PHY131H1F - Class 13

Harlow's Last Class this semester ☹

on Monday Prof. Meyertholen takes over! ☺

Today, starting Chapter 8:

- Dynamics in Two Dimensions
- Dynamics of Uniform Circular Motion
- Banked Curves
- Orbits

Clicker Question

Last day at the end of class I asked:

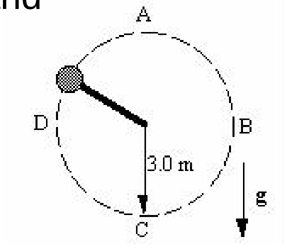
- A ball is whirled on a string in a vertical circle. As it is going around, the tension in the string is

A. greatest at the top of the motion

B. constant.

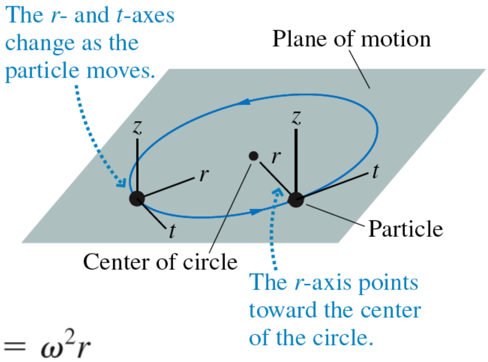
C. greatest at the bottom of the motion

D. greatest somewhere in between the top and bottom.



Uniform Circular Motion

FIGURE 8.3 The *rtz*-coordinate system.



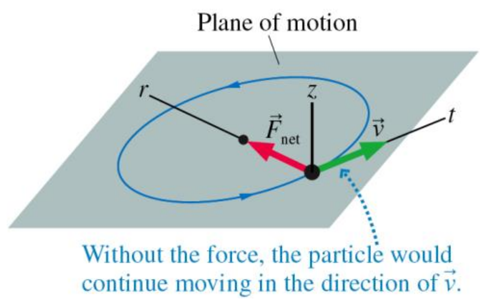
$$a_r = \frac{v^2}{r} = \omega^2 r$$

$$a_t = 0$$

$$a_z = 0$$

Dynamics of Uniform Circular Motion

FIGURE 8.6 The net force points in the radial direction, toward the center of the circle.

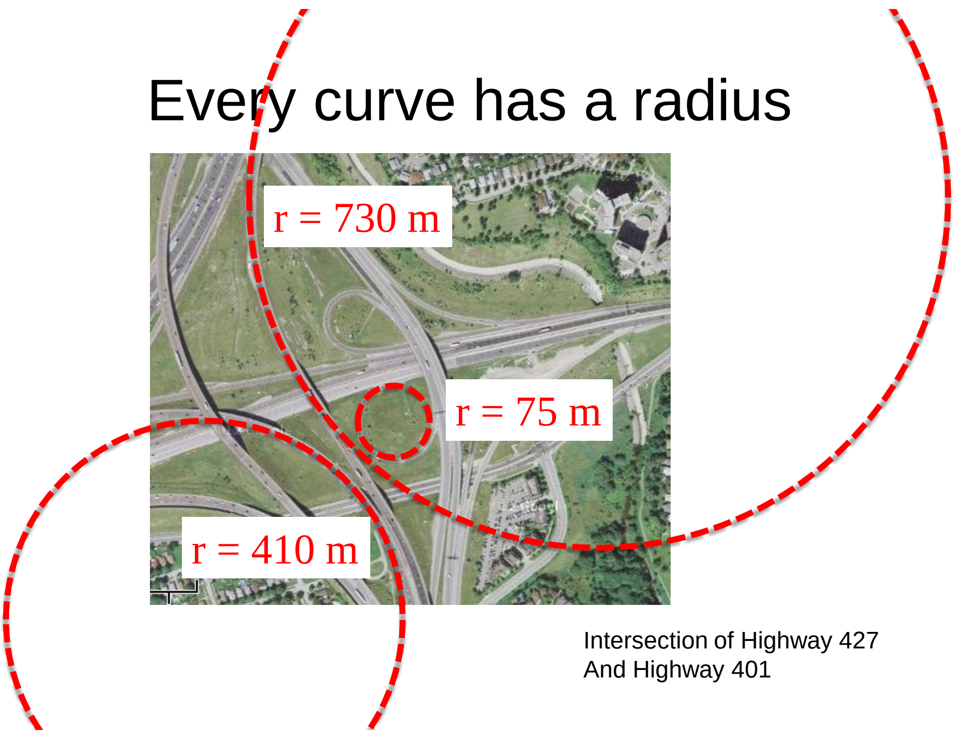


$$(F_{net})_r = \sum F_r = ma_r = \frac{mv^2}{r} = m\omega^2 r$$

$$(F_{net})_t = \sum F_t = ma_t = 0$$

$$(F_{net})_z = \sum F_z = ma_z = 0$$

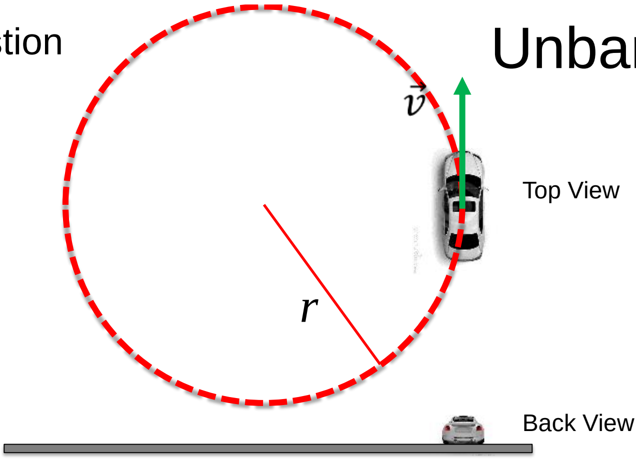
Every curve has a radius



Intersection of Highway 427
And Highway 401

Clicker Question

Unbanked Curve

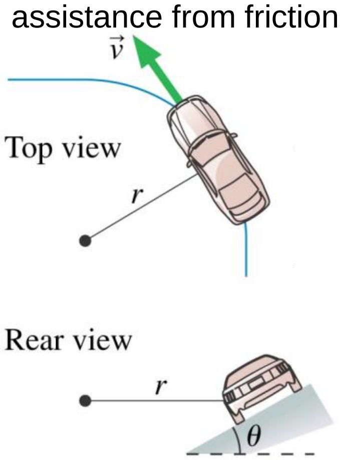


What horizontal force acts on the car to keep it on the curved path?

A. Gravity
B. Normal
C. Kinetic Friction
D. Static Friction
E. Rolling Friction

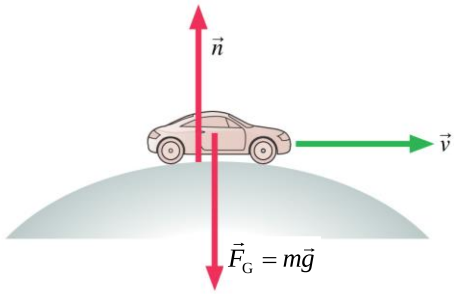
Banked Curve   Example 8.5, pg. 197

A highway curve of radius 70.0 m is banked at a 15° angle. At what speed v_0 can a car take this curve without assistance from friction?



Clicker Question

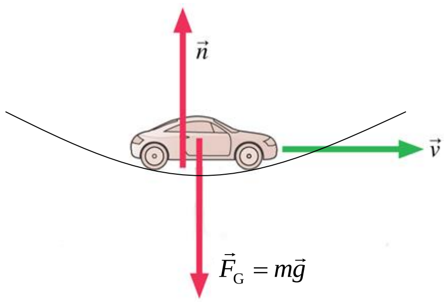
A car is rolling over the top of a hill at speed *v*. At this instant,



A. $n > F_G$.
B. $n < F_G$.
C. $n = F_G$.
D. We can't tell about n without knowing v.

Clicker Question

A car is driving at the bottom of a valley at speed *v*. At this instant,



A. $n > F_G$.
B. $n < F_G$.
C. $n = F_G$.
D. We can't tell about n without knowing v.

Projectile Motion

In the absence of air resistance, a projectile has only one force acting on it: the gravitational force, $F_G = mg$, in the downward direction. If we choose a coordinate system with a vertical *y*-axis, then

$$\vec{F}_G = -mg\hat{j}$$

$$a_x = \frac{(F_G)_x}{m} = 0$$

$$a_y = \frac{(F_G)_y}{m} = -g$$

The vertical motion is free fall, while the horizontal motion is one of constant velocity.

Clicker Question

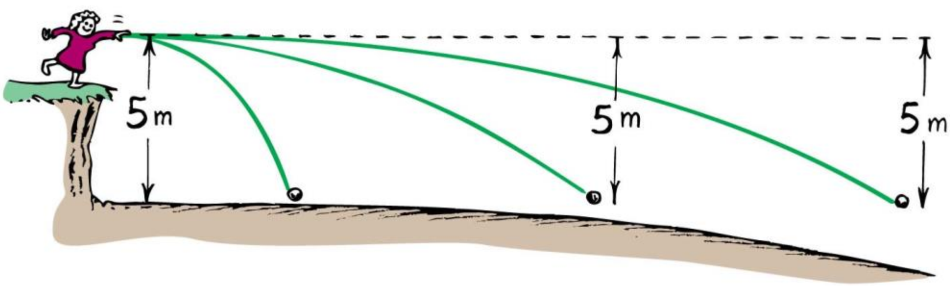
A girl throws a ball in a horizontal direction (dashed line). After the ball leaves the girl's hand, 1.0 seconds later it will have fallen

A. 9.8 meters.

B. 4.9 meters below the dashed line.

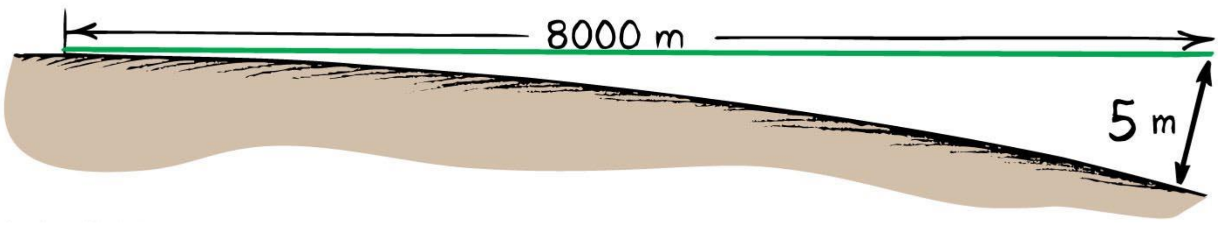
C. less than 4.9 meters below the straight-line path.

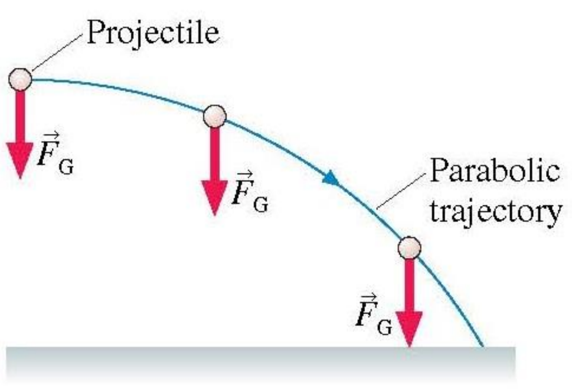
D. more than 4.9 meters below the straight-line path.



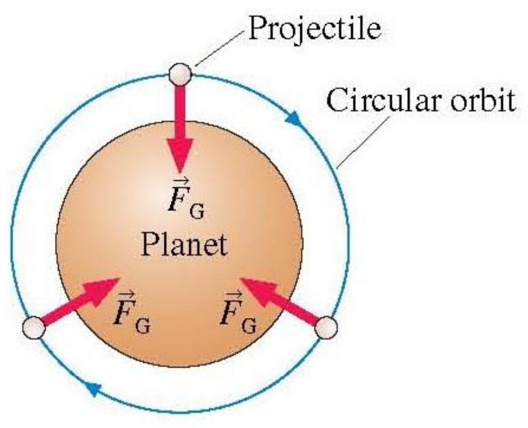
The Curvature of the Earth

- Earth surface drops a vertical distance of 5 meters for every 8000 meters tangent to the surface.





Flat-earth approximation

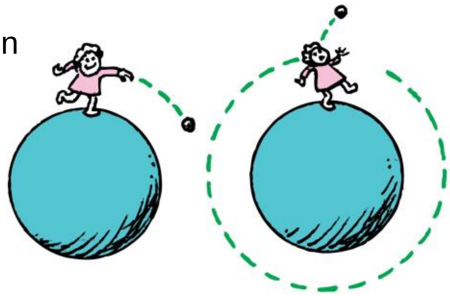


Spherical planet

Circular Satellite Orbits

Satellite in circular orbit

- Speed
  - must be great enough to ensure that its falling distance matches Earth’s curvature.
  - is constant—only direction changes.
  - is unchanged by gravity.



Example

How fast would you have to drive in order to be “weightless” – ie, no normal force needed to support your car?
How long would it take to drive around the world at this speed?

Circular Orbits

An object moving in a circular orbit of radius r at speed v_{orbit} will have centripetal acceleration of

$$a_r = \frac{(v_{\text{orbit}})^2}{r} = g$$

That is, if an object moves parallel to the surface with the speed

$$v_{\text{orbit}} = \sqrt{rg}$$

then the free-fall acceleration provides exactly the centripetal acceleration needed for a circular orbit of radius r.
An object with any other speed will not follow a circular orbit.

Clicker Question

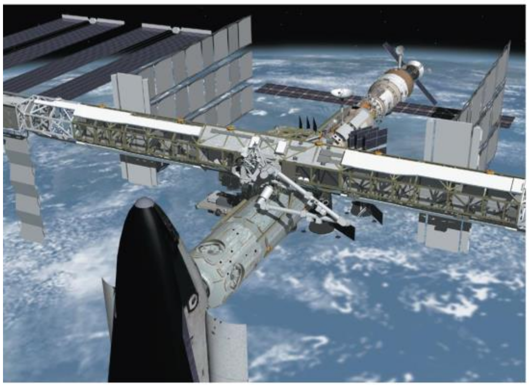
Why are communications satellites typically launched with rockets to heights of more than 100 km?

A. To get outside Earth's gravitational pull so the satellite doesn't fall down
B. To get closer to the Sun in order to collect more solar power
C. To get above the Earth's atmosphere in order to avoid air resistance
D. To get away from radio interference on Earth

Image from http://www.defenseindustrydaily.com/special-report-the-usas-transformational-communications-satellite-system-tsat-0866/

Image from http://www.zatznotfunny.com/2009-02/sirius-xm-headed-for-bankruptcy/]

Circular Satellite Orbits



- Positioning: beyond Earth's atmosphere, where air resistance is almost totally absent
- Example: Low-earth orbit communications satellites are launched to altitudes of 150 kilometers or more, in order to be above air drag
- But even the ISS, as shown, experiences *some* air drag, which is compensated for with periodic upward boosts.

Before Class 14 on Monday

- Please read the rest of Knight **Chapter 8**, and/or watch the Pre-Class Video, now on portal
- MasteringPhysics Problem Set 6 is due on Monday evening.
- It's been a lot of fun – you are an excellent class!
- I'll be back! You will see me again in January for PHY132!
- I hope you keep coming to my office hours T12-1 and F10-11 – I'd love to help!
- The next test is Nov. 11 on Chs. 4-10, which includes forces, momentum and energy

- And I will definitely see you at the Final Exam Dec. 15 2:00pm!

Image from http://wifflegif.com/tags/211457-i-ll-be-back-gifs