PHY131H1F - Class 13

Harlow's Last Class this semester ☹

on Monday Prof. Meyertholen takes over! ☺

Today, Chapter 8 Sections 8.1-8.3:

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

NOTE: We will not cover sections 8.4 and 8.5 in this course.

Clicker Question

Last day at the end of class I asked:

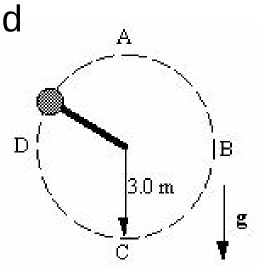
- A ball is whirled on a string in a vertical circle. As it is going around, the tension in the string is

A. greatest at the top of the motion

B. constant.

C. greatest at the bottom of the motion

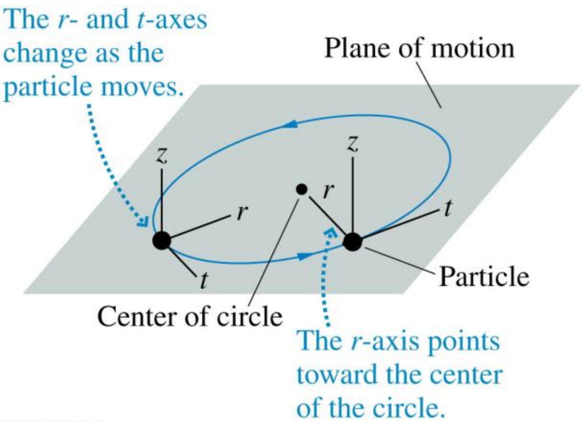
D. greatest somewhere in between the top and bottom.



Class 13 Preclass Quiz on MasteringPhysics

- This was due this morning at 8:00am
- 835 students submitted the quiz on time
- 74% of students answered correctly: Circular motion is best analyzed in a coordinate system with r-, t- and z- axes. If you use x- and y- axes, the x- and y- components are constantly changing!

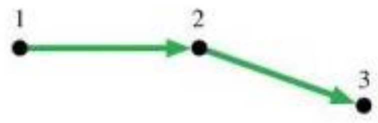
http://uoft.me/rtzcoord

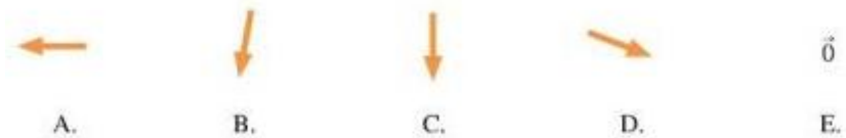


Clicker Question – retry this morning's pre-class reading question.

Class 13 Preclass Quiz on MasteringPhysics

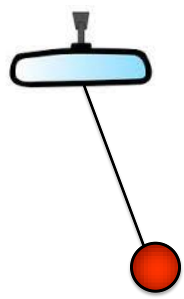
- 45% of students answered correctly: The diagram shows three points of a motion diagram. The particle changes direction with no change of speed. What is the acceleration at point 2?





Clicker Question – retry this morning's pre-class reading question.

- 39% of students answered correctly: A string is attached to the rear-view mirror of a car. A ball is hanging on the other end of the string. The car is driving around in a circle, at a constant speed. Which of the following lists gives all of the forces directly acting on the ball?
- A. Tension
- B. Tension, gravity, the centripetal force and friction
- C. Tension and gravity
- D. Tension, gravity and the centripetal force



Class 13 Preclass Quiz on MasteringPhysics

- Student feedback:
- *"I found banked curves to be the most confusing part of the reading."*
- *"centripetal force is not a force caused by any agent right? it is just a net component of gravity and normal force right?"*
- **Harlow answer**: right. Centripetal force is what you call the net force when the object is traveling in uniform circular motion.
- *"whats the point of the z component in circular motion?"*
- **Harlow answer:** Ya, it's true you can forget about the z.. It's just there for completeness.
- *"I'm still not totally clear on what the rho (p-looking constant) is and how to use it, in air resistance calculations."*
- **Harlow answer:** rho = ρ = density of a fluid in kg/m^3. ie for air just use 1.2

Class 13 Preclass Quiz on MasteringPhysics

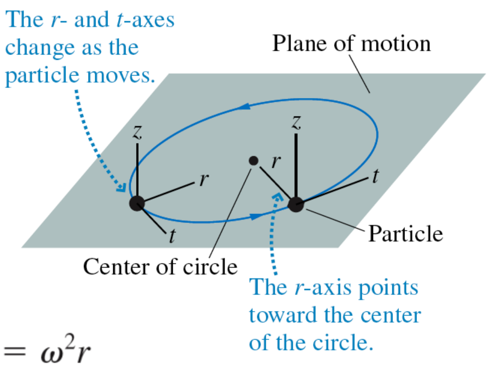
- Student feedback:
- *"All the mid terms are finished and my life is finished."*
- Happy birthday Vanessa T!
- *"Guess you could say this was a pretty r(i)tz-y chapter."*
- *"what day is the exam on? Thanks!"*
- **Harlow answer:** Monday Dec. 15 at 2pm
- *"we have over thousand students registered to this class but usually only around 700 students answer the clicker questions, which mean around 300 students missing from the lecture or doesn't answer clicker questions. is this normal?"*
- **Harlow answer:** The 1000 includes the 200 students in the evening section.

Class 13 Preclass Quiz on MasteringPhysics

- Student feedback:
- *"How do you pronounce the new professors last name?"*
- **Harlow answer:** "My - er - thow – len"
- *"Is Prof. Meyertholen as easygoing as you are? Tell us something about him! Something that he will never tell us would be better!"*
- **Harlow answer:** Yes. He is awesome.

Uniform Circular Motion

FIGURE 8.3 The *rtz*-coordinate system.



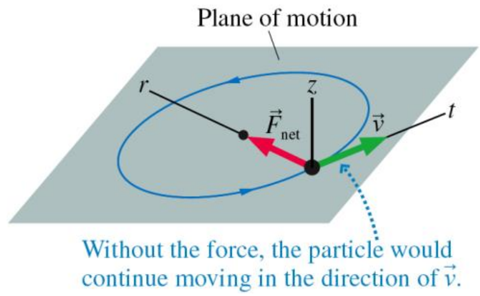
$$a_r = \frac{v^2}{r} = \omega^2 r$$

$$a_t = 0$$

$$a_z = 0$$

Dynamics of Uniform Circular Motion

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

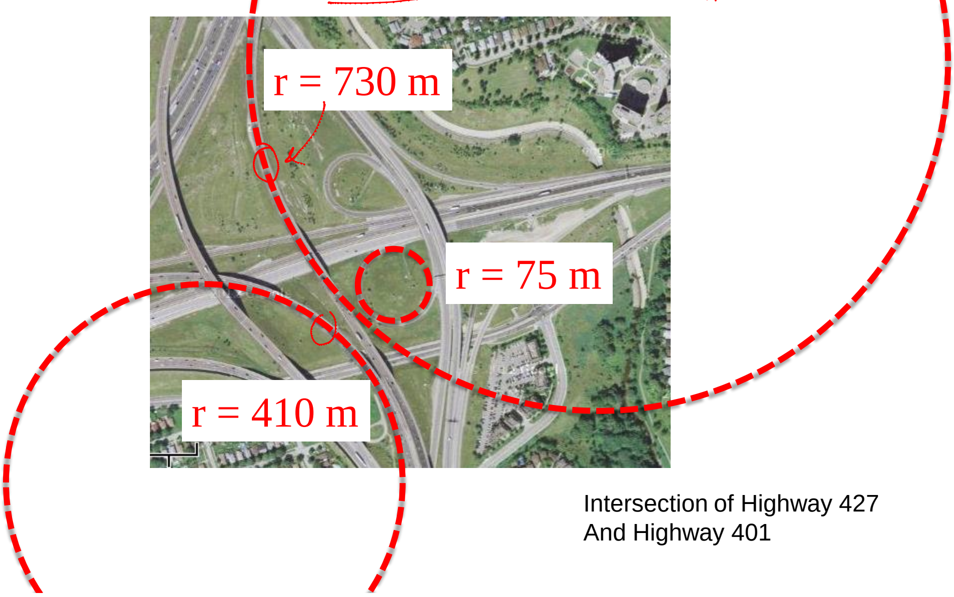


$$(F_{net})_r = \sum F_r = ma_r = \frac{mv^2}{r} = m\omega^2 r$$

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

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

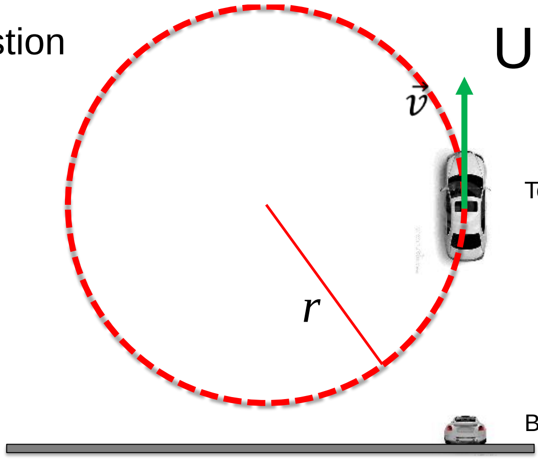
Every curve has a radius



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?

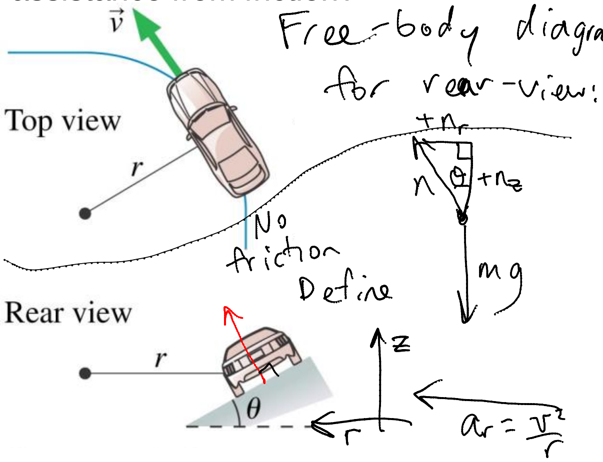
A. Gravity
B. Normal
C. Kinetic Friction
D. Static Friction
E. Rolling Friction

Class 13 Preclass Quiz on MasteringPhysics

- Student feedback:
- *"In the previous chapter, you say the acceleration is zero for the horizontal component, and now, it seems the acceleration is not zero anymore. why is this the case? how do i know when the acceleration for the horizontal component will be zero or not?"*
- Harlow answer: That's true! If the object is on a circular path (as viewed from above) then you know that $a = v^2/r$ sideways.

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?



	r	z
$\vec{n}$	$+n\sin\theta$	$+n\cos\theta$
$m\vec{g}$	0	$-mg$
$\vec{F}_{net}$		

$(F_{Net})_r = \frac{mv^2}{r} = n\sin\theta$

$(F_{Net})_z = 0 = n\cos\theta - mg$

$n\cos\theta = mg$

$\boxed{n = \frac{mg}{\cos\theta}}$

$\frac{\cancel{m}v^2}{r} = \left(\frac{\cancel{m}g}{\cos\theta}\right)\sin\theta \Rightarrow v = \sqrt{gr\frac{\sin\theta}{\cos\theta}}$

$v_0 = \boxed{14\ m/s}$

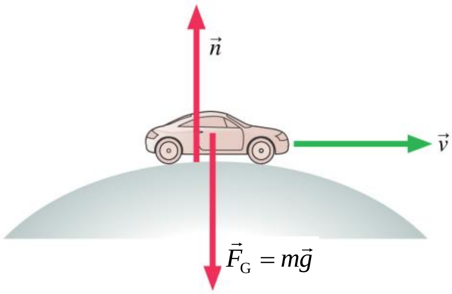
Class 13 Preclass Quiz on MasteringPhysics

- Student feedback:
- *"Experimentally, I know that driving around a corner too fast causes the car to skid up the hill. But why? Which part of our formula suggests that increasing the velocity too much will change the direction of the centripetal acceleration?"*
- **Harlow answer:** to get $F_{net} = mv^2/r$, you solve for f_s and n. If $f_s > \mu_s n$, then that's impossible, and the car can't stay on the circular path of radius r.

- *"I don't really understand how centripetal force can be the net force. What forces are cancelling to have a net force that points inwards?"*
- **Harlow answer:** All the actual forces add to give the inward pointing net force.

Clicker Question

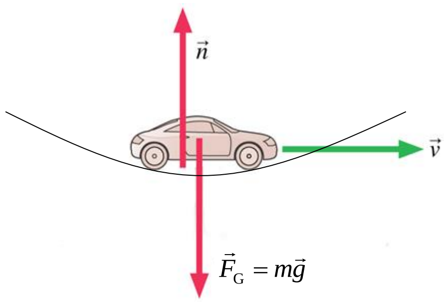
A car is rolling over the top of a hill at speed *v*. At this instant,



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

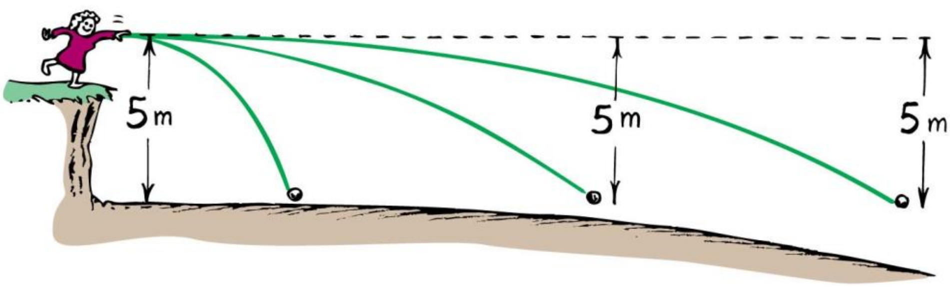
A girl throws a ball in a horizontal direction (dashed line). After the ball leaves the girl's hand, 1.0 seconds later it will have fallen

A. 9.8 meters.

B. 4.9 meters below the dashed line.

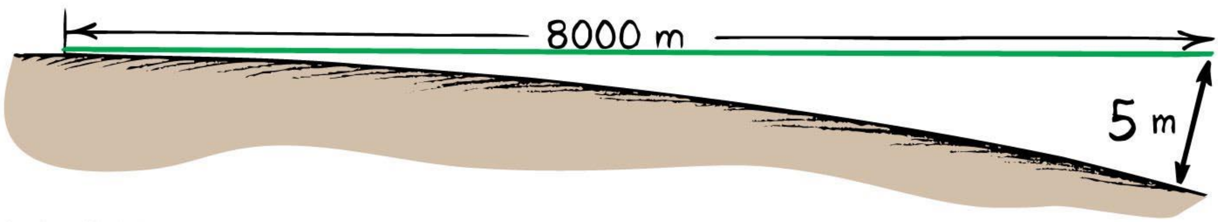
C. less than 4.9 meters below the straight-line path.

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



The Curvature of the Earth

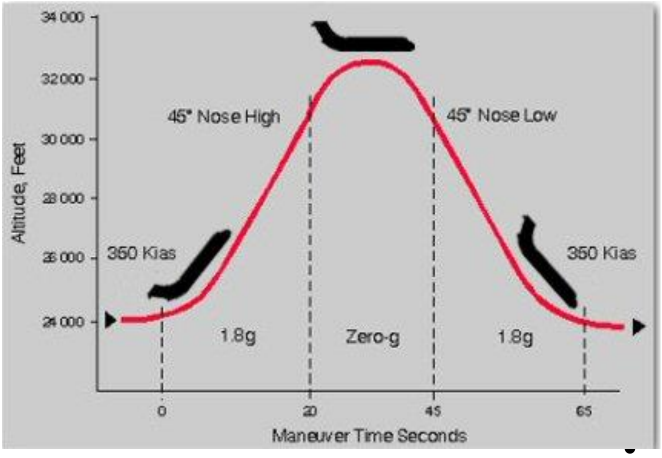
- Earth surface drops a vertical distance of 5 meters for every 8000 meters tangent to the surface.



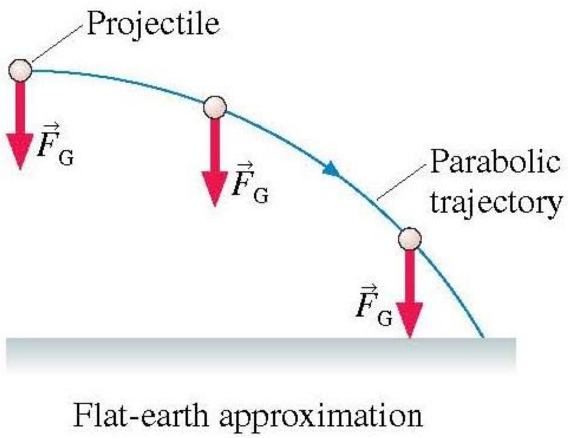
Class 13 Preclass Quiz on MasteringPhysics

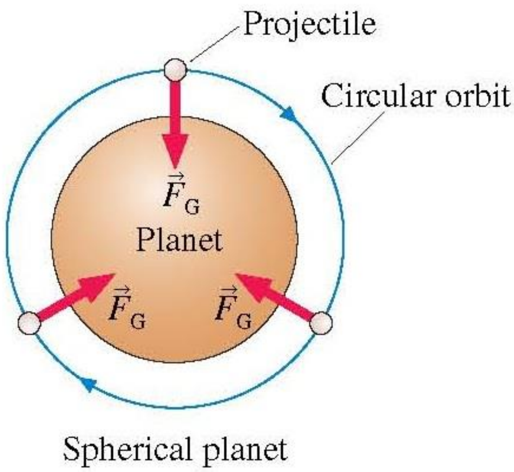
- Student feedback:
- *“I don't really understand how an orbiting spacecraft is actually constantly in free fall...then wouldn't it fall down?”*
- Harlow answer: **As it falls, it is moving so fast sideways, that the Earth curves away** below it. It is moving at the exact right sideways speed so that the Earth is “curving away” at 9.8 m/s^2, so as it falls, it actually never gets closer to the surface!

“Vomit Comet”



- Physicist Stephen Hawking.

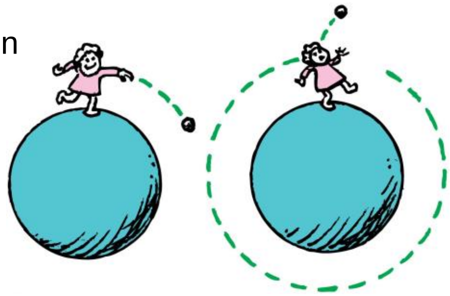




Circular Satellite Orbits

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.

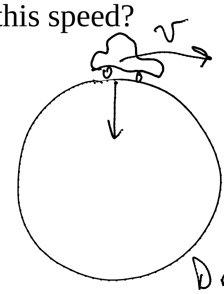


Example $R_{Earth} = 6.4 \times 10^6$ m

(a) How fast would you have to drive in order to be "weightless" – ie, no normal force needed to support your car?

(b) How long would it take to drive around the world at this speed?

(a)



fbd of car:

No normal force

mg

Define $+r$

$$(F_{net})_r = \frac{mv^2}{r} = mg$$

$$v = \sqrt{gr} = \sqrt{9.8(6.4 \times 10^6)}$$

$$= 7900 \frac{m}{s} = 7.9 \frac{km}{s}$$

circumference of Earth

$$C = 2\pi r = 40{,}000 \text{ km}$$

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

$$t = \frac{d}{v} = \frac{40000 \text{ km}}{7.8 \text{ km/s}}$$

$$= 5090 \text{ s}$$

$$\boxed{t = 84 \text{ minutes}}$$

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

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

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

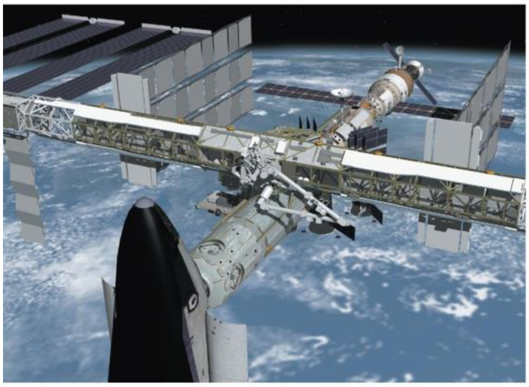
Why are communications satellites typically launched with rockets to heights of more than 100 km?

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 first three sections of Knight **Chapter 9**, 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. 4-9, which includes forces and momentum!

- 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