Circular Motion & Gravitation

Special Cases of Motion

Circular Motion & Gravitation

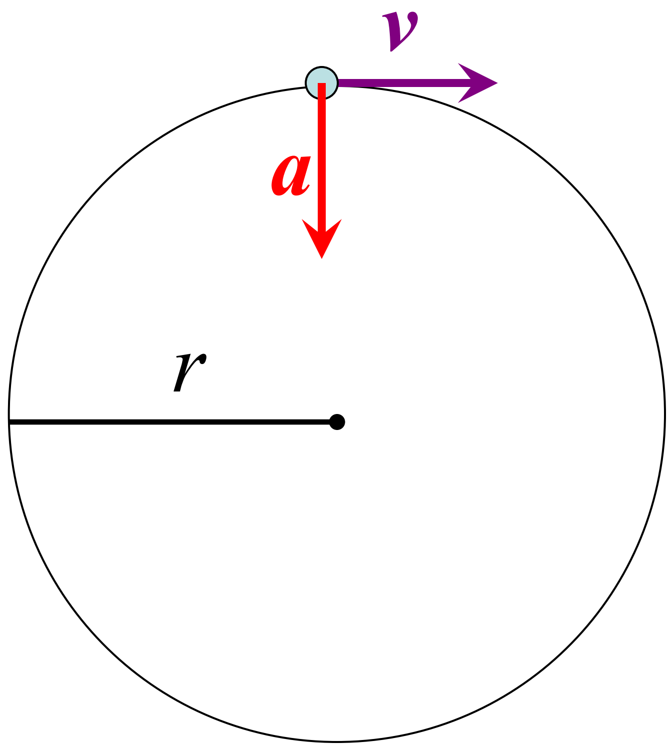
I. Circular Motion
- kinematics & dynamics
- centripetal acceleration
- centripetal force
- nonuniform circular motion
- parametric equations

II. Universal Gravitation
- Newton's "4th" Law
- force fields & orbits
- Kepler's Laws

	The student will be able to:	HW:
1	Solve problems of uniform circular motion involving period, frequency, speed, velocity, acceleration, force.	1 – 10
2	Distinguish, explain, and apply the concepts of centripetal and centrifugal force.	11 – 13
3	Solve problems of uniform circular motion or cycloid motion by use of parametric equations.	14 – 15
4	Solve problems of nonuniform circular motion involving constant rate of change in speed in which there are radial and tangential components of acceleration.	16 – 18
5	State and apply Newton's Law of Universal Gravitation.	19 – 23
6	Define and apply gravitational field strength.	24 – 28
7	Solve problems involving circular orbits.	29 – 34
8	State, apply, and derive Kepler's 3rd Law	35 – 36

$$f = \frac{1}{T}$$

$$T = \frac{1}{f}$$



$$v = \frac{2\pi r}{T}$$

$$a = \frac{v^2}{r}$$

where: r = radius
T = period
f = frequency
v = speed
a = acceleration

Uniform Circular Motion

- Uniform in this context means constant speed. (We *will* study **non**uniform circular motion!)
- Even though speed is constant, velocity is not.
- Object must accelerate toward the center of the circle (can call it "centripetal acceleration").
- Because acceleration is toward center there must be a net force toward the center (can call it "centripetal force").

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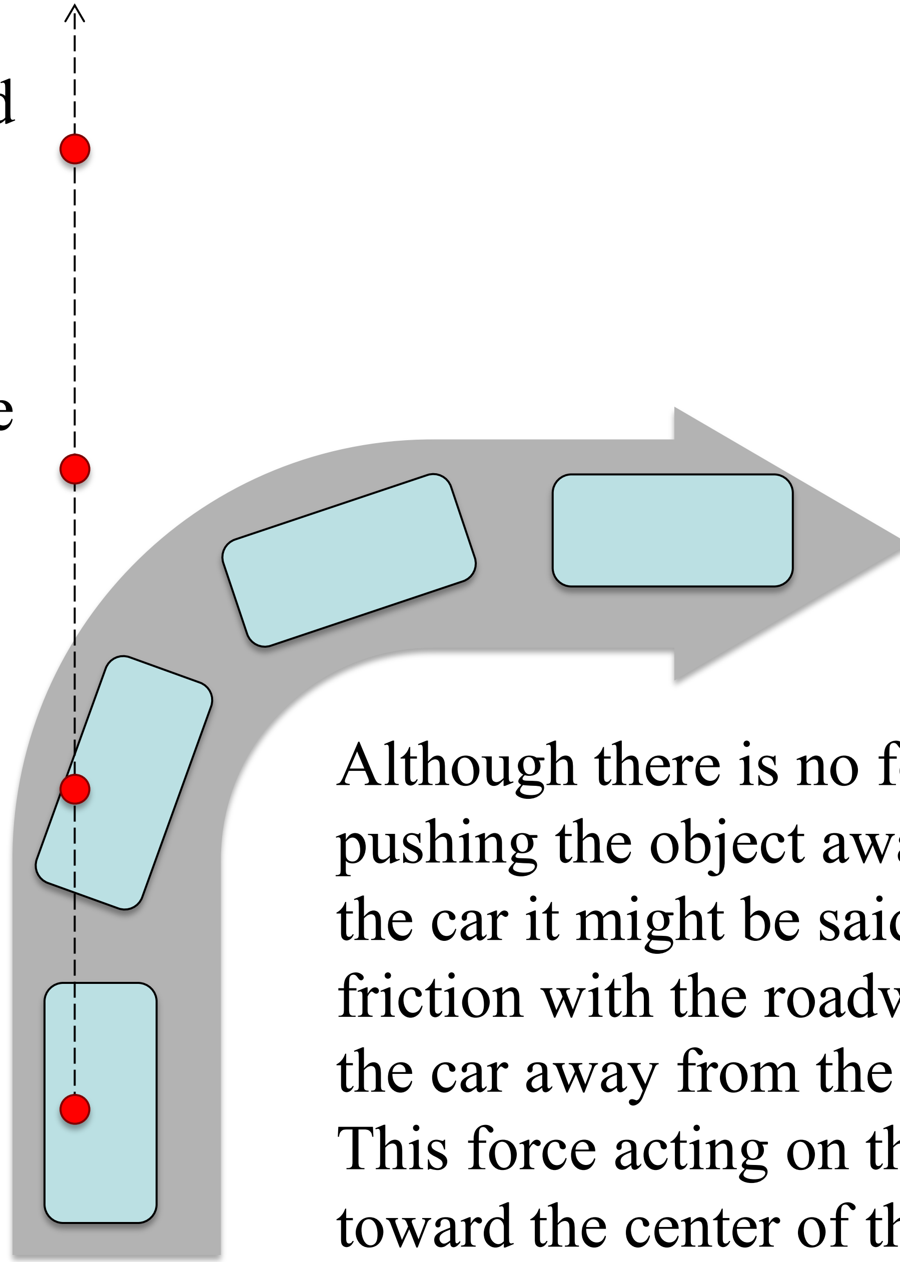
Centrifugal vs. Centripetal

- The word "centrifugal" means the opposite of the word "centripetal".
- Centrifugal = away from the center
- A "centrifugal force" then would be a force pushing or pulling away from the center of the circle…

Fictitious Force

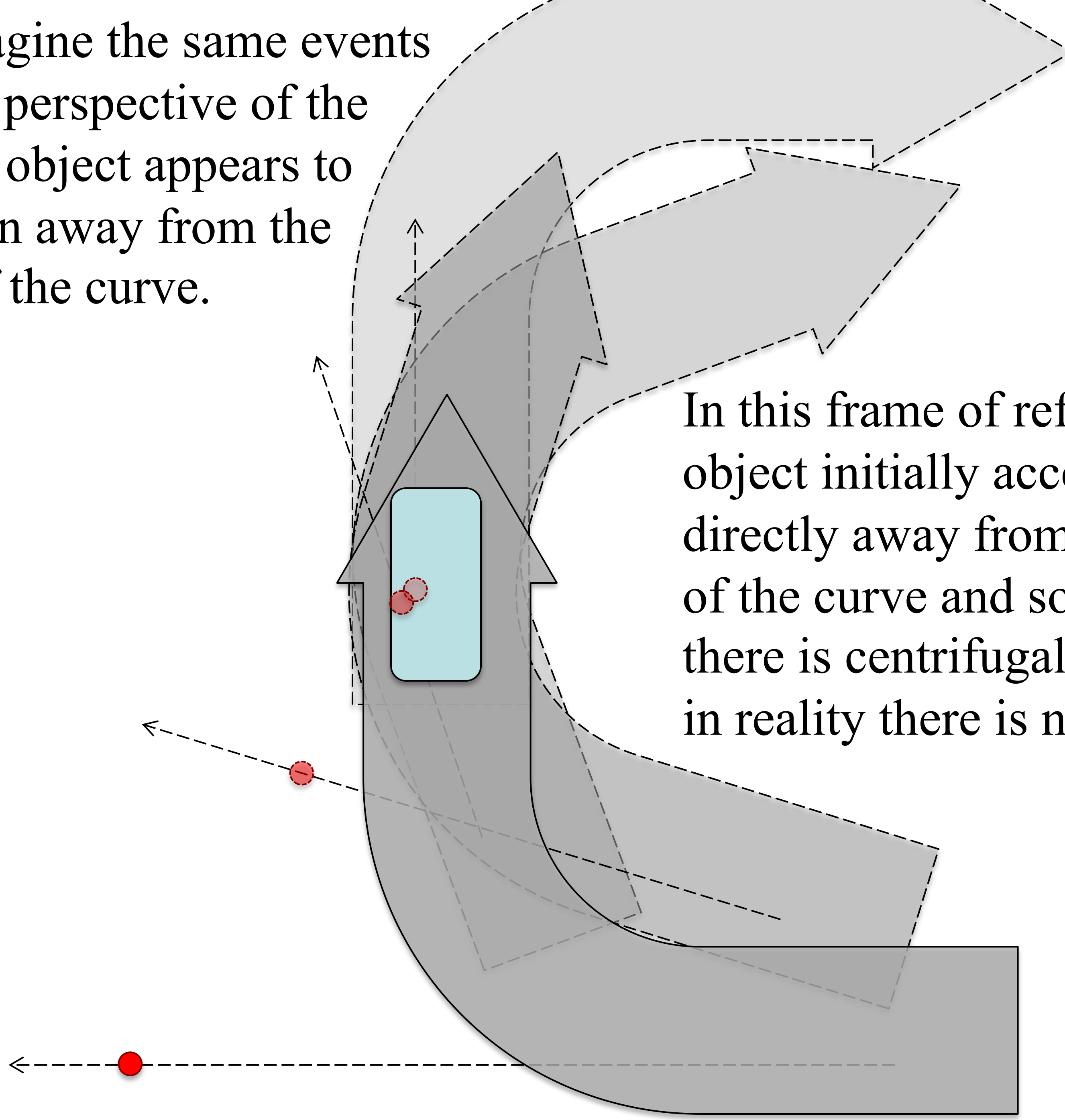
- In most cases, what would appear to be a "centrifugal force" is in reality the effect of *inertia* and is not a force at all! "Centrifugal force" does not exist!
- Because of inertia an object has the tendency to move in a straight line, which would naturally result in it moving away from the center!
- A rotating/revolving frame of reference is a ***noninertial frame*** and the effect of inertia is sometimes considered to be a "fictitious" or "pseudo-force".
- The fictitious centrifugal force can be modeled by: "force" = mass * (– acceleration of the frame)

Here imagine a bird's eye view of a car going around a curve in the road. An object left on the roof of the car would fly off and follow a straight line at the original speed of the car due to its inertia (not due to force).



Although there is no force pushing the object away from the car it might be said that friction with the roadway pulls the car away from the object! This force acting on the car is toward the center of the curve and is a real centripetal force.

Now imagine the same events from the perspective of the car. The object appears to be thrown away from the center of the curve.



In this frame of reference the object initially accelerates directly away from the center of the curve and so it appears there is centrifugal force, when in reality there is no such force.

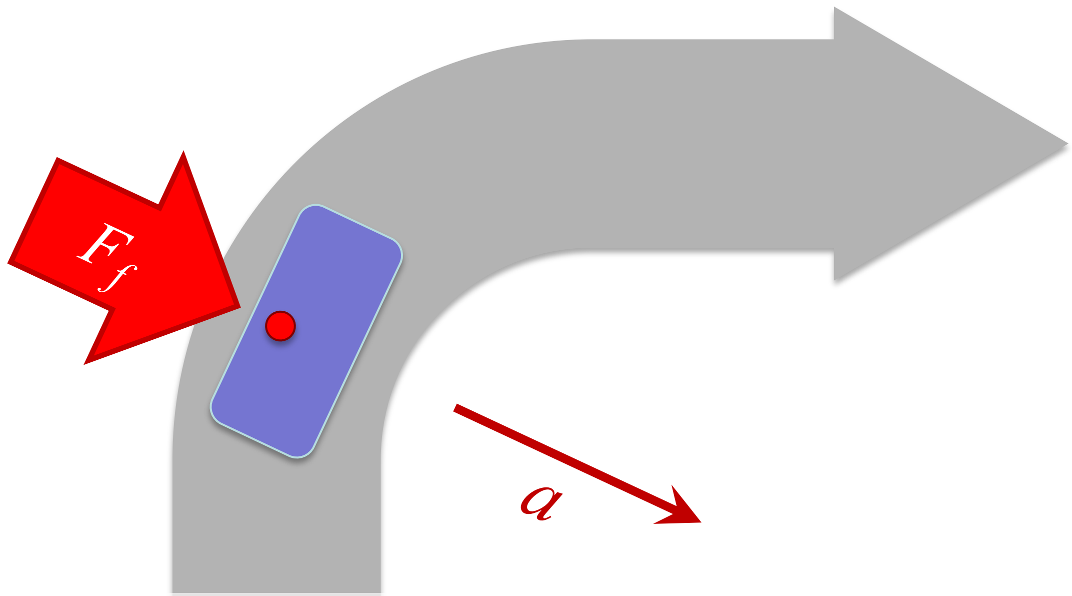
Inertial Frame

Now imagine that there is enough friction for the object to remain on the roof as the car goes around the curve:

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

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

$$F_f = ma$$



In the Earth frame the object is accelerating. There is no "centrifugal force". Friction is the "centripetal force" causing the acceleration toward the center.

Noninertial Frame

Centrifugal force:
(fictitious force!)

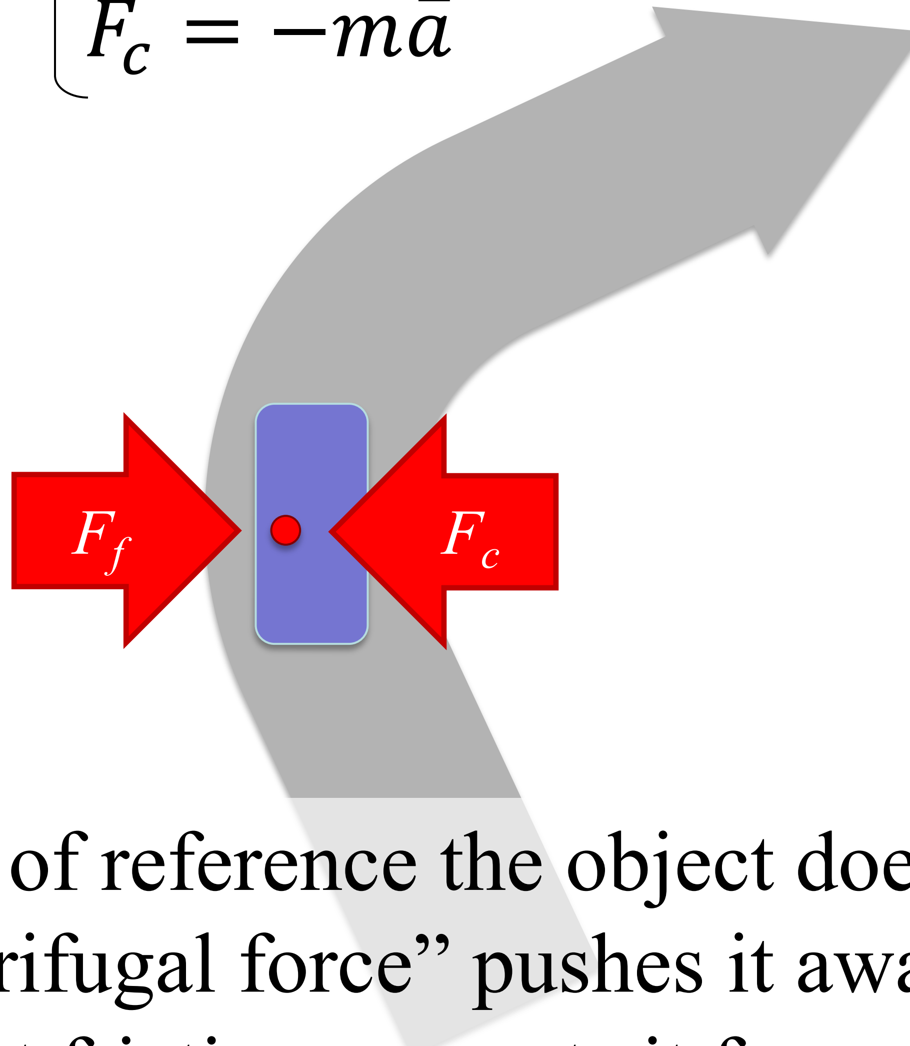
$$\begin{cases} \vec{F}_c = m(-\vec{a}) \\ \vec{F}_c = -m\vec{a} \end{cases}$$

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

$$\vec{F}_f + \vec{F}_c = 0$$

$$F_f + (-ma) = 0$$

$$F_f = ma$$



In the car's frame of reference the object does not accelerate. "Centrifugal force" pushes it away from the center but friction prevents it from sliding.