Uniform Circular Motion and Universal Gravitation

Chapter 6

16 April 2020

Circular Motion

- Uniform circular motion –
  - Speed is constant. Velocity is not.
  - Now using polar coordinates, not xyz.
    - (r, θ, z)
  - The velocity component in the radial direction is zero <u>if uniform motion</u>.
  - The velocity component in the z-direction is zero.
  - The tangential component of the velocity is not zero, but it is constant.

Problems

- The crankshaft in your car rotates at 3000 rpm. What is the frequency in revolutions per second?

- A record turntable rotates at 33.3 rpm. What is the period in seconds?

EXAMPLE 8.2 The acceleration of an atomic electron

We will later study the Bohr atom. This is a simple model of the hydrogen atom in which an electron orbits a proton at a radius of 5.29×10^{-11} m with a period of 1.52×10^{-16} s. What is the electron's centripetal acceleration?

Forces on an object traveling in a uniform circular motion

Free body diagram?

Look at the forces at several places on the circle

– are they the same everywhere?

- which way does the net force point?

- acceleration points in the same direction as the net force

- for uniform circular motion, this is a fixed point at the center of the circle.

Cause and Effect

Remember, Newton's Laws tell us about causes (forces) and effects (acceleration – a *change* in motion).

So first we look at the net effect of all forces acting on an object.
(For uniform circular motion – all net forces are acting in the radial direction.)
Then, we can look at the effects of the net force.
Net force = cause
Acceleration in the radial direction = effect

Then, we look at the radial acceleration and its' relationship with speed and radius on a circular path.

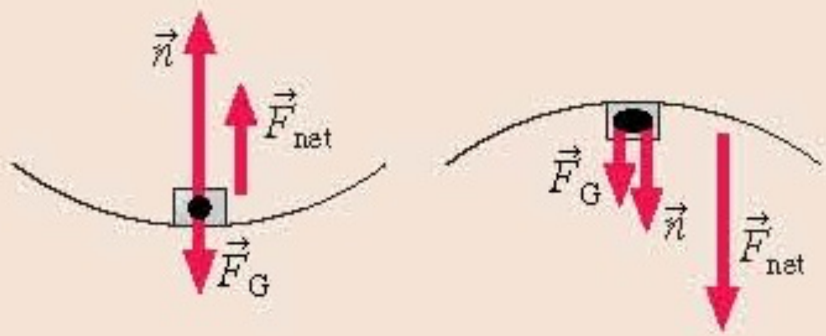
$$a_r = v^2/r$$
$$F_{net} = ma_r = mv^2/r$$

So how can we apply this to vertical circular motion and other non-uniform circular motions?

Applications

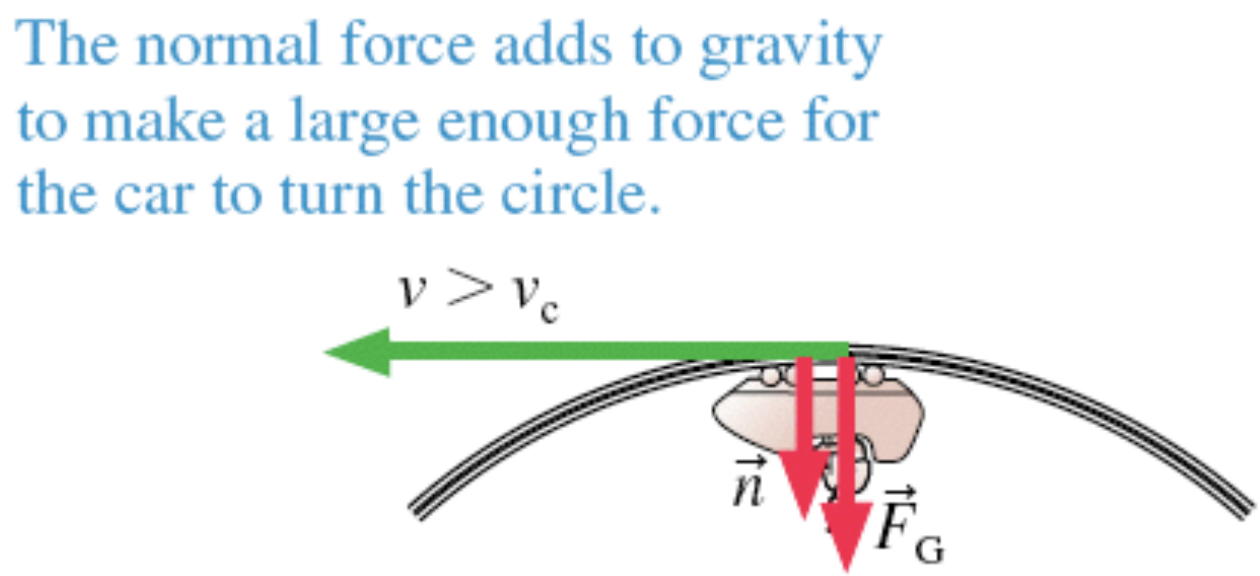
Loops

Circular motion requires a net force pointing to the center. n must be > 0 for the object to be in contact with a surface.



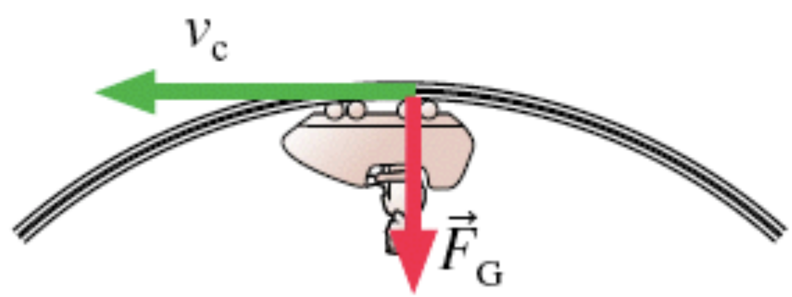
Why Does the Person Stay in the Roller Coaster?

FIGURE 8.18 A roller coaster car at the top of the loop.



Why Does the Person Stay in the Roller Coaster?

At v_c, gravity alone is enough force for the car to turn the circle. $\vec{n} = \vec{0}$ at the top point.



Calculate the magnitude of the force between the Earth and the moon. Assume the orbit is circular, and calculate the period of the Moon's orbit.

- Qualitative Representation

- Variables (known, unknown) and Equations

$G = 6.67 \times 10^{-11}\ Nm^2/kg^2$ $m_{Earth} = 5.98 \times 10^{24}$ kg

$M_{moon} = 7.36 \times 10^{22}$ kg Average orbital radius = 3.84×10^5 km

Calculate the acceleration due to gravity on the surface of Mars.

- Qualitative Representation

- Variables (knowns, unknowns) and Equations

M_{mars} = 6.418 x 10^{23} kg **r_{Mars} = 3.38 x 10^{6} m**

Calculate the *altitude* for a geosynchronous orbit, and the speed of the satellite.

- **Qualitative Representation**

- **Variables (knowns, unknowns) and Equations**

$G = 6.67 \times 10^{-11}\ Nm^2/kg^2$ $m_{Earth} = 5.98 \times 10^{24}\ kg$

$r_{Earth} = 6.38 \times 10^6\ m$