You can draw here

GET READY: Go here and make sure you see the “Are you Ready” Sli.do Q

Canvas -> Course Content -> Lecture (under Week 9 - Chapter 8)

Physics 111 - Lecture 9

November 5, 2020

Do not draw in/on this box!

You can draw here

You can draw here

Reminders/Announcements

- Bonus Test 3 (Chapters 6 and 7) starts today from 6PM - Saturday at 6 PM

- Next Wednesday, Thursday, Friday are all off due to Remembrance Day and midterm break

    - All Tutorials are cancelled,
    - Office hours on Wed/Thurs/Fri are cancelled
    - For us, business as usual (but deadlines extended for the due)
    - HW09 is due Monday Nov. 16 at 6 PM
    - No LL next week
    - Test window moved to Sun Nov 15 - Tues Nov 17

Reminders/Announcements

	Homework (due Thurs 6 pm)	Test/Bonus Test (Thurs 6pm - Sat 6pm)	Learning Log (Sat 6pm)
Week 1	-	-	-
Week 2	HW01 - Intro to Mastering Physics	Test 0 **(not for marks)**	Learning Log 1
Week 3	HW02 - Chapter 2 HW03 - Chapter 3	Test 1 (on Chapters 2 & 3)	Learning Log 2
Week 4	HW04 - Chapter 4	Bonus Test 1	Learning Log 3
Week 5	HW05 - Chapter 5	Test 2 (on Chapters 4 and 5)	Learning Log 4
Week 6	N/A	N/A	N/A
Week 7	HW06 - Chapter 6	Bonus Test 2	Learning Log 5
Week 8	HW07 - Chapter 7	Test 3	Learning Log 6
Week 9	HW08 - Chapter 8	Bonus Test 3	Learning Log 7
Week 10	HW09 - Chapter 9 (deadline extended)	Test 4 (window moved to Sun Nov 15 - Tues Nov 17 due to Fall mini-break)	No Learning Log
Week 11	HW10	Bonus Test 4	Learning Log 8
Week 12	HW 11	Test 5	Learning Log 9
Week 13	HW 12	Bonus Test 5	Learning Log 10

Chapter 7
Important Concepts

Are Newton's laws different in two dimensions?

No. Newton's laws are vector equations, and they work equally well in two and three dimensions. For motion in a plane, we'll focus on how a force *tangent* to a particle's trajectory changes its speed, while a force *perpendicular* to the trajectory changes the particle's direction.

« LOOKING BACK Chapter 4 Kinematics of projectile and circular motion

Newton's Second Law

Expressed in x- and y-component form:

$$(F_{\text{net}})_x = \sum F_x = ma_x$$

$$(F_{\text{net}})_y = \sum F_y = ma_y$$

Expressed in rtz-component form:

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

$$(F_{\text{net}})_t = \sum F_t = \begin{cases} 0 & \text{uniform circular motion} \\ ma_t & \text{nonuniform circular motion} \end{cases}$$

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

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How do we analyze circular motion?

Circular motion must have a force component toward the center of the circle to create the centripetal acceleration. In this case the acceleration components are radial and, perhaps, tangential. We'll use a different coordinate system, *rtz* coordinates, to study the dynamics of circular motion

Why doesn't the water fall out of the bucket?

How can you swing a bucket of water over your head without the water falling out? Why doesn't a car going around a loop-the-loop fall off at the top? Circular motion is not always intuitive, but you'll strengthen your ability to use Newtonian reasoning by thinking about some of these problems.

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Projectile Motion: Review

- Consider a projectile with initial speed v_0, and a launch angle of θ above the horizontal.
- In Chapter 4 we found that the distance it travels before it returns to the same elevation from which it was launched (the *range*) is

Trajectories of a projectile launched at different angles with a speed of 99 m/s.

$$\text{range} = \frac{v_0^2 \sin(2\theta)}{g}$$

- The maximum range occurs for $\theta = 45^{\circ}$.
- All of these results *neglect* the effect of air resistance.

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Projectile Motion

- The acceleration of a typical projectile subject to drag force from the air is:

$$a_x = -\frac{\rho CA}{2m} v_x \sqrt{v_x^2 + v_y^2}$$

$$a_y = -g - \frac{\rho CA}{2m} v_y \sqrt{v_x^2 + v_y^2}$$

- The components of acceleration are *not* independent of each other.
- These equations can only be solved numerically.
- The figure shows the numerical solution for a 5-g plastic ball.

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Uniform Circular Motion

- A particle in uniform circular motion with angular velocity ω has velocity $v = \omega r$, in the tangential direction.
- The acceleration of uniform circular motion points to the center of the circle.
- The rtz-components of $\vec{v}$ and $\vec{a}$ are

$$v_r = 0 \qquad a_r = \frac{v^2}{r} = \omega^2 r$$

$$v_t = \omega r \qquad a_t = 0$$

$$v_z = 0 \qquad a_z = 0$$

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Does this analysis apply to orbits?

Yes, it does. The circular orbit of a satellite or planet is motion in which the force of gravity is creating the inward centripetal acceleration. You'll see that an orbiting projectile is in free fall.

« LOOKING BACK Section 6.3 Gravity and weight

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Gravity on a Rotating Earth

- The figure shows an object being weighed by a spring scale on the earth's equator.
- The observer is hovering in an inertial reference frame above the north pole.
- If we pretend the spring-scale reading is $F_{Sp} = F_G = mg$, this has the effect of "weakening" gravity.
- The free-fall acceleration we measure in our rotating reference frame is

$$g = \frac{F_G}{m} = \frac{F_{M \text{ on } m} - m\omega^2 R}{m} = \frac{GM}{R^2} - \omega^2 R = g_{earth} - \omega^2 R$$

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Loop-the-Loop

- Consider the roller-coaster free-body diagram at the *bottom* of the loop.
- Since the net force is toward the center (upward at this point), $n > F_G$.
- This is why you "feel heavy" at the bottom of the valley on a roller coaster.

$$\sum F_r = n_r + (F_G)_r = n - mg = ma_r = \frac{m(v_{bot})^2}{r}$$

$$n = mg + \frac{m(v_{bot})^2}{r}$$

- The normal force at the bottom is *larger* than mg.

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Loop-the-Loop

- The figure shows the roller-coaster free-body diagram at the *top* of the loop.
- The track can only push on the wheels of the car, it cannot pull, therefore $\vec{n}$ presses *downward.*
- The car is still moving in a circle, so the net force is also downward:

$$\sum F_r = n_r + (F_G)_r = n + mg = \frac{m(v_{top})^2}{r}$$

$$n = \frac{m(v_{top})^2}{r} - mg$$

- The normal force at the at the top can exceed mg if v_{top} is large enough.

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Loop-the-Loop

- At the top of the roller coaster, the normal force of the track on the car is

$$n = \frac{m(v_{\text{top}})^2}{r} - mg$$

- As v_{top} decreases, there comes a point when n reaches zero.
- The speed at which $n = 0$ is called the **critical speed**:

$$v_{\text{c}} = \sqrt{\frac{rmg}{m}} = \sqrt{rg}$$

- This is the slowest speed at which the car can complete the circle without falling off the track near the top.

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Loop-the-Loop

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.

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

The gravitational force is too large for the car to stay in the circle!

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Nonuniform Circular Motion

- The figure shows a particle moving in a circle of radius r.
- In addition to a radial force component—required for all circular motion—this particle experiences a tangential force component and hence a tangential acceleration:

$$a_t = \frac{dv_t}{dt}$$

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Dynamics of Nonuniform Circular Motion

- Force and acceleration are related through Newton's second law:

$$(F_{\text{net}})_r = \sum F_r = ma_r = \frac{mv_t^2}{r} = m\omega^2 r$$
$$(F_{\text{net}})_t = \sum F_t = ma_t$$
$$(F_{\text{net}})_z = \sum F_z = 0$$

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Question: Curves on roads are “banked” so that at the recommended speed, the driver does not have to rely on Friction between the car tires and the road surface to round the curve.

At what angle **ϴ** should the curve be banked if the recommended velocity is **v**, and the radius of the road curvature is **r,** and the car + driver mass is **m**?

Chapter 8
Clicker Questions

Let's try this: If we do breakout rooms, and you do not want to participate with your peers, that's fine!

Stay in the main room and don't join the room!!

QuickCheck 8.3

An ice hockey puck is tied by a string to a stake in the ice. The puck is then swung in a circle. What force or forces does the puck feel?

A. A new force: the centripetal force.
B. A new force: the centrifugal force.
C. One or more of our familiar forces pushing outward.
D. One or more of our familiar forces pulling inward.
E. I have no clue.

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QuickCheck 8.4

An ice hockey puck is tied by a string to a stake in the ice. The puck is then swung in a circle.

What force is producing the centripetal acceleration of the puck?

A. Gravity

B. Air resistance

C. Friction

D. Normal force

E. Tension in the string

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QuickCheck 8.9

A physics textbook swings back and forth as a pendulum. Which is the correct free-body diagram when the book is at the bottom and moving to the right?

A. B. C. D. E.

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QuickCheck 8.10

A car that's out of gas coasts over the top of a hill at a steady 20 m/s. Assume air resistance is negligible. Which free-body diagram describes the car at this instant?

A. B. C. D. E.

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QuickCheck 8.11

A roller coaster car does a loop-the-loop. Which of the free-body diagrams shows the forces on the car at the top of the loop? Rolling friction can be neglected.

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QuickCheck 8.12

A ball rolls ccw around the inside of a horizontal pipe. The ball is fastest at the lowest point, slowest at the highest point. At the point shown, with the ball moving down, what is the direction of the net force on the ball?

A. B. C. D. E.

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