Welcome back to Physics 215

Today's agenda:

- *Angular momentum*
- *Rolling without slipping*

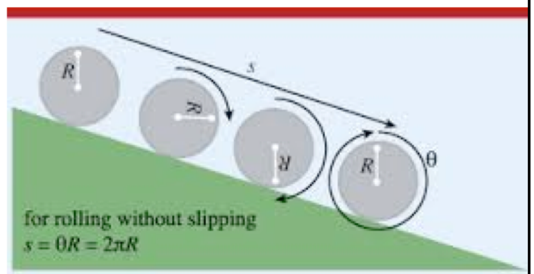


Figure 1. The conditions for pure rolling.

Linear and rotational motion

- Force
- Acceleration

$$\vec{F}_{\text{net}} = \sum \vec{F} = m\vec{a}$$

- Momentum

$$\vec{p} = m\vec{v}$$

- Kinetic energy

$$K = \tfrac{1}{2}mv^2$$

- Torque
- Angular acceleration

$$\vec{\tau}_{\text{net}} = \sum \vec{\tau} = I\vec{\alpha}$$

- Angular momentum**

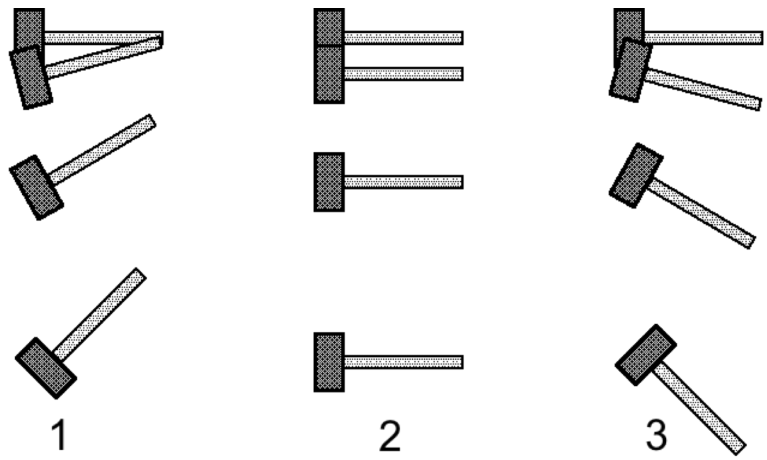
$$\vec{L} = I\vec{\omega}$$

- Kinetic energy

$$K = \tfrac{1}{2}I\omega^2$$

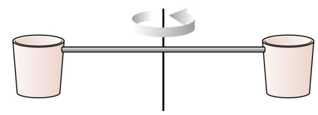
**** about a fixed axle or axis of symmetry**

SG A hammer is held horizontally and then released. Which way will it fall?



Falling bodies rotate about their center of mass!

SG Two buckets spin around in a horizontal circle on frictionless bearings. Suddenly, it starts to rain. As a result,



A. The buckets speed up because the potential energy of the rain is transformed into kinetic energy.
B. The buckets continue to rotate at constant angular velocity because the rain is falling vertically while the buckets move in a horizontal plane.
C. The buckets slow down because the angular momentum of the bucket + rain system is conserved.
D. The buckets continue to rotate at constant angular velocity because the total mechanical energy of the bucket + rain system is conserved.
E. None of the above.

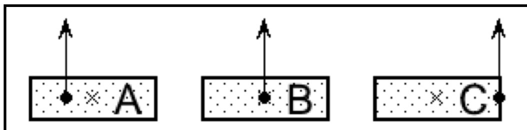
General motion of extended objects

- Net force ➔ acceleration of CM
- Net torque about CM ➔ angular acceleration (rotation) about CM
- Resultant motion is superposition of these two motions
- Total kinetic energy $K = K_{CM} + K_{rot}$

SG Three identical rectangular blocks are at rest on a flat, frictionless table. The same force is exerted on each of the three blocks for a very short time interval. The force is exerted at a different point on each block, as shown.

After the force has stopped acting on each block, which block will spin the fastest?

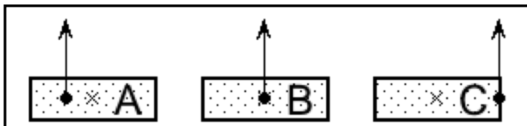
1. A.
2. B.
3. C.
4. A and C.



Top-view diagram

SG Three identical rectangular blocks are at rest on a flat, frictionless table. The same force is exerted on each of the three blocks for a very short time interval. The force is exerted at a different point on each block, as shown.

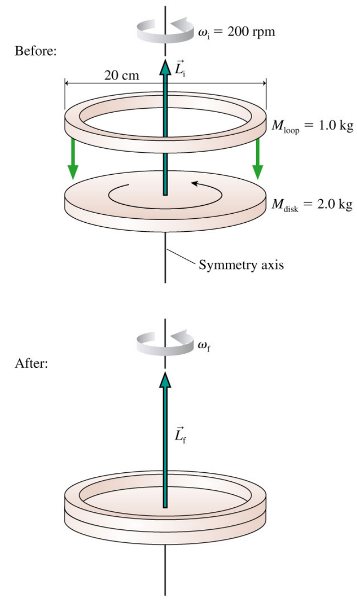
After each force has stopped acting, which block's center of mass will have the greatest speed?



Top-view diagram

1. A.
2. B.
3. C.
4. A, B, and C have the same C.O.M. speed.

A 20-cm diameter, 2.0 kg solid disk is rotating at 200 rpm. A 20-cm-diameter, 1.0 kg circular loop is dropped straight down onto the rotating disk. Friction causes the loop to accelerate until it is riding on the disk. What is the final angular velocity of the combined system?



Rolling without slipping

Δx_{cm} =

Δx_{cm} =

v_{cm} =

v_{cm} =

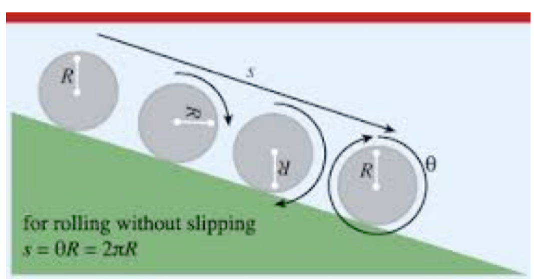
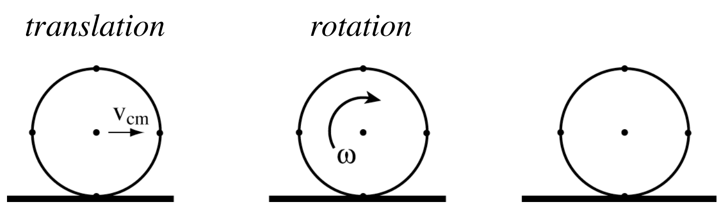


Figure 1. The conditions for pure rolling.

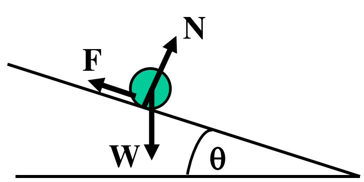
Rolling without slipping



$v_{cm} =$

$a_{cm} =$

Rolling without slipping



$\Sigma F = ma_{CM}$

$\Sigma \tau = I\alpha$

Now $a_{CM} = R\alpha$ if no slipping

So, $m a_{CM}$

and F =

Kinetic energy of rolling

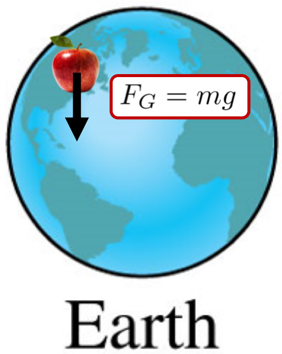
- The total kinetic energy of a rolling object is the sum of its rotational and translational kinetic energies:

SG. Two cylinders with the same radius and same total mass roll down a ramp. In cylinder A, a set of 8 point masses are equally spaced in a circle with radius r1 around the cylinder's axis of rotation, while in cylinder B, the 8 point masses are a distance r2 > r1 from the center. Which cylinder reaches the bottom of the ramp first?

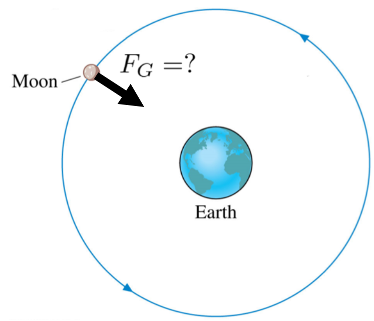
A. Cylinder A
B. Cylinder B
C. They both reach the bottom at the same time
D. Not enough information to tell

Gravity on earth

Anywhere on the surface of the earth (e.g. in Syracuse):



Still true elsewhere?



Gravity

- Before 1687, large amount of data collected on motion of planets and Moon (Copernicus, Galileo, Brahe, Kepler)
- Newton showed that this could all be understood with a new ***Law of Universal Gravitation***

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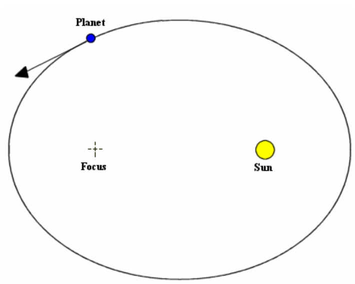
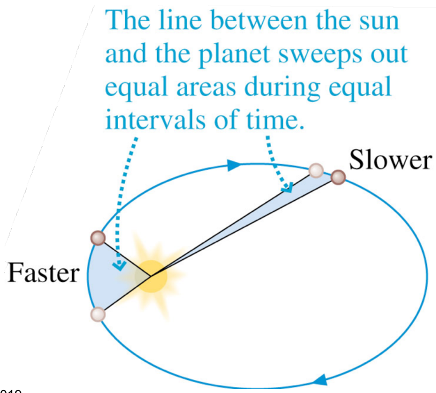
Kepler's Laws experimental observations

1. Planets move on ellipses with the sun at one focus of the ellipse (actually, CM of sun + planet at focus).



Kepler's Laws
experimental observations

2. A line from the sun to a given planet sweeps out equal areas in equal times.

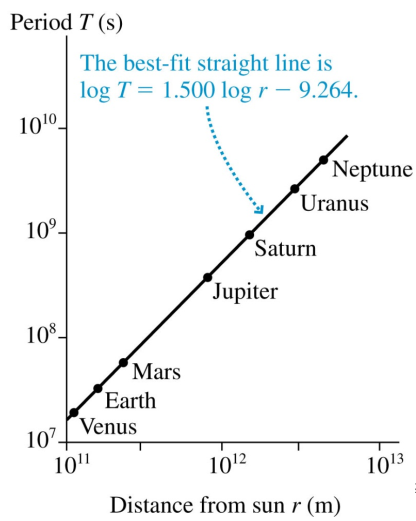


*Conservation of angular momentum

SG The following is a log-log plot of the orbital period (T) compared to the distance to the sun(r). What is the relationship between T and r?

1. Log T = C r
2. $T^2 = C r^3$
3. T = C r
4. $T^3 = C r^2$

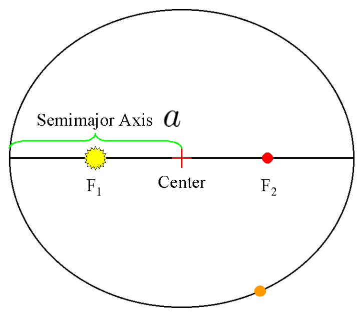
For some constant C



Kepler's Laws
experimental observations

3. Square of orbital period is proportional to cube of semimajor axis.

$$T^2 \sim a^3$$

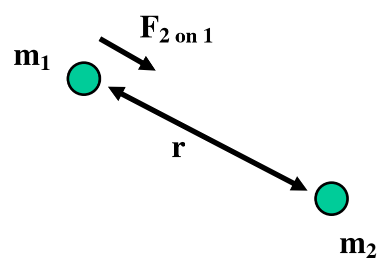


Universal Gravity

- Mathematical Principles of Natural Philosophy:

Every particle in the Universe attracts every other with a force that is directly proportional to their masses and inversely proportional to the square of the distance between them.

Inverse square law



Interpretation

- F acts along line between bodies
- $F_{12} = -F_{21}$ in accord with Newton's Third Law
- ***Acts at a distance*** (even through a vacuum) …
- G is a universal constant = 6.7×10^{-11} N·m²/kg²

How to measure G?