PHY131H1F

Class 13

Harlow’s Last Class ☹ on Monday Prof. Meyertholen takes over! ☺

> “For I must be traveling on, now
> ‘Cause there’s too many places
> I’ve got to see”
> – Lynyrd Skynyrd *Freebird*

Today:

- Dynamics in Two Dimensions
- Dynamics of Uniform Circular Motion
- Fictitious Forces

Vertical Circular Motion

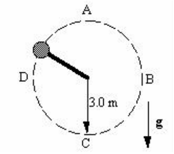
- A ball is whirled on a string in a vertical circle. As it is going around, the tension in the string is

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.



In situation (a), block B has a mass *m*.

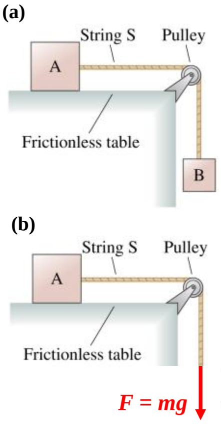
In situation (b), there is no hanging block, instead a downward pulling force is applied to the end of the string of magnitude *F* = *mg*.

In which situation will block A have a greater magnitude of acceleration?

A. situation (a)

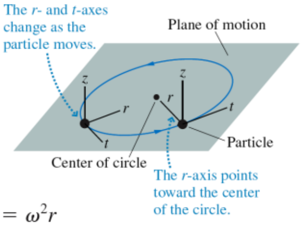
B. situation (b)

C. neither



Uniform Circular Motion

FIGURE 8.3 The *rtz*-coordinate system.



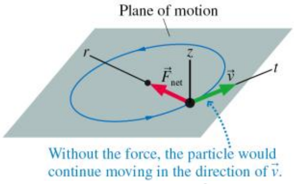
$$a_r = \frac{v^2}{r} = \omega^2 r$$

$$a_t = 0$$

$$a_z = 0$$

Dynamics of Uniform Circular Motion

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

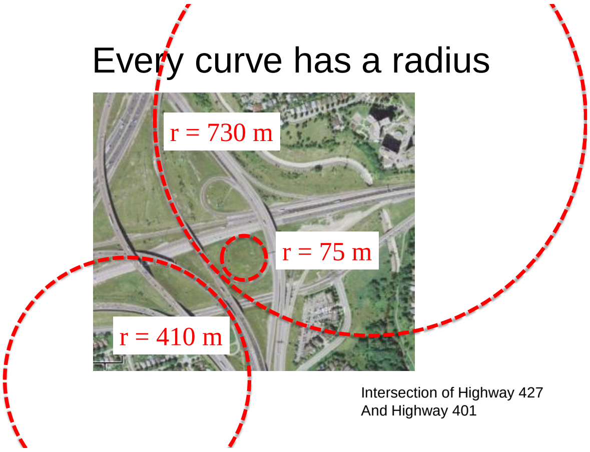


$$(F_{\text{net}})_r = \sum F_r = ma_r = \frac{mv^2}{r} = m\omega^2 r$$

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

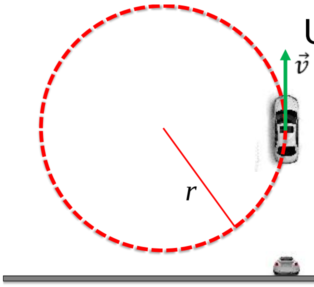
$$(F_{\text{net}})_z = \sum F_z = ma_z = 0$$

Every curve has a radius



Intersection of Highway 427
And Highway 401

Unbanked Curve

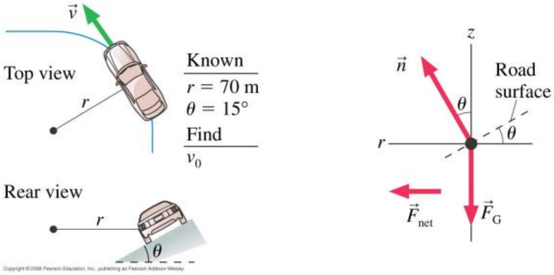


What horizontal force acts on the car to keep it on the curved path?

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

Banked Curve Example 8.5, pg.217

- 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?



Tonight at 55 Dundas St. W.:

Wednesday, October 24 at 7:30 pm
AT RYERSON UNIVERSITY, TORONTO

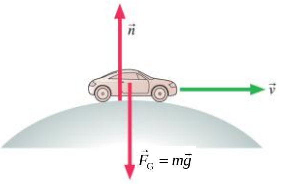
NSERC RCI FOUNDATION LECTURE*

Global Warming "Futures": How Reliable are the Model Projections?

W. Richard Peltier, B.S., M.Sc., Ph.D., Department of Physics, University of Toronto, Recipient of the 2011 Gerhard Herzberg Canada Gold Medal for Science and Engineering

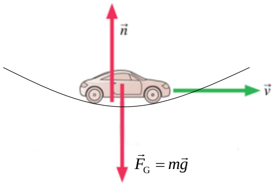
The problem of global climate warming remains an unmet challenge to the ability of the international community to respond. Warming due to increasing atmospheric greenhouse gas concentrations, caused primarily by human influence due to fossil fuel burning, is undeniable. Denial of the accuracy of the scientific projections of plausible futures is most often based upon claims that such projections depend upon overly complex computer models. I will discuss the physics embodied in these models and the tests that have been performed to establish their validity. These tests include not only verification of past projections by comparing them to subsequent observations, but also tests against episodes of extreme climate change that are known to have occurred in the past. I will also discuss what the models suggest will be the climate future in the next century of the Great Lakes Basin region of North America, a landscape inhabited by 35 million persons.

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.

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

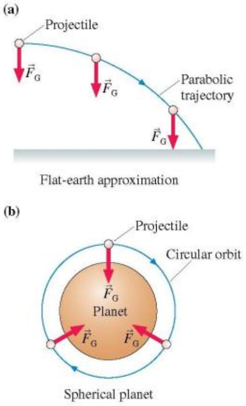
In the absence of air resistance, a projectile has only one force acting on it: the gravitational force, $F_G = mg$, in the downward direction. If we choose a coordinate system with a vertical y-axis, then

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

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

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

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



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

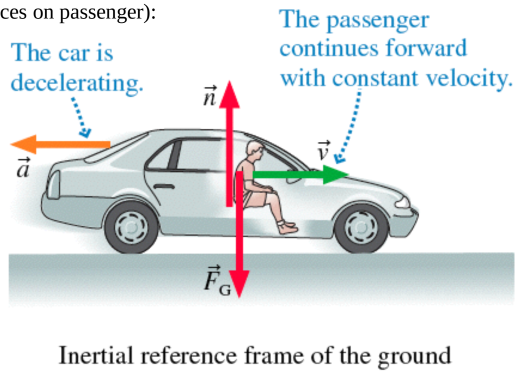
$$v_{\text{orbit}} = \sqrt{rg}$$

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.

Fictitious Forces

- If you are riding in a car that makes a sudden stop, you may feel as if a force “throws” you forward toward the windshield.
- There really is no such force.
- The real force is the backwards force of the dashboard on you when you hit it.
- Some books (not Knight) describe the experience in terms of what are called **fictitious forces**.
- These are not real, but they help describe motion *in a noninertial reference frame.*
- Knight avoids fictitious forces by doing all the calculations in inertial frames (better).

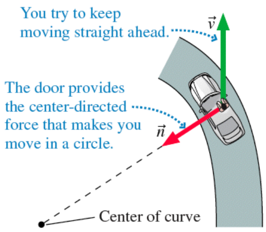
- This is what *really* happens in a sudden stop (no forward forces on passenger):



“Centrifugal Force” (a fictitious force)

- If the car you are in turns a corner quickly, you feel “thrown” against the door.
- The fictitious “force” that seems to push an object to the outside of a circle is called the “*centrifugal force*”.
- It helps describe your experience *relative to a noninertial reference frame*.
- In the inertial frame of the ground, the only real force is toward the centre not away.

Reality: Bird’s-eye view of a passenger as a car turns a corner.



Why Does the Water Stay in my coffee cup?

- Watch Harlow swing a cup of water over his head. If he swings the cup quickly, the water stays in. But the students in the front row will get a shower if he swings too slowly.

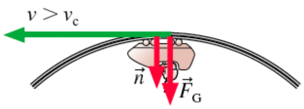
- The critical angular velocity ω_c is that at which gravity alone is sufficient to cause circular motion at the top.

$$\omega_c = \sqrt{\frac{g}{r}}$$

More than enough angular speed

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

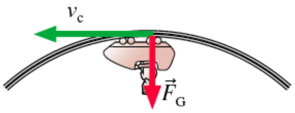
The normal force adds to gravity to make a large enough force for the car to turn the circle.



The point is: Normal force must always be *away* from the surface. It can never be *toward* the surface (unless the surface is covered with glue!)

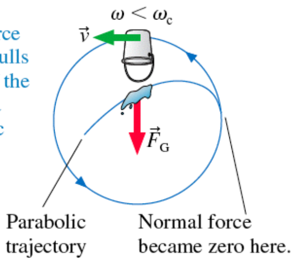
Just enough angular speed

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



Not enough angular speed

If $\omega < \omega_c$, the gravitational force is too large. It pulls the water out of the circle and into a tighter parabolic trajectory.



Before Class 14 on Wednesday

- Please read the Knight **Chapter 9**, and/or watch the Pre-Class Video, now on portal
- Note there is a MasteringPhysics Problem Set due on Friday.
- It's been a lot of fun – you are an excellent class!
- I hope you keep coming to my office hours W3-4 and F9-10 – maybe I can help
- The next test is Nov. 20 on Chs. 4-11, which includes momentum and energy
- And I will definitely see you at the Final Exam Dec. 13 2:00pm!