PHYS 1441 – Section 002
Lecture #18

Wednesday, Nov. 17, 2010

Dr. Jaehoon Yu

- Center of Mass
- Velocity of the Center of Mass
- Fundamentals of Rotational Motion
- Equations of Rotational Kinematics
- Relationship Between Angular and Linear Quantities

Announcements

- Two colloquia this week
  - One at 4pm Wednesday, Nov. 17
  - Another at 4pm Friday, Nov. 19

Physics Department
The University of Texas at Arlington
COLLOQUIUM

Mechanically Strong Lightweight Aerogels

Dr. Hongbing Lu
Department of Mechanical Engineering/ UT Dallas

4:00p.m Wednesday November 17, 2010
At SH Rm 101

Abstract:

Monolithic, low-density (down to 1.0 mg/cm3, less than dry air density) 3-D assemblies of nanoparticles (e.g. silica), known as aerogels, are characterized by large specific surface areas and high porosity; they demonstrate low thermal conductivity, low dielectric constants and high acoustic impedance. Traditional aerogels, however, are extremely hygroscopic and fragile materials, limiting their applications to a few specialized environments, such as the materials for capture of hypervelocity particles in space (NASA's Stardust Program) and as integrated structural and thermal insulation materials for electronic boxes aboard planetary vehicles (the Mars Rovers in 1997 and 2004).

The aerogel fragility problem is traced to the weak points in aerogels' framework, the necks connecting neighboring spherical secondary nanoparticles. This problem has been resolved successfully by Leventis (see, for example, Leventis, Acc. Chem. Res. 2007, 40, 874-884) using polymer nanoencapsulation of the skeletal network of inorganic nanoparticles to bridge the nanoparticles and stiffen all the necks. The resulting polymer cross-linked aerogels may combine a high specific compressive strength with the thermal conductivity of Styrofoam.

In collaboration with Leventis we have carried out experiments to characterize the physical, chemical and mechanical properties of this new class of aerogels using a range of techniques including SEM, TEM, SANS. Digital image correlation was used to measure surface deformations. X-ray computed tomography was used to determine the structures for simulations. Material point method (MPM) was used to simulate the deformations to determine the structure-property relationship. Results indicate that both polymer nanoencapsulated aerogels and purely organic aerogels have superior mechanical properties, with the specific energy absorption reaching 192 J/g. The simulation results demonstrate the capability of the MPM in simulations of porous nanostructured materials under compression, experiencing elastic, compaction and densification stages. The work indicates a paradigm in the design of porous nanostructured materials, comprising three degrees of freedom, namely the chemical identity of the nanoparticles, the crosslinking polymer and the nanostructure morphology. Currently technology is evaluated for applications as lightweight multifunctional materials with high-specific strength combined with acoustic attenuation, artificial heart valve leaflets, energetic materials and energy-absorption materials for ballistic impact.

Refreshments will be served in the Physics Lounge at 3:30 pm

Physics Department
The University of Texas at Arlington
COLLOQUIUM

Magnetocalorie Effect in Mn & Fe based Materials

Dr. Ekkes Bruck

Fundamental Aspects of Materials and Energy,
Faculty of Applied Sciences, TU Delft, Mekelweg 15,
2629 JB Delft, the Netherlands

4:00p.m Friday November 19, 2010
At SH Rm 101

Abstract:

Modern society relies on readily available refrigeration. Magnetic refrigeration has three prominent advantages compared to compressor-based refrigeration. First there are no harmful gasses involved, second it may be built more compact as the working material is a solid and third magnetic refrigerators generate much less noise [1].

Recently a new class of magnetic refrigerant-materials for room-temperature applications was discovered [2, 3]. These new materials have important advantages over existing magnetic coolants: They exhibit a large magnetocaloric effect (MCE) in conjunction with a magnetic phase-transition of first order. This MCE is, larger than that of Gd metal, which is used in most demonstration refrigerators built to explore the potential of this evolving technology. Especially, materials based on transition elements like manganese and iron appear to be promising for industrial applications. However, if the first order phase-transition is accompanied by large thermal hysteresis, simple refrigeration cycles can not be employed. Also the determination of the MCE for these materials with large hysteresis appears not to be straightforward. For optimal performance of the magnetocaloric devices also the thermal conductivity and the response to mechanical stress need to be tested. We discuss how one may tailor materials to meet the requirements for large MCE in combination with other favorable properties.

As the Curie temperature of transition-metal compounds can easily exceed room temperature it becomes feasible to use them also in power conversion applications. A promising field is the conversion of waste heat to electric power with devices without moving parts.

Reminder: Extra-Credit Special Project

- Derive the formula for the final velocity of two objects which underwent an elastic collision as a function of known quantities m_1, m_2, v_{01} and v_{02} in page 12 of this lecture note in a far greater detail than the note.
  - 20 points extra credit
- Show mathematically what happens to the final velocities if $m_1=m_2$ and describe in words the resulting motion.
  - 5 point extra credit
- Due: Start of the class Monday, Nov. 29

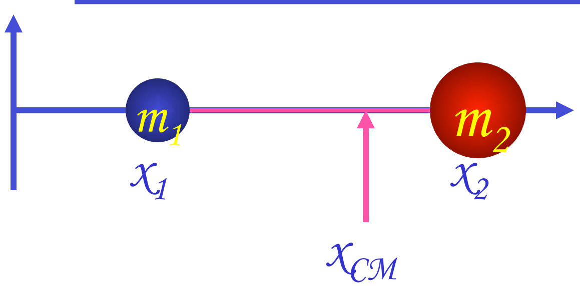
Center of Mass

We've been solving physical problems treating objects as sizeless points with masses, but in realistic situations objects have shapes with masses distributed throughout the body.

Center of mass of a system is the average position of the system's mass and represents the motion of the system as if all the mass is on that point.

What does above statement tell you concerning the forces being exerted on the system?

The total external force exerted on the system of total mass M causes the center of mass to move at an acceleration given by $\vec{a} = \sum \vec{F} / M$ *as if the entire mass of the system is on the center of mass.*



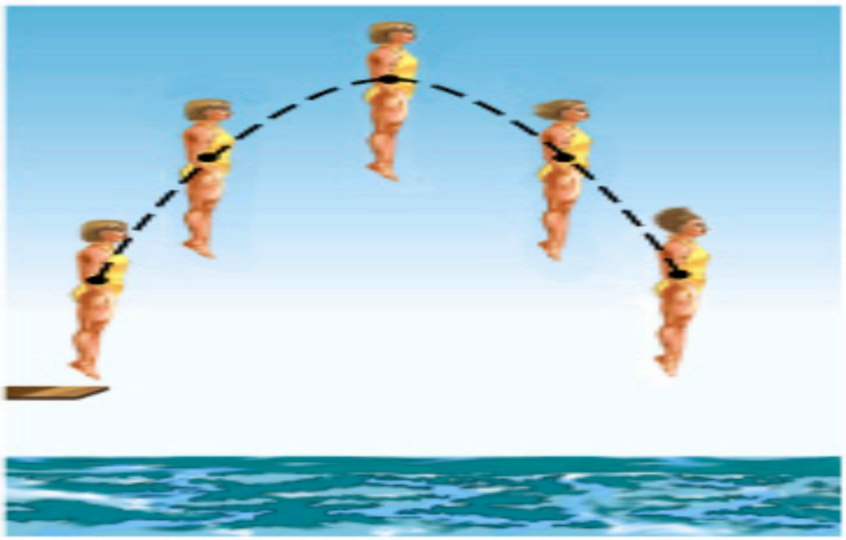
Consider a massless rod with two balls attached at either end.

The position of the center of mass of this system is the mass averaged position of the system

$$x_{CM} \equiv \frac{m_1 x_1 + m_2 x_2}{m_1 + m_2}$$

CM is closer to the heavier object

Motion of a Diver and the Center of Mass


(a)


(b)

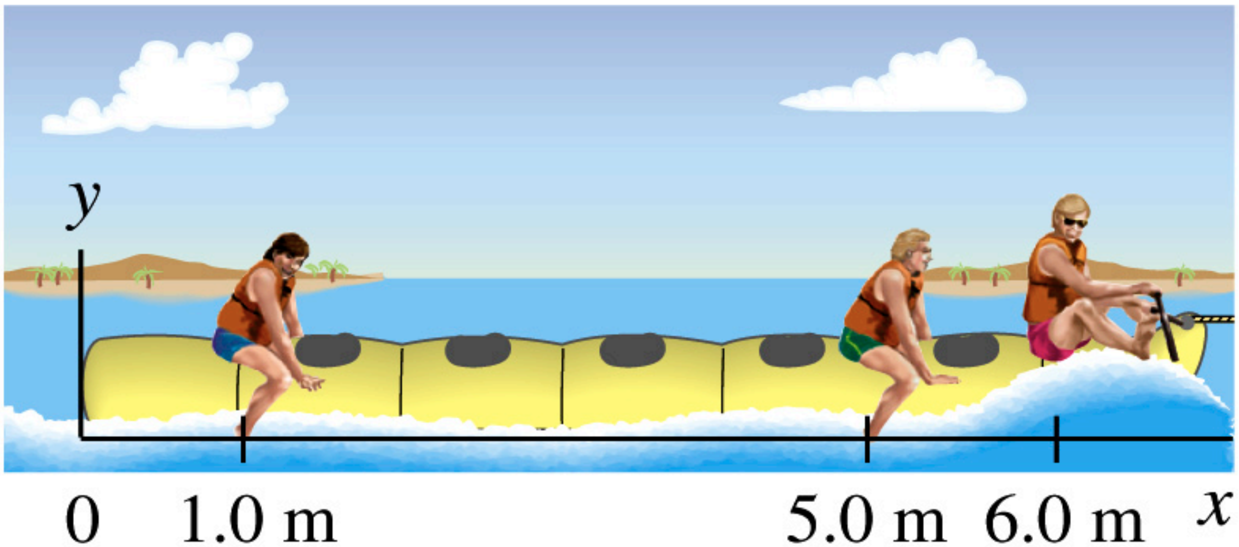
Diver performs a simple dive.
The motion of the center of mass follows a parabola since it is a projectile motion.

The motion of the center of mass of the diver is always the same.

Diver performs a complicated dive.
The motion of the center of mass still follows the same parabola since it still is a projectile motion.

Ex. 7 – 12 Center of Mass

Thee people of roughly equivalent mass M on a lightweight (air-filled) banana boat sit along the x axis at positions x_1=1.0m, x_2=5.0m, and x_3=6.0m. Find the position of CM.

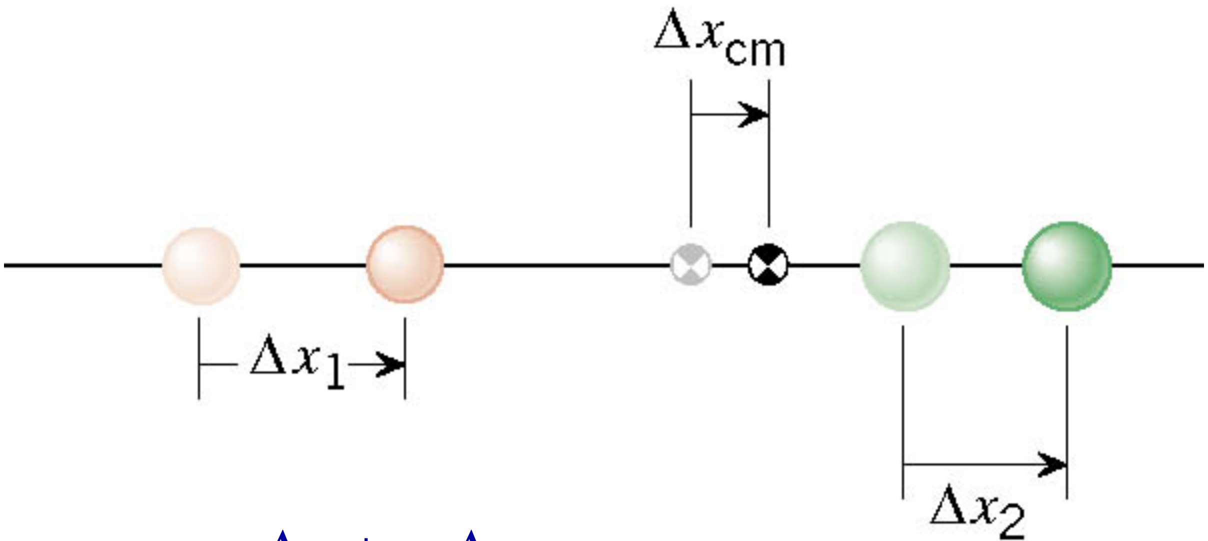


Using the formula for CM

$$x_{CM} = \frac{\sum_i m_i x_i}{\sum_i m_i}$$

$$= \frac{M \cdot 1.0 + M \cdot 5.0 + M \cdot 6.0}{M + M + M} = \frac{12.0M}{3M} = 4.0(m)$$

Velocity of the Center of Mass



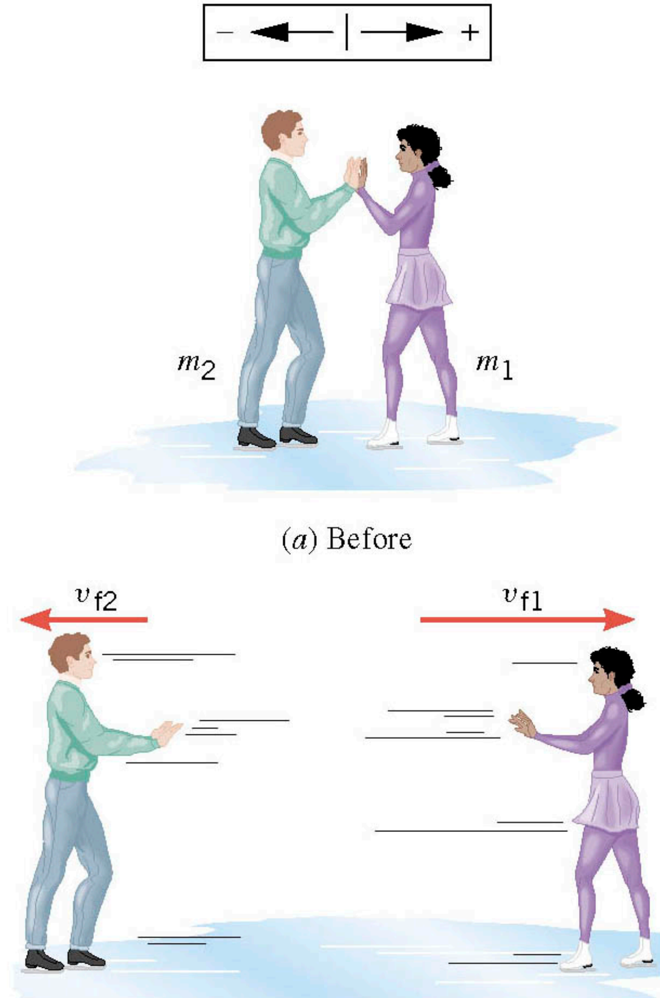
$$\Delta x_{cm} = \frac{m_1 \Delta x_1 + m_2 \Delta x_2}{m_1 + m_2}$$

$$\Rightarrow v_{cm} = \frac{\Delta x_{cm}}{\Delta t} = \frac{m_1 \Delta x_1 / \Delta t + m_2 \Delta x_2 / \Delta t}{m_1 + m_2} = \frac{m_1 v_1 + m_2 v_2}{m_1 + m_2}$$

In an isolated system, the total linear momentum does not change, therefore the velocity of the center of mass does not change.

Another Look at the Ice Skater Problem

Starting from rest, two skaters push off against each other on ice where friction is negligible. One is a 54-kg woman and one is a 88-kg man. The woman moves away with a velocity of +2.5 m/s. What is the velocity of the center of mass of this system?



(a) Before

(b) After

$$v_{10} = 0\,m/s \qquad v_{20} = 0\,m/s$$

$$v_{cm0} = \frac{m_1 v_1 + m_2 v_2}{m_1 + m_2} = 0$$

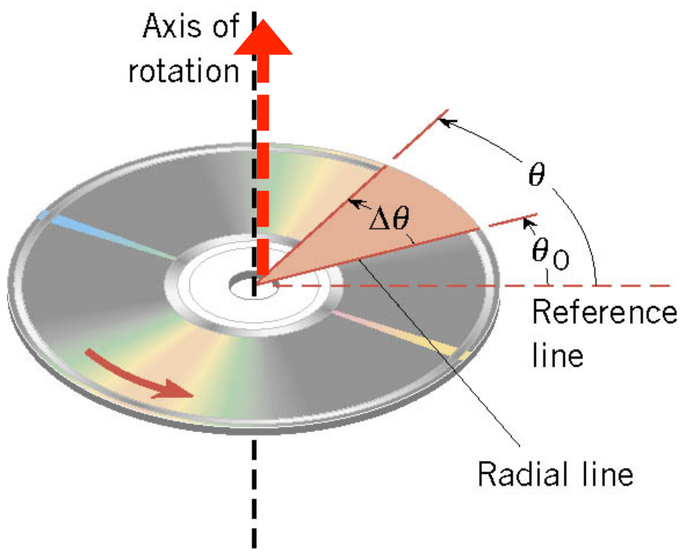
$$v_{1f} = +2.5\,m/s \qquad v_{2f} = -1.5\,m/s$$

$$v_{cmf} = \frac{m_1 v_{1f} + m_2 v_{2f}}{m_1 + m_2}$$

$$= \frac{54 \cdot (+2.5) + 88 \cdot (-1.5)}{54 + 88} = \frac{3}{142} = 0.02 \approx 0\,m/s$$

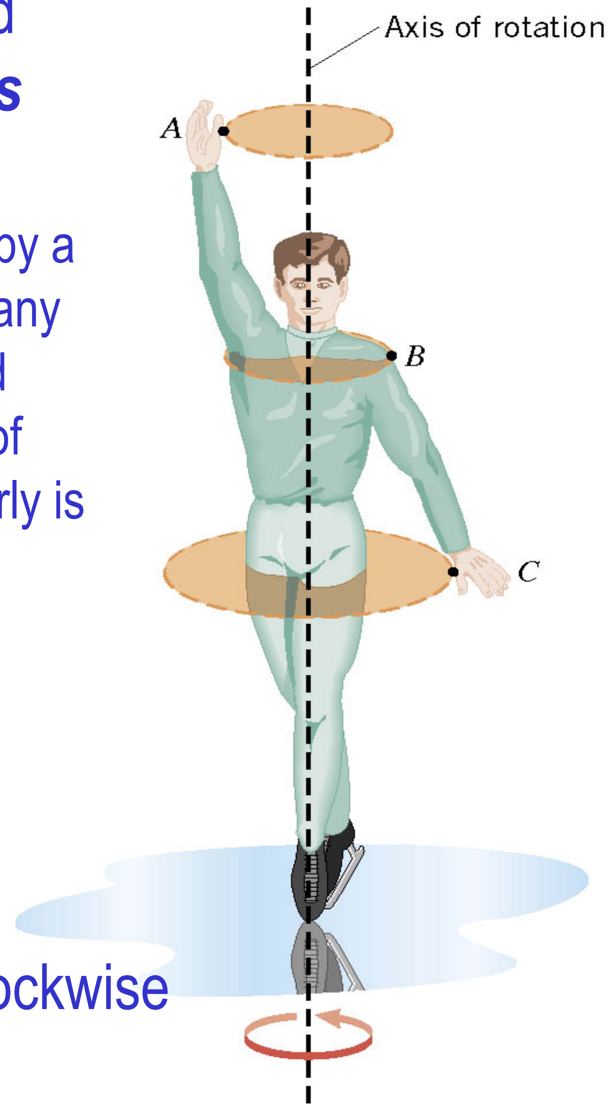
Rotational Motion and Angular Displacement

In a simplest kind of rotation, points on a rigid object moves on circular paths about the ***axis of rotation.***



The angle swept out by a line passing through any point on the body and intersecting the axis of rotation perpendicularly is called the ***angular displacement.***

$$\Delta\theta = \theta - \theta_o$$



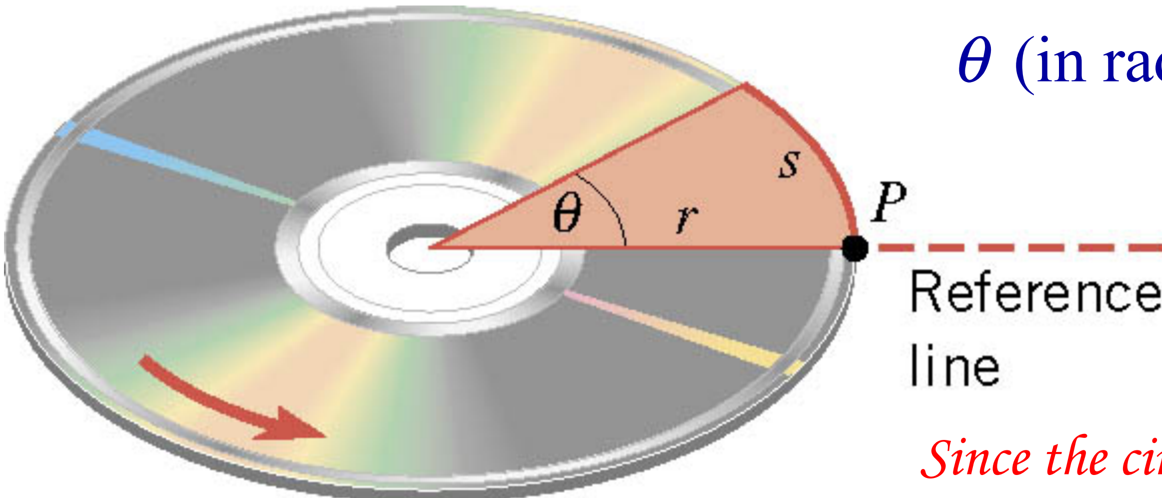
It's a vector!! So there must be directions…

How do we define directions? +:if counter-clockwise

-:if clockwise

The direction vector points gets determined based on the right-hand rule. These are just conventions!!

SI Unit of the Angular Displacement



$$\theta \text{ (in radians)} = \frac{\text{Arc length}}{\text{Radius}} = \frac{s}{r}$$

Dimension? None

For one full revolution:

Since the circumference of a circle is $2\pi r$

$$\theta = \frac{2\pi r}{r} = 2\pi \text{ rad} \rightarrow 2\pi \text{ rad} = 360^\circ$$

How many degrees is in one radian?

1 radian is $1 \text{ rad} = \frac{360^\circ}{2\pi} \cdot 1rad = \frac{180^\circ}{\pi} \cdot 1rad \cong \frac{180^\circ}{3.14} \cdot 1rad \cong 57.3^\circ$

How radians is one degree?

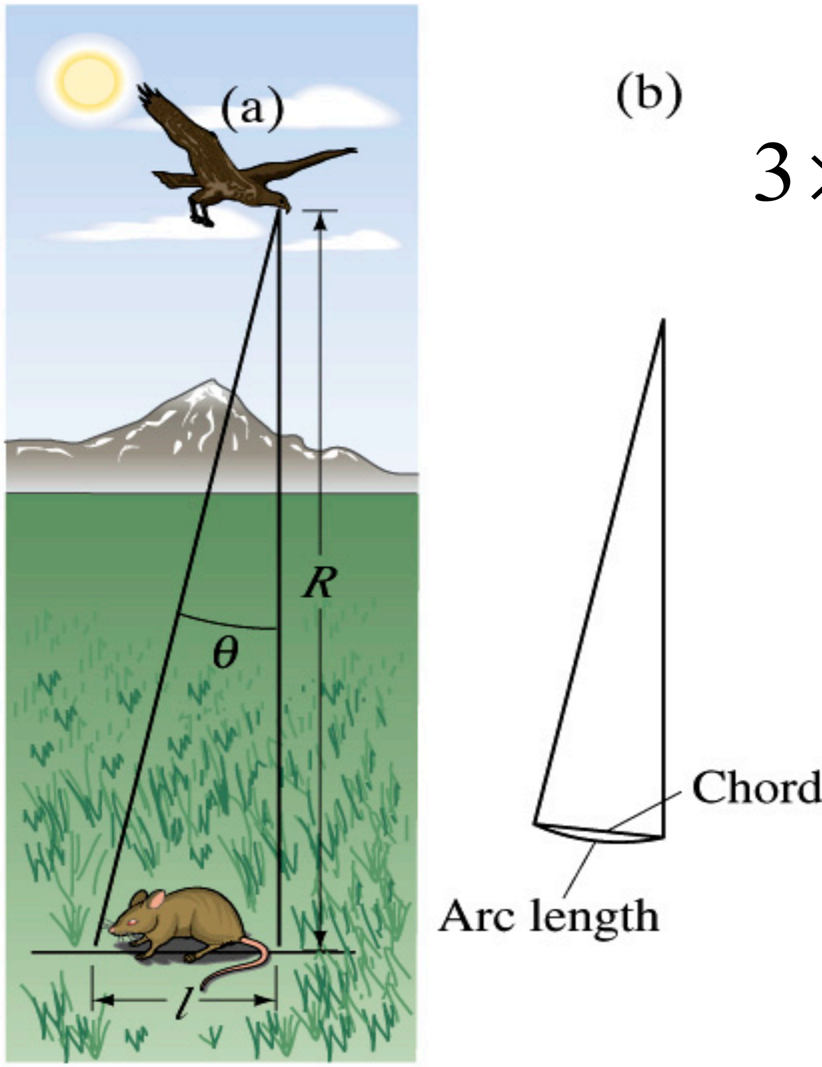
And one degrees is $1^\circ = \frac{2\pi}{360^\circ} \cdot 1^\circ = \frac{\pi}{180^\circ} \cdot 1^\circ \cong \frac{3.14}{180^\circ} \cdot 1^\circ \cong 0.0175rad$

How many radians are in 10.5 revolutions? $10.5rev = 10.5rev \cdot 2\pi \frac{rad}{rev} = 21\pi\,(rad)$

Very important: In solving angular problems, all units, degrees or revolutions, must be converted to radians.

Example 8 – 1

A particular bird's eyes can barely distinguish objects that subtend an angle no smaller than about 3×10^{-4} rad. (a) How many degrees is this? (b) How small an object can the bird just distinguish when flying at a height of 100m?



(a) One radian is 360°/2π. Thus

$$3 \times 10^{-4} rad = \left(3 \times 10^{-4} rad\right) \times \left(360^\circ / 2\pi\, rad\right) = 0.017^\circ$$

(b) Since l=rΘ and for small angle arc length is approximately the same as the chord length.

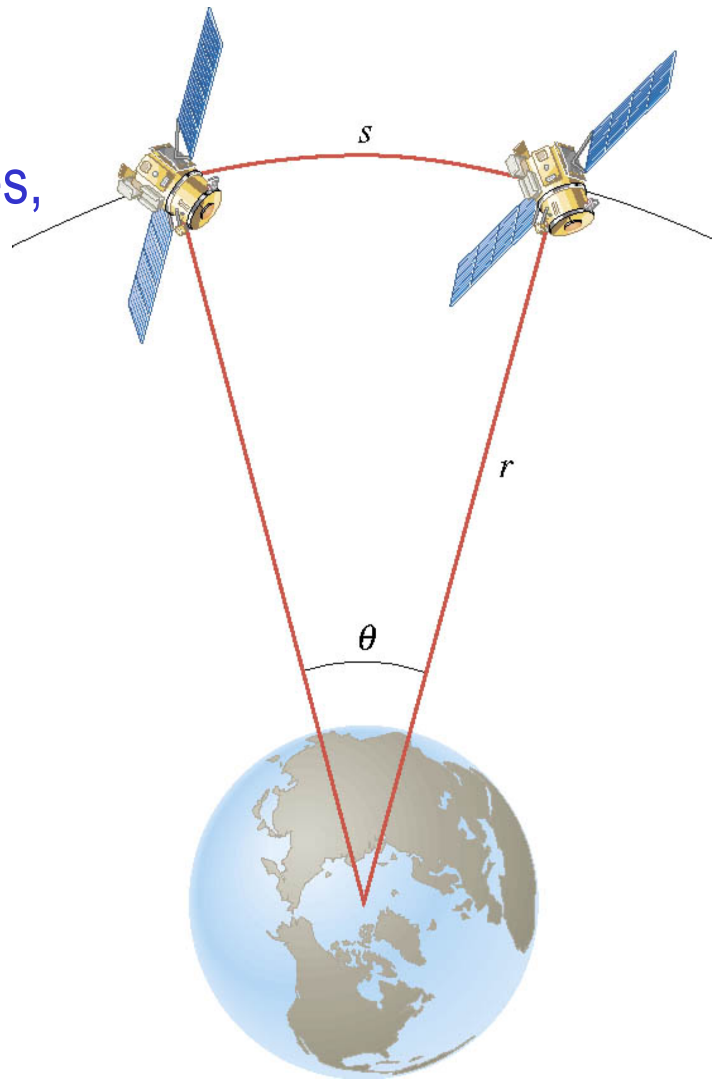
$$l = r\theta =$$

$$100m \times 3 \times 10^{-4} rad =$$

$$3 \times 10^{-2} m = 3cm$$

Ex. Adjacent Synchronous Satellites

Synchronous satellites are put into an orbit whose radius is 4.23×10^7m. If the angular separation of the two satellites is 2.00 degrees, find the arc length that separates them.



What do we need to find out? The Arc length!!!

$$\theta \text{ (in radians)} = \frac{\text{Arc length}}{\text{Radius}} = \frac{s}{r}$$

Convert degrees to radians

$$2.00\,\text{deg}\left(\frac{2\pi \text{ rad}}{360\,\text{deg}}\right) = 0.0349 \text{ rad}$$

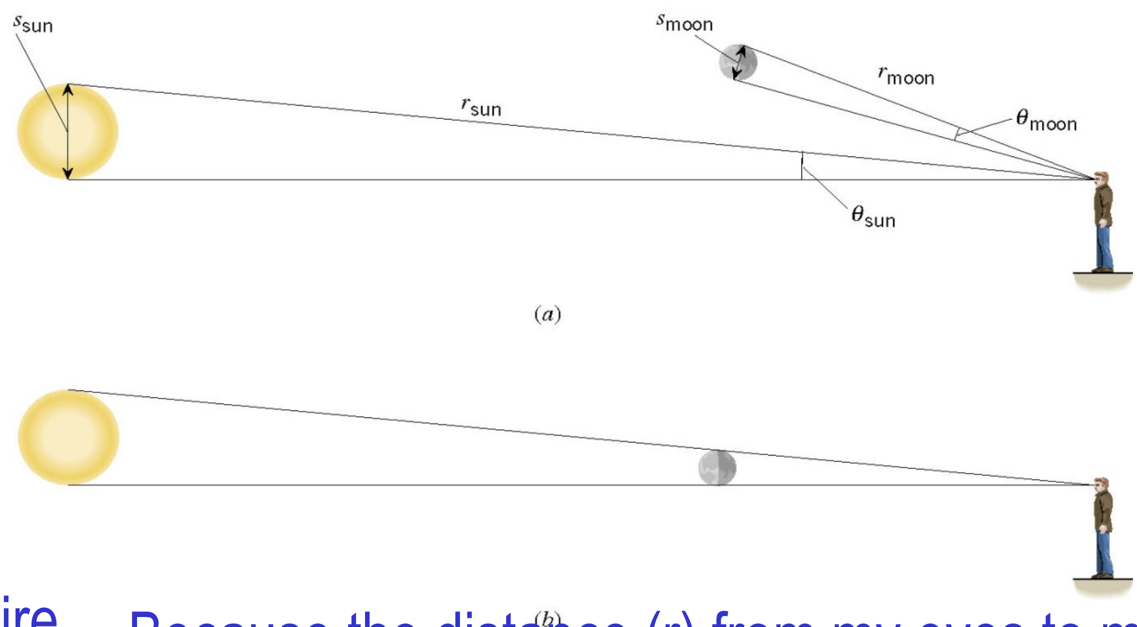
$$s = r\theta = \left(4.23\times10^7\,\text{m}\right)\left(0.0349 \text{ rad}\right)$$

$$= 1.48\times10^6\,\text{m} \;\; \text{(920 miles)}$$

Ex. A Total Eclipse of the Sun

The diameter of the sun is about 400 times greater than that of the moon. By coincidence, the sun is also about 400 times farther from the earth than is the moon. For an observer on the earth, compare the angle subtended by the moon to the angle subtended by the sun and explain why this result leads to a total solar eclipse.

$$\theta \text{ (in radians)} = \frac{\text{Arc length}}{\text{Radius}} = \frac{s}{r}$$



I can even cover the entire sun with my thumb!! Why?

Because the distance (r) from my eyes to my thumb is far shorter than that to the sun.