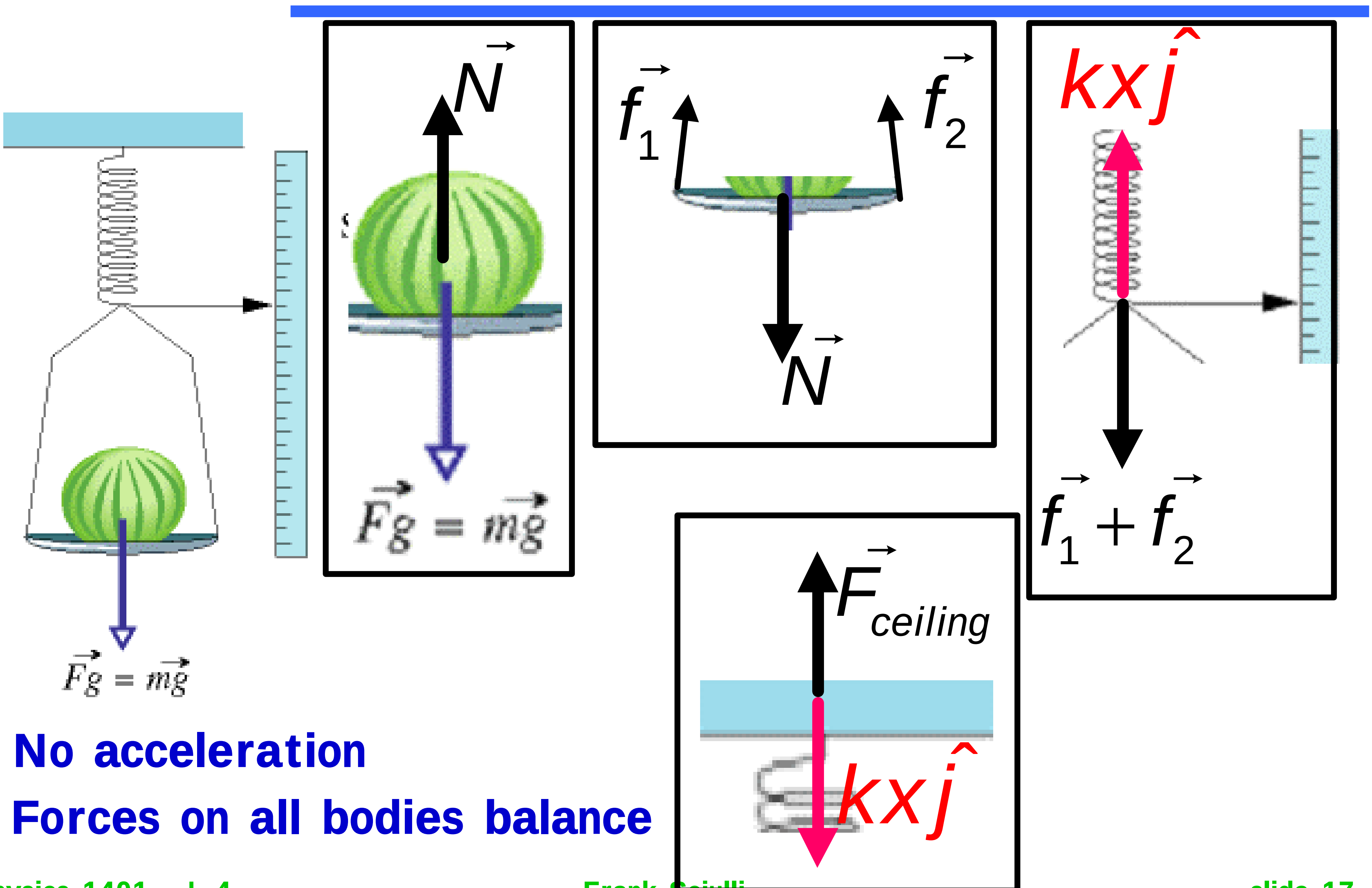




- Shown are forces on the BODY!
- What are the forces on the TABLE?

- Read and work through all the sample problems!
- We will do a few.

Scale: Forces on the isolated pieces



No acceleration

Forces on all bodies balance

Recommendations
Ch 5 & 6

- Read and understand the text.
- Read the questions posed in the sample problems. Try to do them yourself first, but understand them all.
- Check that you understand the "Review and Summary" on page 90 and 110.
- Do the assigned homework problems.
- Make sure you know how to do others.