Phys101 Lecture 6
Circular Motion

Key points:

- **Centripetal acceleration**
- **Uniform Circular Motion - dynamics**

Ref: 5-1,2,3,5,6.

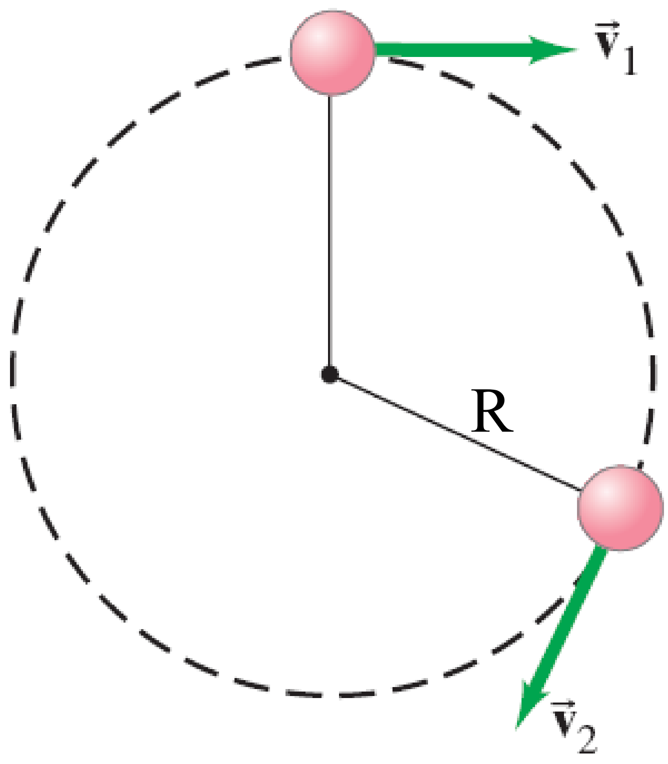
Uniform Circular Motion—Kinematics

Uniform circular motion: motion in a **circle** of constant **radius** at constant **speed**

Instantaneous velocity is always **tangent** to the circle.

The magnitudeof the velocity is constant:

$$v_1 = v_2 = v$$

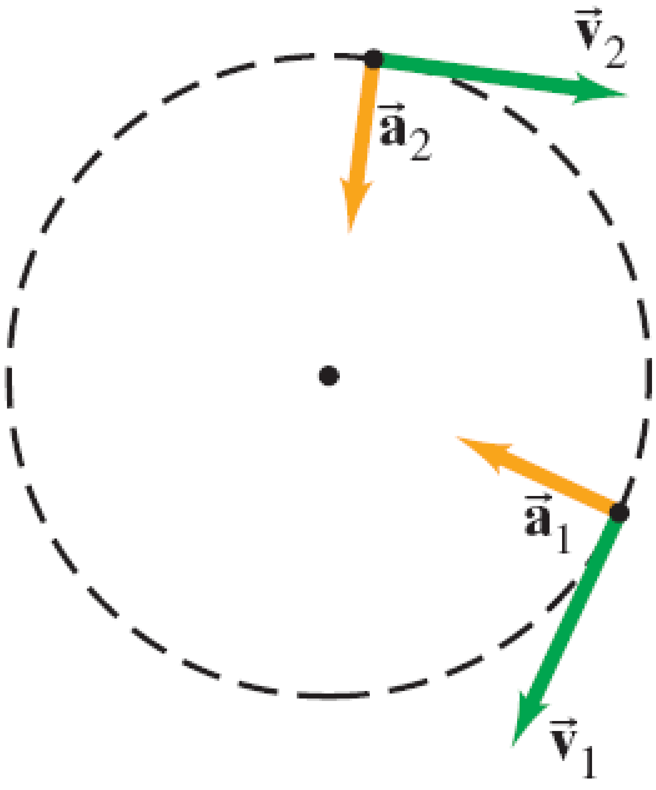


Centripetal acceleration

The acceleration, called the centripetal acceleration, points toward the center of the circle.

The magnitude of centripetal acceleration is:

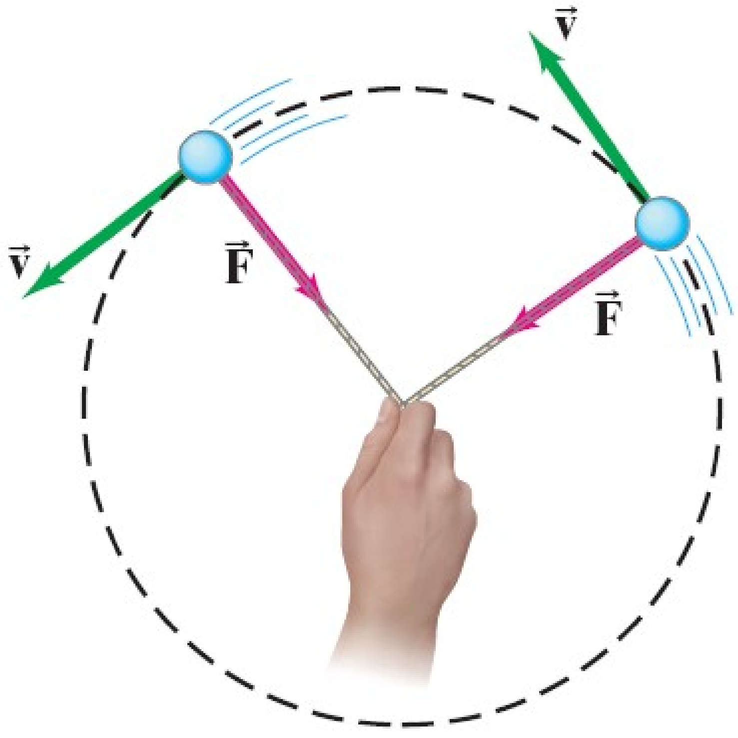
$$a_R = \frac{v^2}{R}$$



Dynamics of Uniform Circular Motion

For an object to be in uniform circular motion, Newton's 2nd law requires a net force acting on it. This net force is called centripetal force:

$$\Sigma F_R = ma_R = m\frac{v^2}{r}.$$



Physically, the centripetal force can be the tension in a string, the gravity on a satellite, the normal force of a ring, etc.

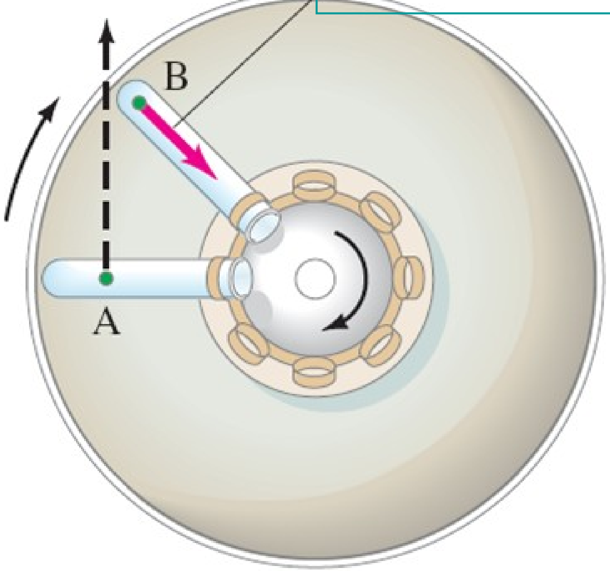
Note: Don't count the centripetal force as an additional force in the free-body-diagram! It refers to the required net force for circular motion.

Centrifuge

A centrifuge works by spinning very fast. A small object in the tube requires a large centripetal force. When the liquid can't provide such a large force, the object will move (sink) to the end of the tube.

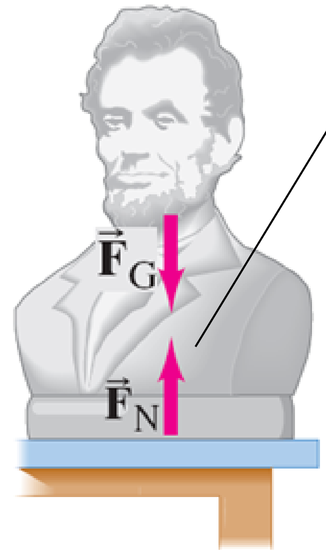
Force reuired for circular motion:

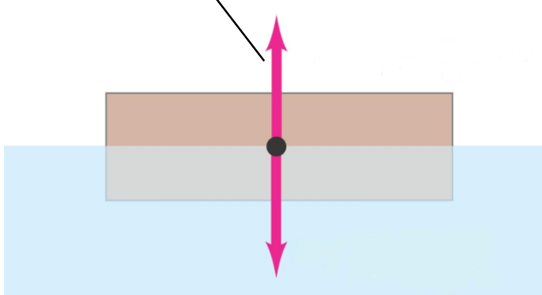
$$F_R = ma_R = \frac{mv^2}{R}$$



Force reuired for staying in position:

$$F_N = mg$$



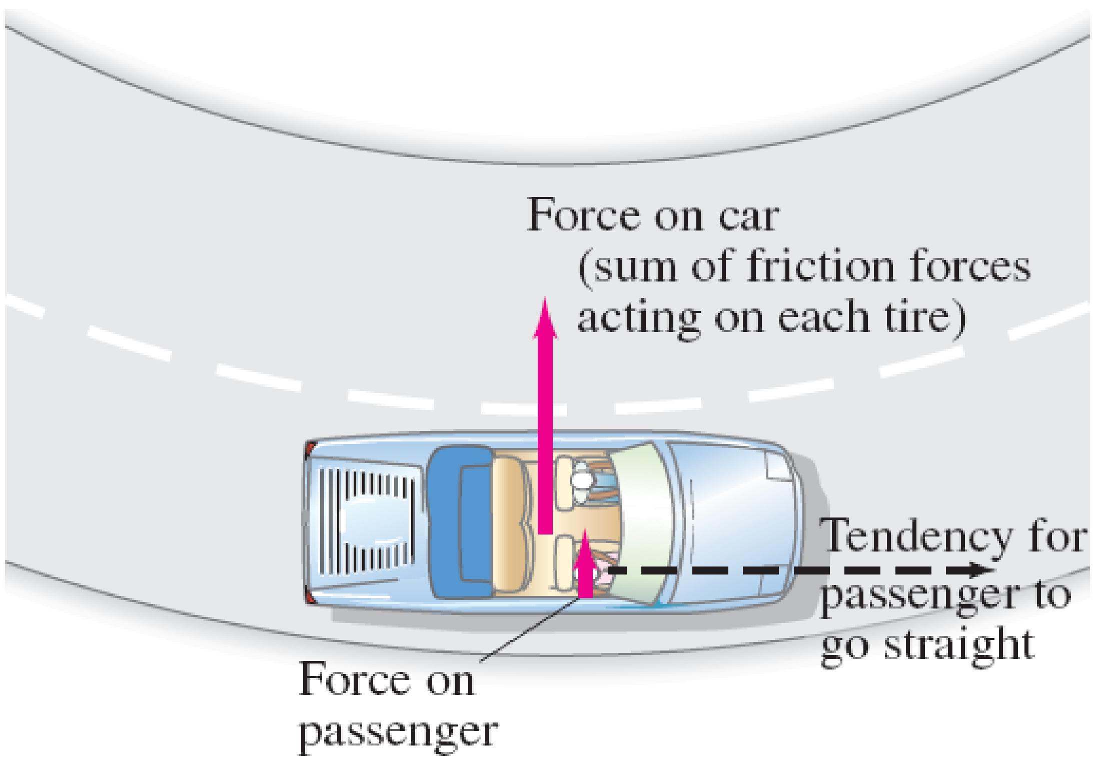


Example: Ultracentrifuge.

The rotor of an ultracentrifuge rotates at 50,000 rpm (revolutions per minute). A particle at the top of a test tube is 6.00 cm from the rotation axis. Calculate its centripetal acceleration, in "*g*'s."

Highway Curves: Banked and Unbanked

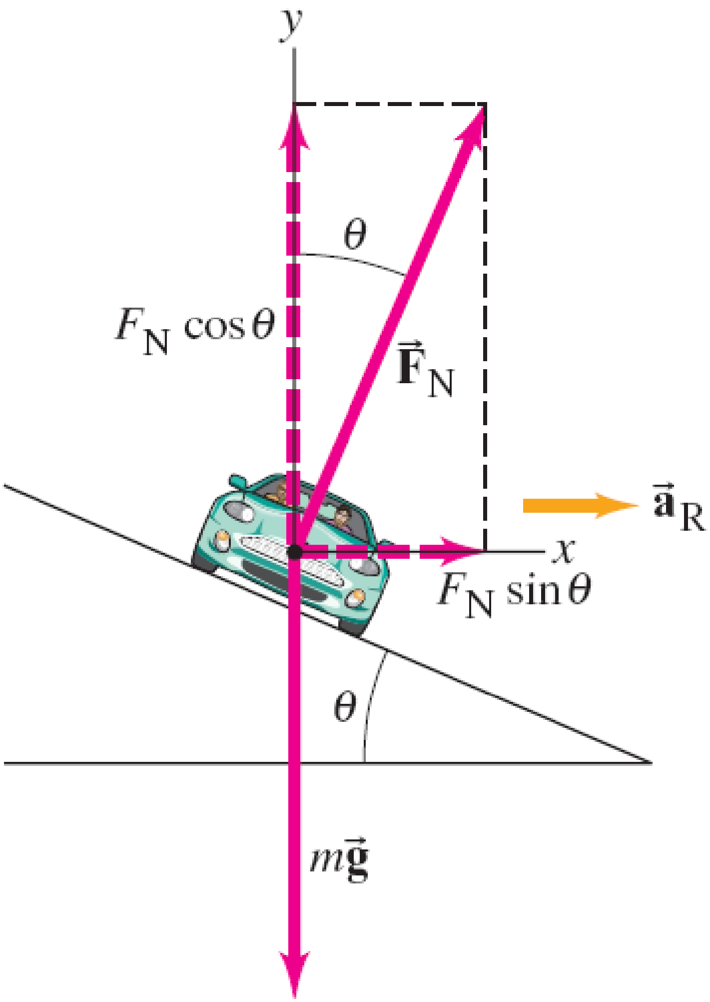
When a car goes around a curve, there must be a net force toward the center of the circle of which the curve is an arc. If the road is flat, that force is supplied by friction.



Highway Curves: Banked and Unbanked

If the frictional force is insufficient, the car will tend to move more nearly in a straight line, as the skid marks show.

Highway Curves: Banked and Unbanked



Banking the curve can help keep cars from skidding. When the curve is banked, the centripetal force can be supplied by the horizontal component of the **normal** force. In fact, for every banked curve, there is one speed at which the entire centripetal force is supplied by the horizontal component of the **normal** force, and no friction is required.

Example: Banking angle.

(a) For a car traveling with speed v around a curve of radius r, determine a formula for the angle at which a road should be banked so that no friction is required. (b) What is this angle for an expressway off-ramp curve of radius 50 m at a design speed of 50 km/h?