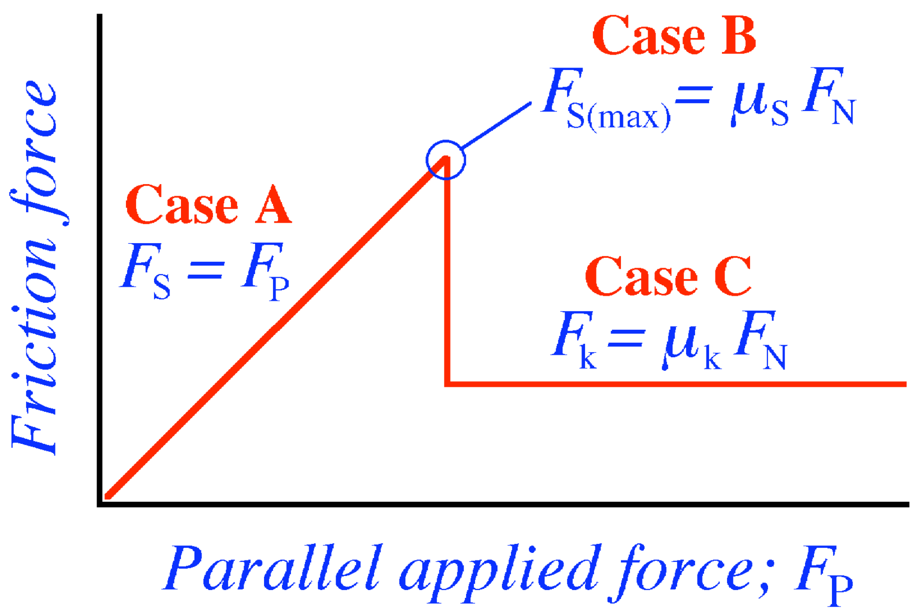
Lecture 6

Friction

and

Circular Motion

Properties of Friction



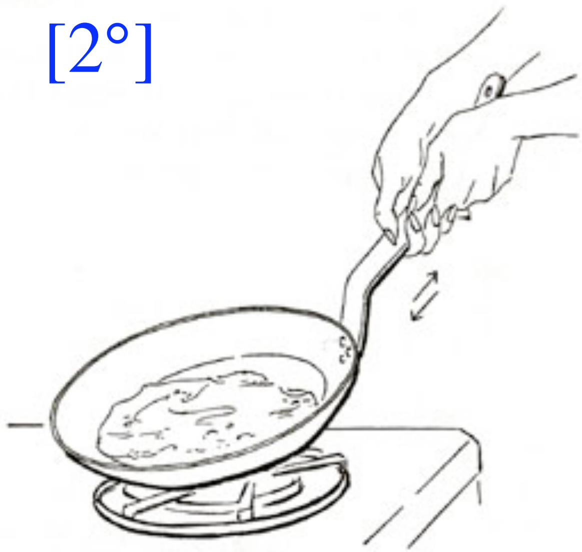
This graph is an idealisation. In softer, stickier materials like rubber, the transition from static to kinetic is not so sharp

Problem

The coefficient of static friction between teflon and scrambled eggs is about 0.04.

What is the smallest angle from the horizontal that will cause the eggs to slide across the bottom of a teflon coated pan?

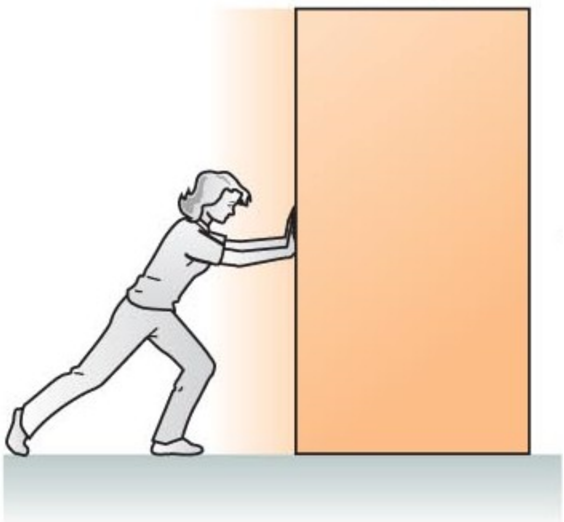
[2°]



Problem 2

You push a 100.0 kg box along the ground with constant horizontal force 600.0 N. For box on ground $\mu_k = 0.100$

Find the acceleration.



[5.02 ms^{-2}]

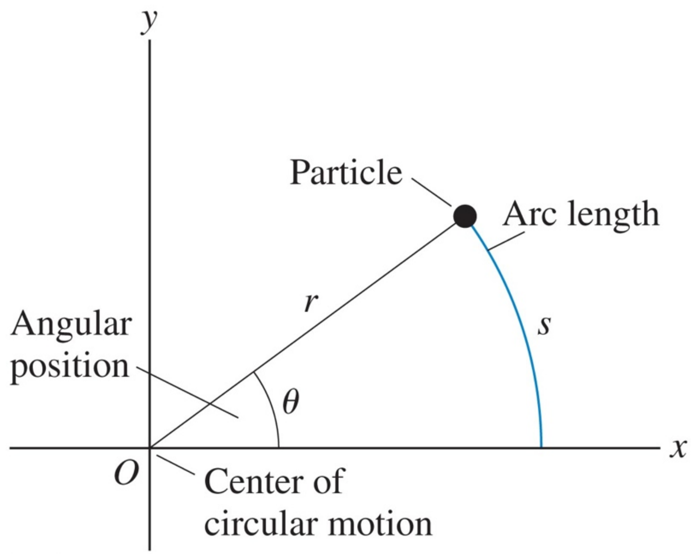
CIRCULAR MOTION

KJF §6.1–6.4

Angular position

If an object moves in a circle of radius r, then after travelling a distance s it has moved an angular displacement θ:

$$\theta = \frac{s}{r}$$



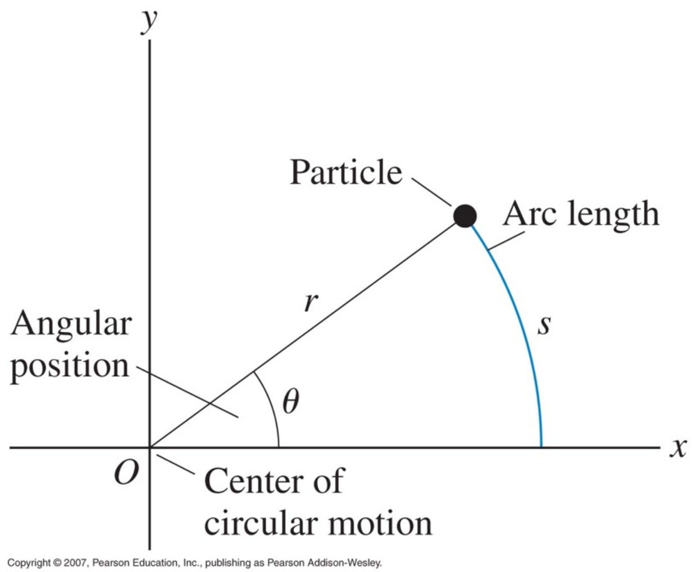
θ is measured in radians
(2π radians = 360°)

KJF §3.8

Tangential velocity

If motion is *uniform* and object takes time *t* to execute motion, then it has tangential velocity of magnitude *v* given by

$$v = \frac{s}{t}$$



Period of motion T = time to complete one revolution (units: s)

Frequency f = number of revolutions per second (units: s^{-1} or Hz)

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

Angular velocity

Define an angular velocity ω

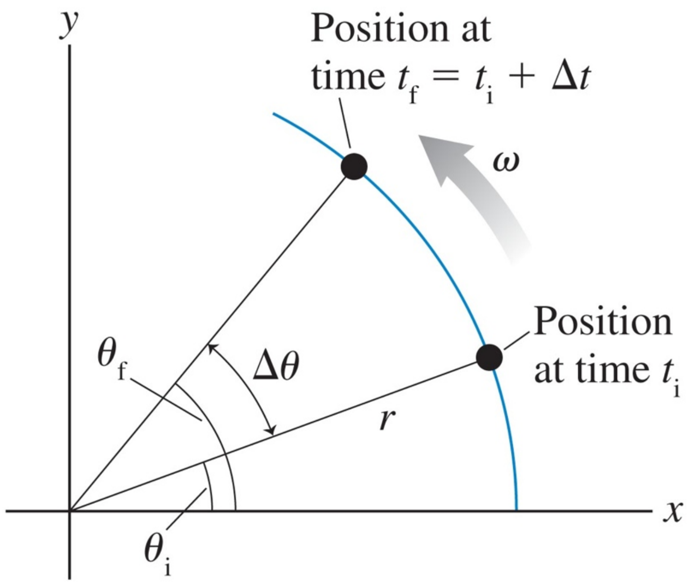
$$\omega = \frac{\text{angular displacement}}{\text{time interval}} = \frac{\theta}{t}$$

Uniform circular motion is when ω is constant.

Combining last 3 equations:

$$v = r\omega$$

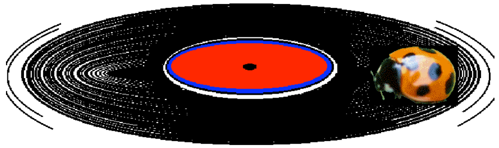
period $T = \dfrac{2\pi}{\omega}$



KJF §6.1

Question

You place a beetle on a uniformly rotating record



(a) Is the beetle's *tangential* velocity different or the same at different radial positions?

(b) Is the beetle's *angular* velocity different or the same at the different radial positions?

*Remember; all points on a rigid rotating object will experience the **same** angular velocity*

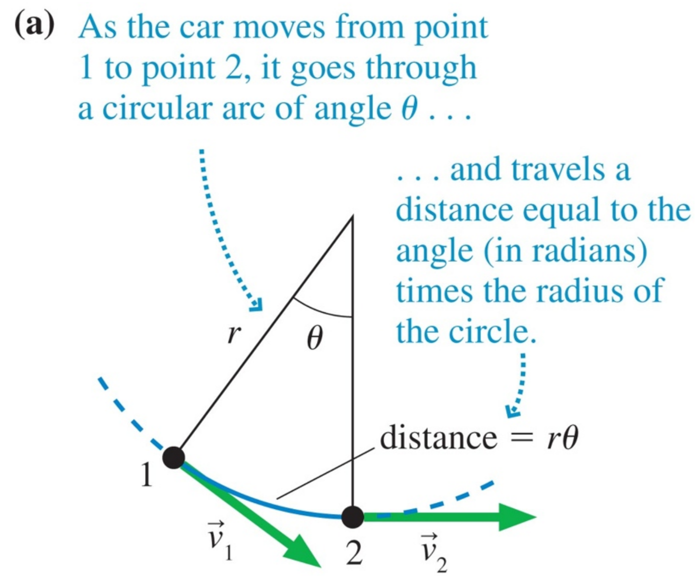
Consider an object is moving in uniform circular motion – tangential speed is constant.

Is the object accelerating?

Velocity is a *vector*
∴ changing direction

⇒ acceleration

⇒ net force



The change in velocity

$\Delta \underline{v} = \underline{v}_2 - \underline{v}_1$

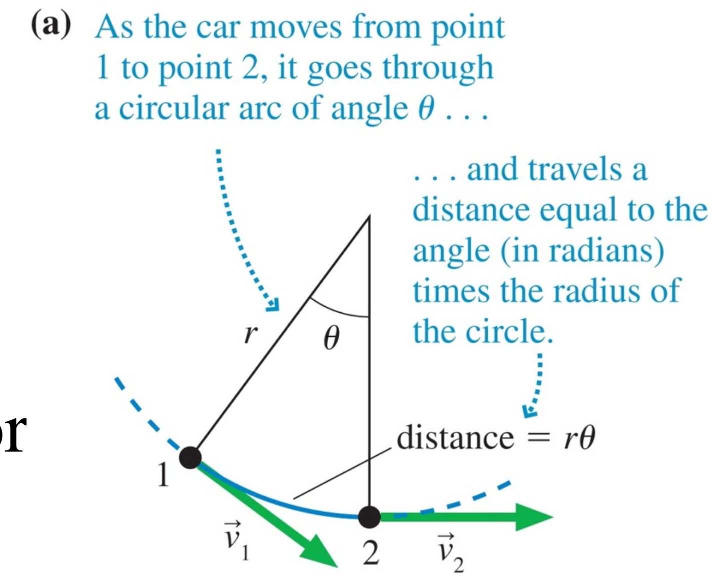
and $\Delta \underline{v}$ points towards the centre of the circle

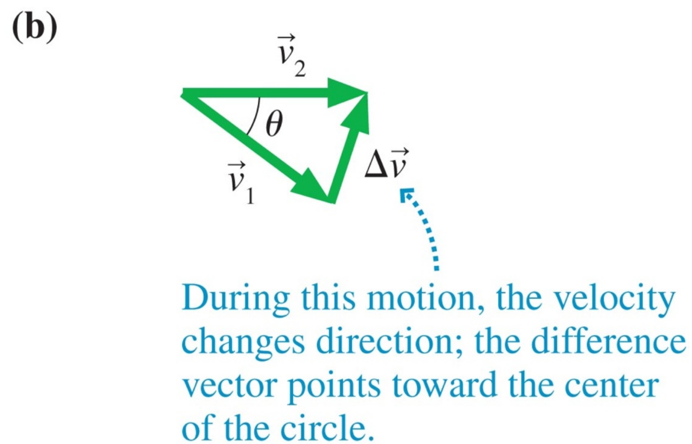
Angle between velocity vector is θ so

$\Delta v = v\theta$

and so

$$a = \frac{\Delta v}{\Delta t} = \frac{v\theta}{r\theta/v} = \frac{v^2}{r}$$





KJF §3.8

Centripetal acceleration

Acceleration points towards centre
– centripetal acceleration a_c

$$a_c = \frac{v^2}{r} = \omega^2 r$$

Since the object is accelerating, there must be a force to keep it moving in a circle

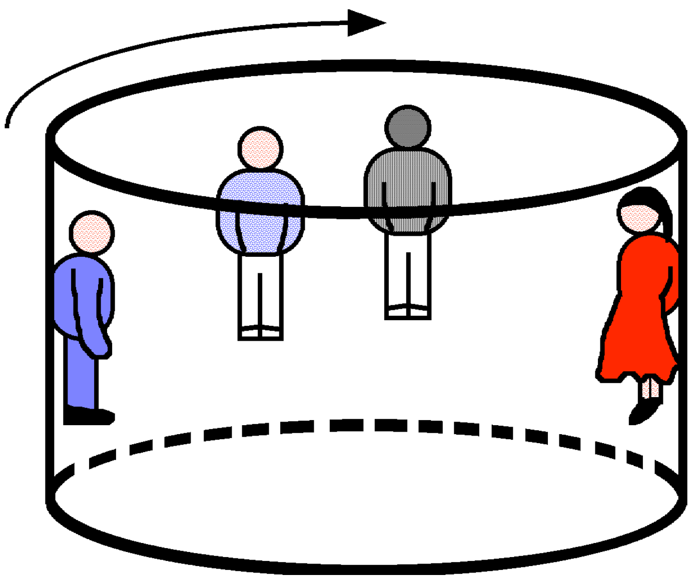
$$F_c = \frac{mv^2}{r} = m\omega^2 r$$

This centripetal force may be provided by friction, tension in a string, gravity etc. or combinations. *Examples*?

KJF §6.2

Problem 1

You enter the carnival ride called "The Rotor". The circular room is spinning and you and other riders are stuck to the circular wall.



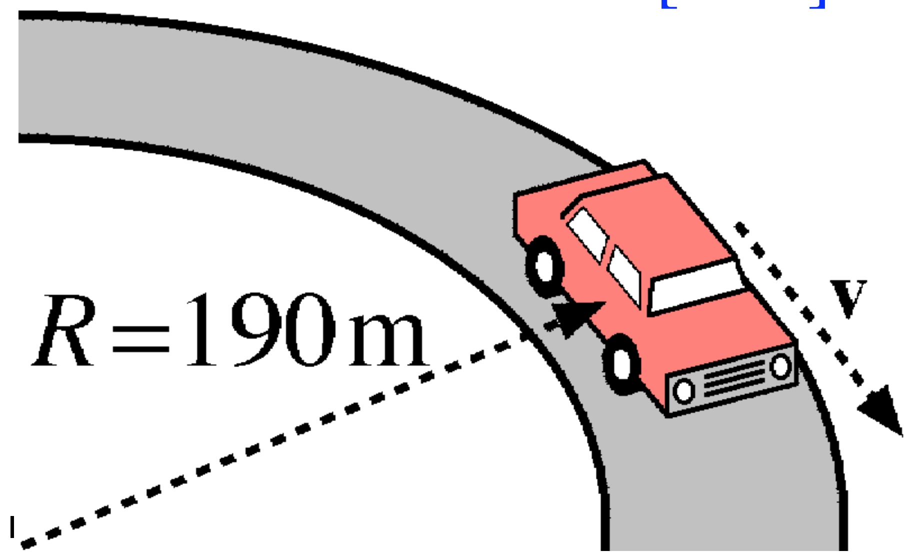
- Draw a free-body diagram of the woman in red
- Is she in equilibrium? Explain
- What force is providing the centripetal force?

Problem 2

A car of mass 1.6 t travels at a constant speed of 72 km/h around a horizontal curved road with radius of curvature 190 m. (Draw a free-body diagram)

What is the minimum value of μ_s between the road and the tyres that will prevent slippage?

[0.21]

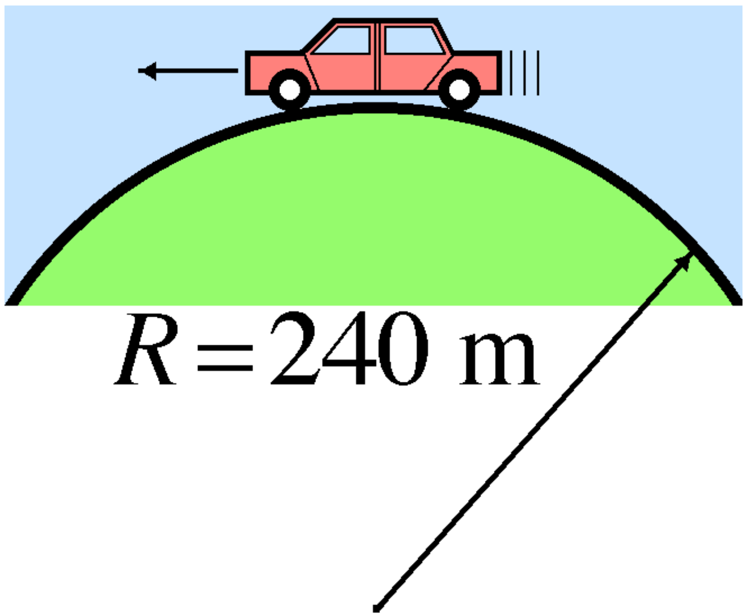


Problem 3

A car is driving at constant speed over a hill, which is a circular dome of radius 240 m.

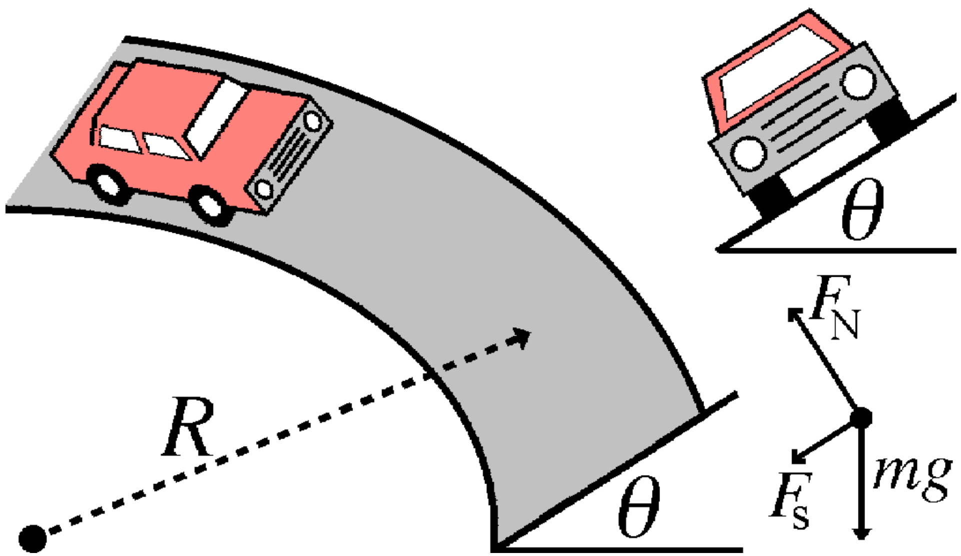
Above what speed will the car leave the road at the top of the hill?

[175 km/h]



Banked road

On a curve, if the road surface is "banked" (tilted towards the curve centre) then the horizontal component of the normal force can provide some (or all) of the required centripetal force. Choose v & θ so that less or no static friction is required.



KJF example 6.6

KJF example 6.6

A curve of radius 70m is banked at a 15° angle. At what speed can a car take this curve without assistance from friction?

[14 ms^{-1} = 50 km h^{-1}]