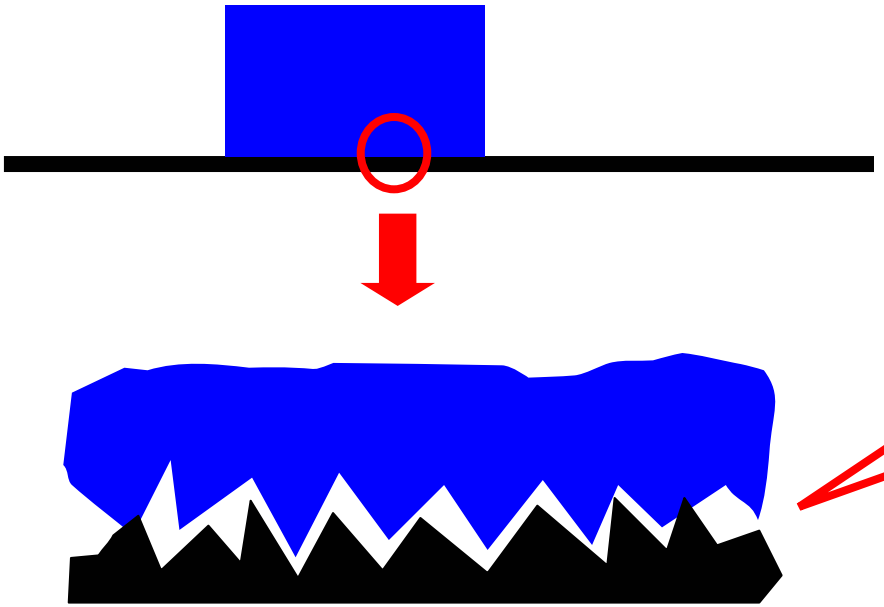
L-9 Friction and Rotation

- What is friction and what determines how big it is?
- How can friction keep us moving in a circle?
- What keeps us moving in circles ?
- center of gravity

What is friction?

- Friction is a force that acts between two surfaces that are in contact
- It always acts to **oppose** motion
- It is different depending on whether or there is motion or not.
- It is actually a force that occurs at the microscopic level.

A closer look at friction



Magnified view of surfaces

At the microscopic level even two smooth surfaces look bumpy → this is what produces friction

Static friction

If we push on a block and it doesn't move then the force we exert is less than the friction force.

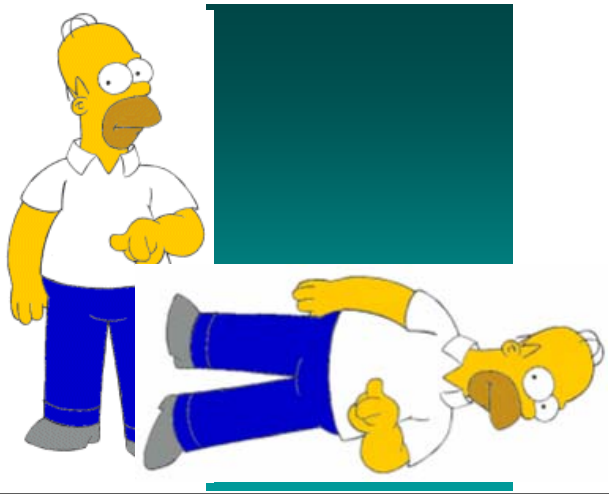
This is the **static friction** force at work

If I push a little harder, the block may still not move → the friction force can have any value up to some maximum value.

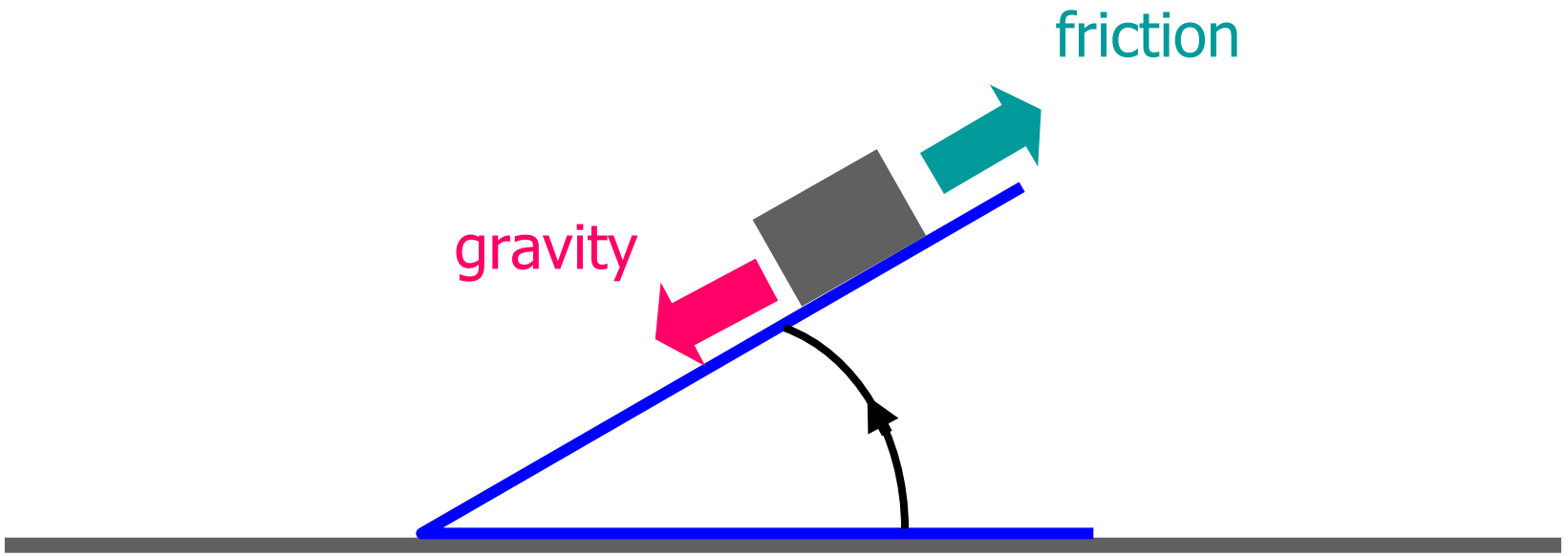
Kinetic friction

- If I keep increasing the pushing force, at some point the block moves → this occurs when the push P exceeds the maximum static friction force.
- When the block is moving it experiences a smaller friction force called the **kinetic friction force**
- It is a common experience that it takes more force to get something moving than to keep it moving.

Homer discovers that kinetic friction is less than static friction!

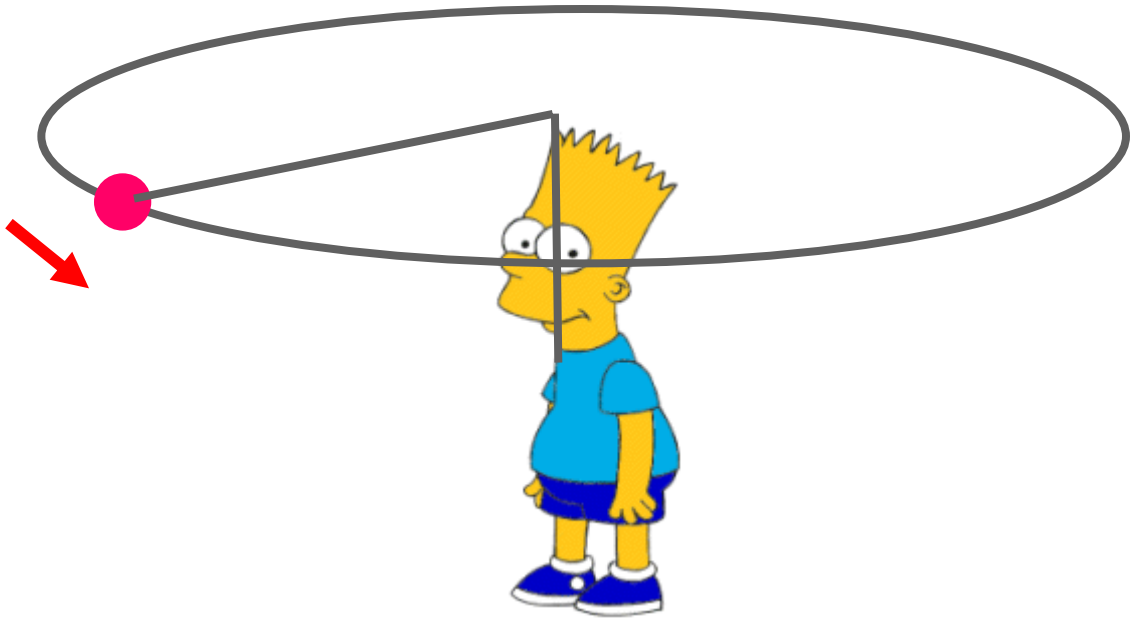


Measuring friction forces



At some point as the angle if the plane is increased the block will start slipping.
At this point, the friction force and gravity are equal.

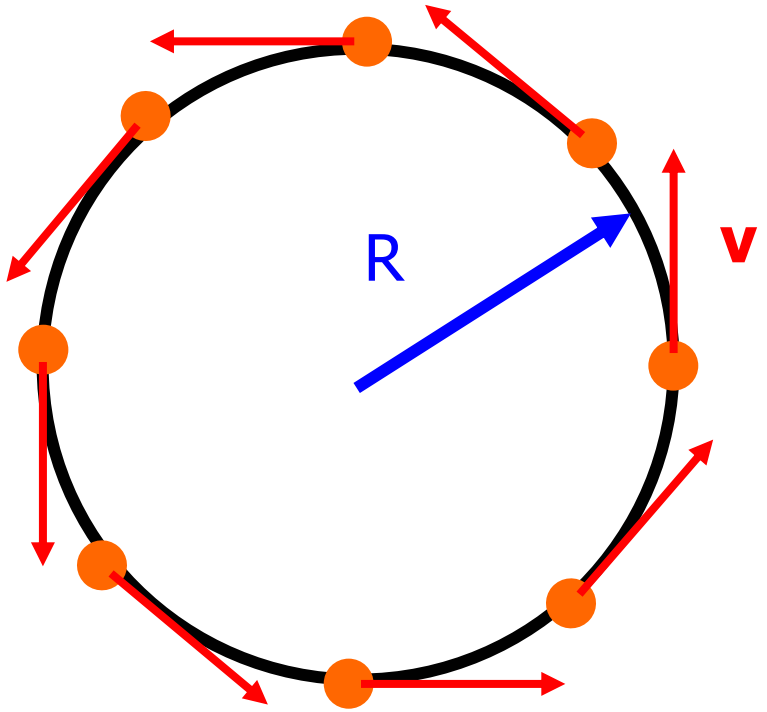
Going in circles



Bart swings the tennis ball around his head in a circle. The ball is accelerating, what force makes it accelerate?

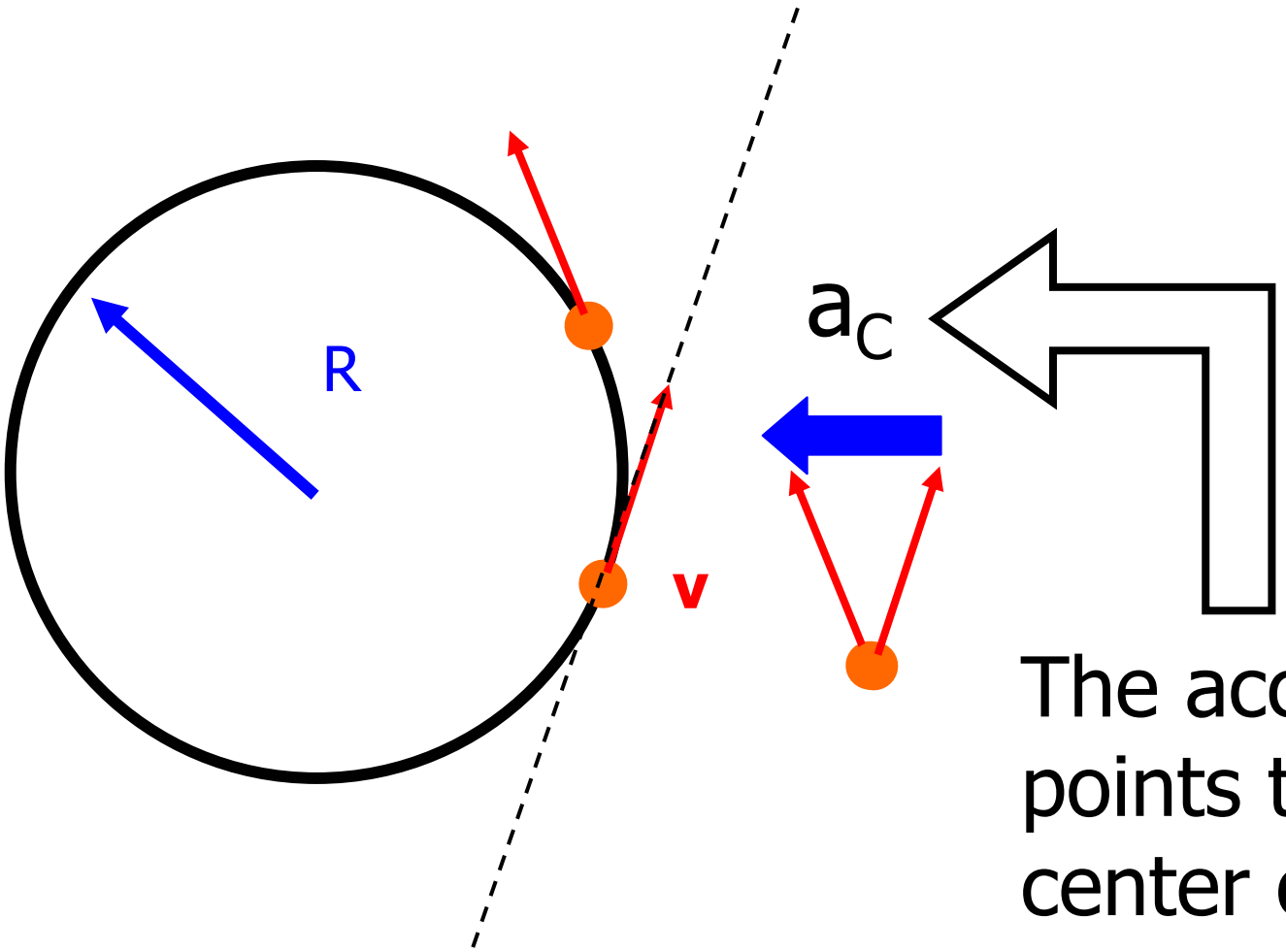
Uniform circular motion

The speed stays constant, but the direction changes



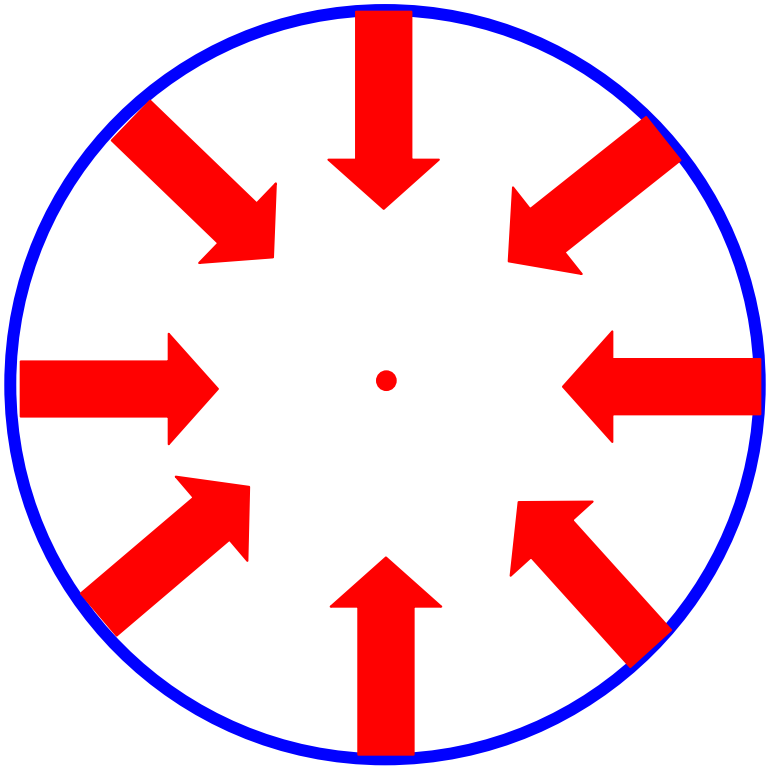
The acceleration in this case is called **centripetal** acceleration

Centripetal acceleration, a_C



The acceleration points toward the center of the circle

Centripetal acceleration

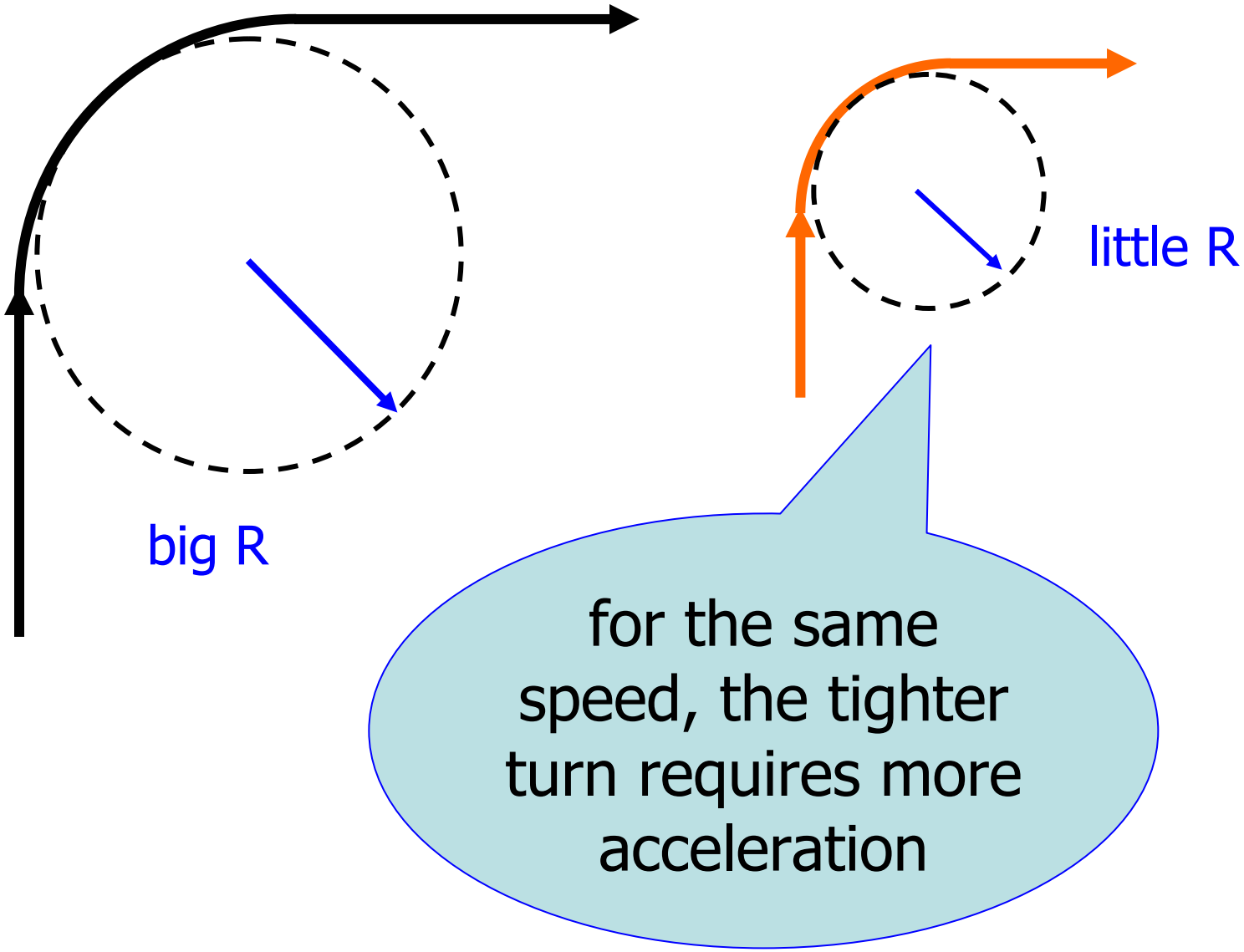


toward the
center
of the circle

Magnitude of centripetal acceleration

- The centripetal acceleration depends on two factors → the speed with which you take the turn and how tight the turn is
- More acceleration is required with a higher speed turn
- more acceleration is required with a tighter turn→ smaller radius of curvature

Wide turns and tight turns



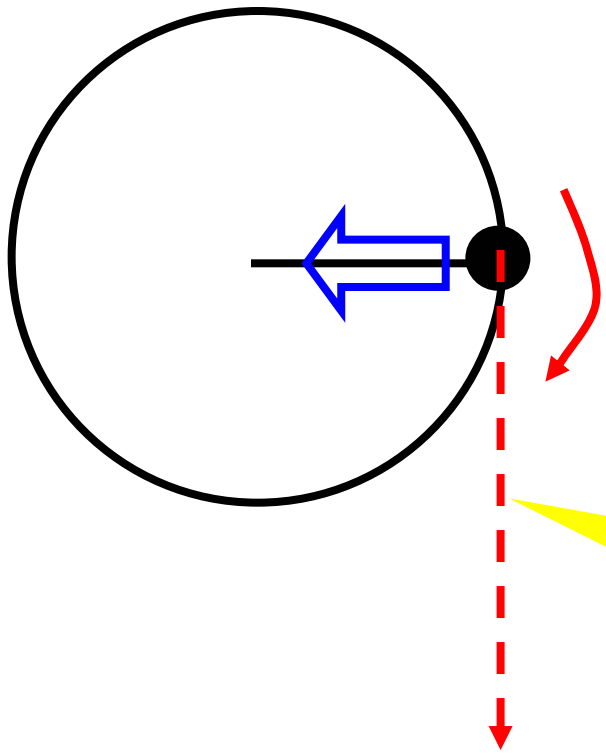
Centripetal acceleration

- centripetal acceleration

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

- for some turns, the “safe” speed is posted
- a force is needed to produce this centripetal acceleration→
- **CENTRIPETAL FORCE**
- where does this force come from?

Ball on a string



The tension in the string provides the necessary centripetal force to keep the ball going in a circle.

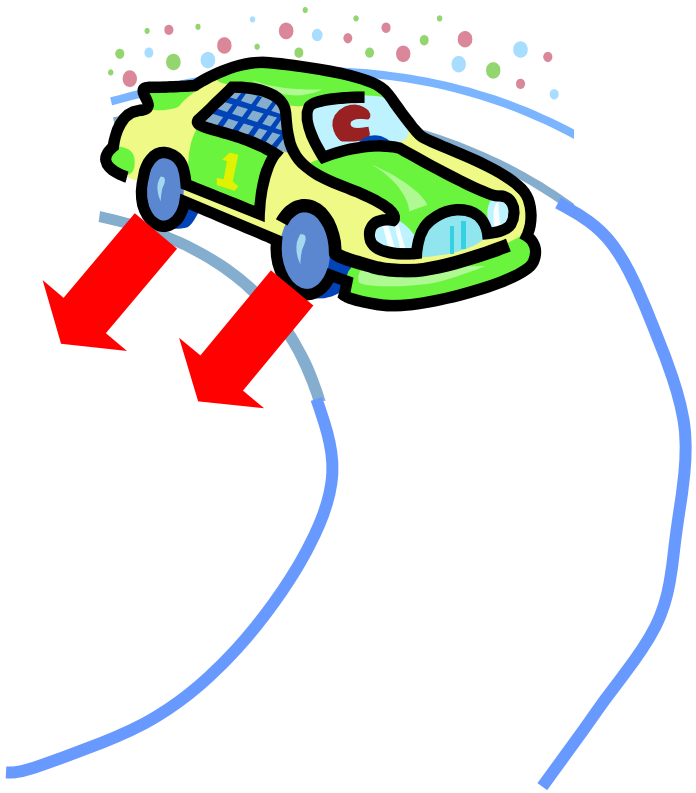
path of ball if the string breaks

Example

- What is the tension in a string used to twirl a 0.3 kg ball at a speed of 2 m/s in a circle of 1 meter?
- Force = mass x acceleration [$m \times a_C$]
- acceleration $a_C = v^2 / R = (2\ m/s)^2 / 1\ m$

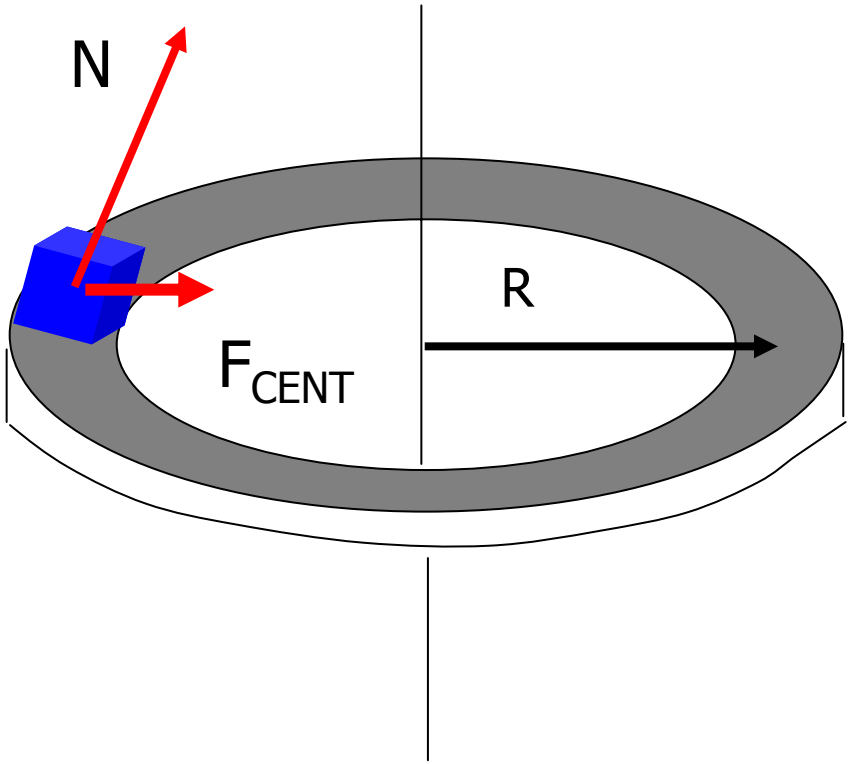
  $= 4\ m/s^2$
- force = $m\ a_C = 0.3 \times 4 = 1.2\ N$
- If the string is not strong enough to handle this tension it will break and the ball goes off in a straight line.

Negotiating a flat (level) turn



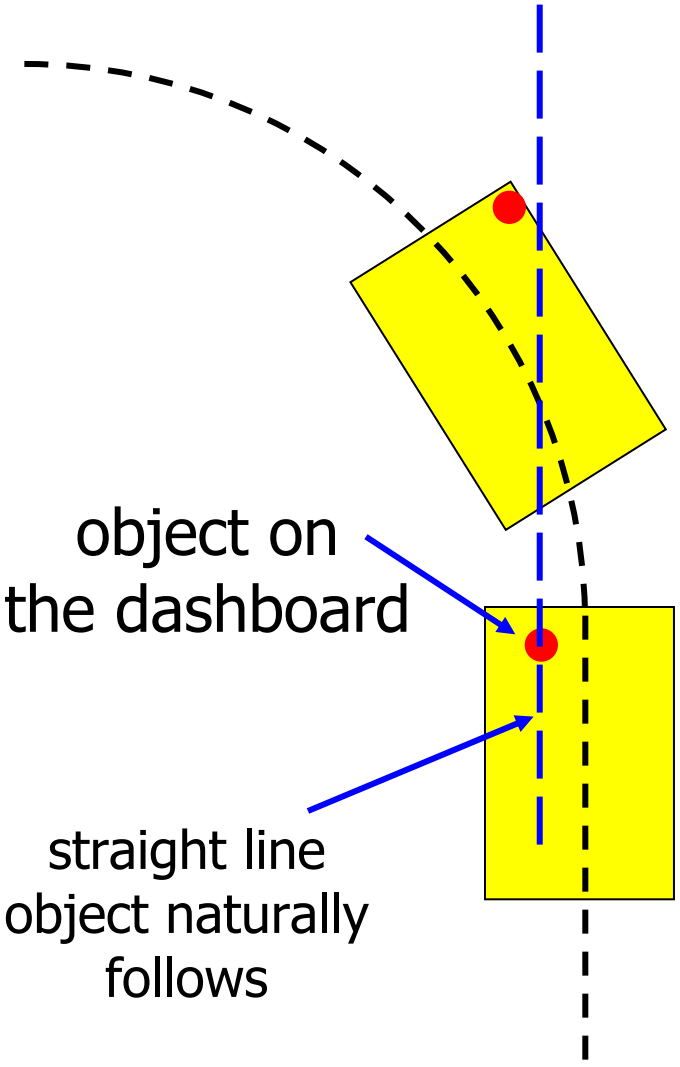
- The centripetal force is provided by the **friction** force between the road and tires.
- this force is reduced if the road is wet or icy

Banked turns



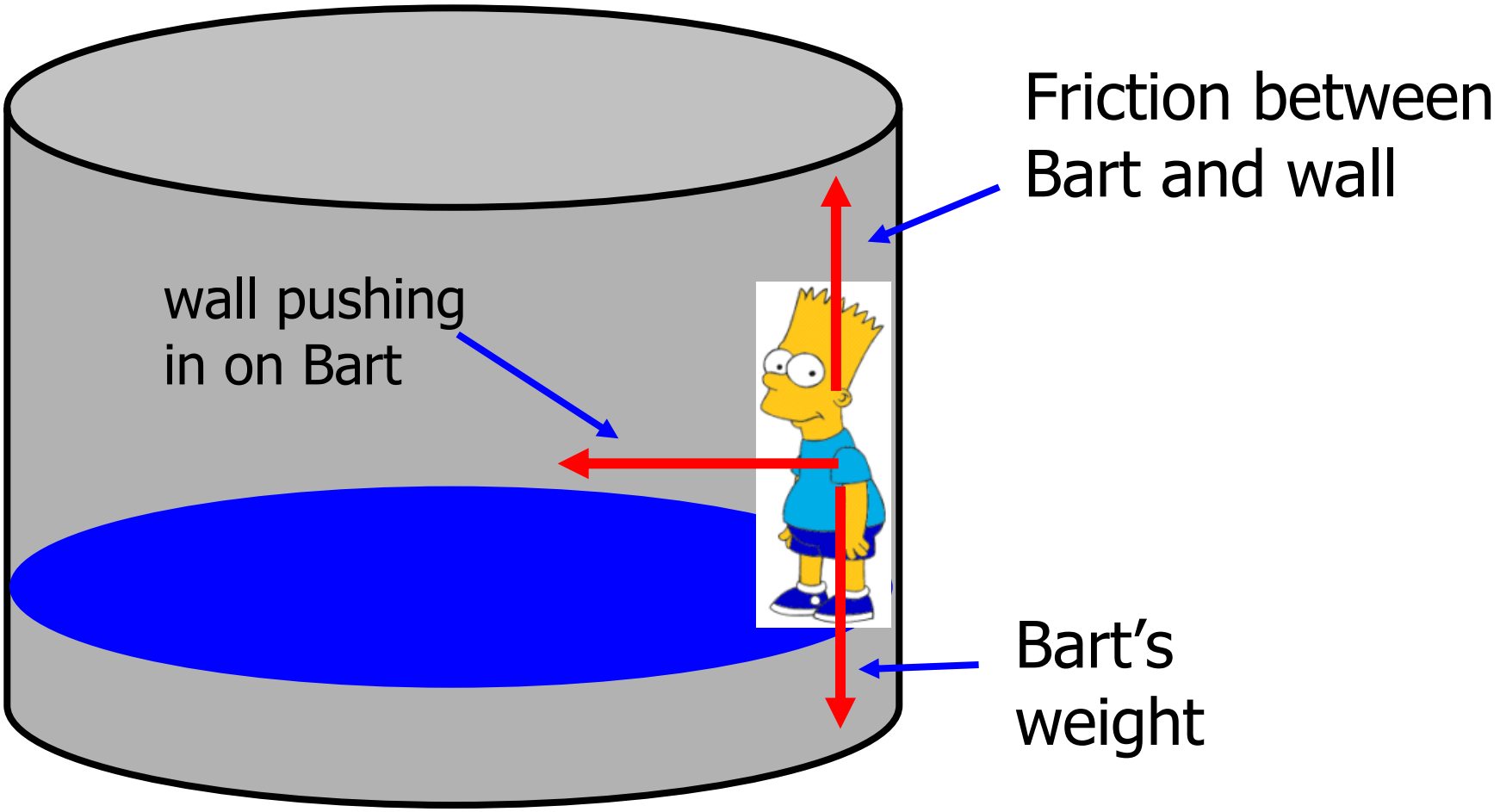
- Since the road is banked (not horizontal) the force of the road on the box is not vertical
- Part of the force on the box from the road points toward the center of the circle
- This provides the centripetal force
- No friction is necessary to keep the box in the circle

What's this Centrifugal force ? ?



- The red object will make the turn only if there is enough friction on it
- otherwise it goes straight
- the apparent outward force is called the **centrifugal force**
- **it is NOT A REAL force!**
- it doesn't go in a circle until something makes it!

Silly Silo (Rotor)

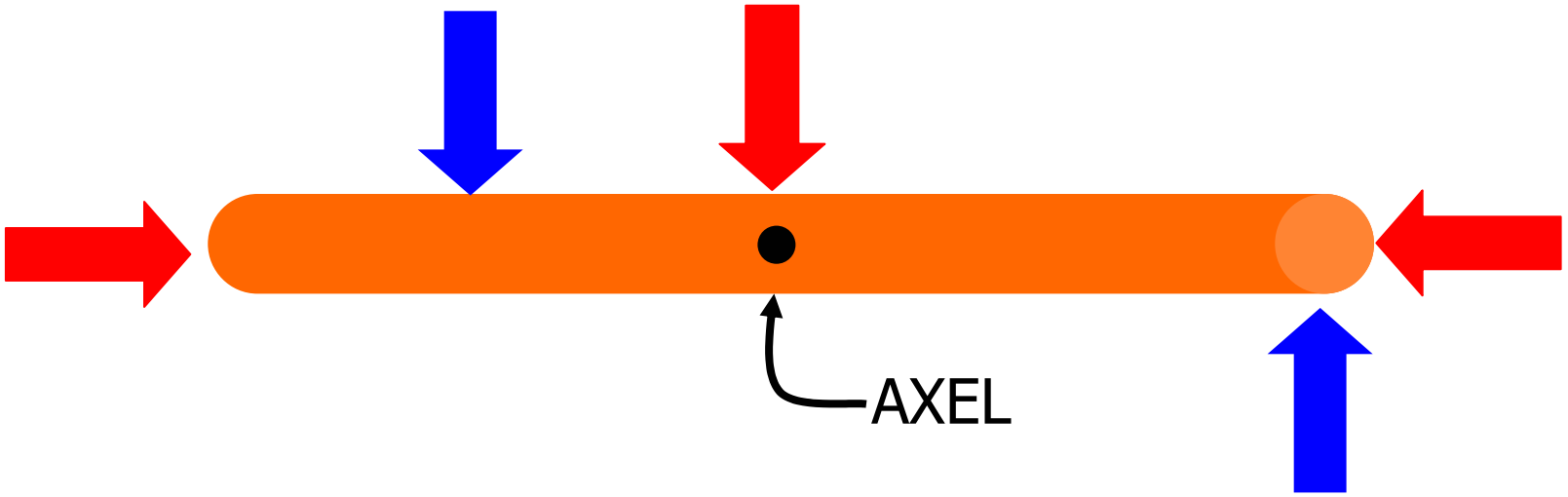


The inward wall force keeps Bart in the circle.
Friction keeps him from falling down.

What makes something rotate in the first place?

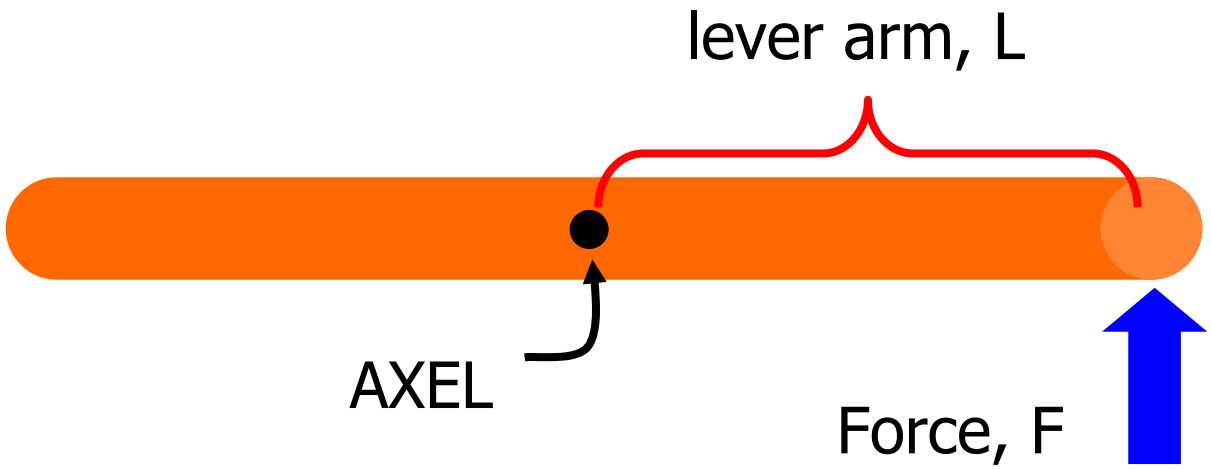
TORQUE

How do I apply a force to make the rod rotate about the axel? Not just anywhere!



TORQUE

- To make an object rotate, a force must be applied in the right place.
- the combination of force and point of application is called **TORQUE**



Torque = force times lever arm

$$\text{Torque} = F \times L$$