

PHYS 1443 – Section 003

Lecture #11

Monday, March 8, 2021

*Dr. **Jaehoon** Yu*

- CH4: Newton's Laws of Motion
 - Motion with friction
- CH5: Circular Motion and Gravitation
 - Kinematics of Uniform Circular Motion
 - Dynamics of Uniform Circular Motion
 - Newton's Law of Universal Gravitation

Today's homework is homework #7, due 11pm, Tuesday, March 30!!



Announcements

- Reading Assignments: CH5.4, 5.5 and 5.9
- Mid-term comprehensive in class next Wednesday, March 10
 - Roll call begins at **2:20pm**.
 - Covers CH1.1 – what we learn today, Monday, March 8 (CH5.5?)+ Math refresher
 - Please do not miss the exam! → You will get an F!!
 - BYOF: You may bring one 8.5x11.5 sheet (front and back) of **handwritten** formulae and values of constants for the test
 - No derivations, word definitions, setups or solutions of any problems, figures, pictures, diagrams or arrows, etc!
 - Must email me the photos of front and back of the formula sheet, including the blank at jaehoonyu@uta.edu no later than **12:00pm the day of the test**
 - The subject of the email should be the same as your file name
 - File name must be FS-E2-LastName-FirstName-SP21.pdf
 - Once submitted, you cannot change, unless I ask you to delete part of the sheet!
- Quiz results: Class average – 30/70 → 43/100 (Q1: 62/100) Top: 70/70
- Reminder: Extra credit special COVID seminar at 4pm Saturday, March 20
 - Extra credit for participation and for asking the relevant questions

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Reminder: SP #3 – Statistical Analysis : COVID19

- Make comparisons of COVID-19 statistics between the U.S., South Korea, Italy and Texas from <https://coronaboard.com> on spreadsheet
 - Total **44 points**: 1 point for each of the top 20 cells and 2 points for each of the 8 cells for vaccination
- Fill the US Historic event analysis table at the bottom 12 cells of the sheet (2 points per cell, **24 points** total) and make a >3 sentence statement on COVID19 with respect to other events (**6 points**)
- What are the 3 fundamental quantitative requirements for opening up (2 points each, **6 points** total)?
 - **Must be quantitative! (e.g. number of tests per capita per day, positivity rate, etc)**
- Assess the readiness of the three fundamental requirements U.S. (Do NOT just take politician's words!). Must provide the independent scientific entity's reference you took the information from. (2 point each, **total 6 points**)
- Evaluate **quantitatively** the success/failure of the US responses to COVID-19 in 2020 in 5 sentences and that in 2021 in 5 sentences. **Must provide quantitative reasons behind your conclusion!** (2 points each sentence, **20 points total**)
- Assess **quantitatively** the effectiveness of wearing masks (**4 points**) and at least 4 reasons for it being effective (1 point each, **0.5 point extra after the first 4**).
- **Possible maximum: 122 points total**
- **Due: 11pm, Friday, March 19**
 - Submit one pdf file SP3-YourLastName-YourFirstName.pdf, including the spreadsheet
 - Spreadsheet will be posted on canvas. Download ASAP.

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PHYS1443-003, Spring 21, Special Project #3, Statistical Analysis - COVID19

Name:			Date & time of your COVID-19 Data:		
Items		U.S.A	South Korea	Italy	Texas
Total Population					
COVID-19 Confirmed cases	Total				
	Cases per 1M people				
COVID-19 Deaths	Total				
	Death per 1M people				
COVID-19 Testing	Total				
	Testing per 1M people				
	Poditivity Rate				
COVID-19 Vaccination to date	Total				
	Per 1M people				
		COVID-19	US H1N1	US Vietnam War	US World War II
US Historic Event Analysis	Time period (mm/dd/yy - MM/DD/YY)				
	Duration in Months				
	Total deaths				
	Death per month				



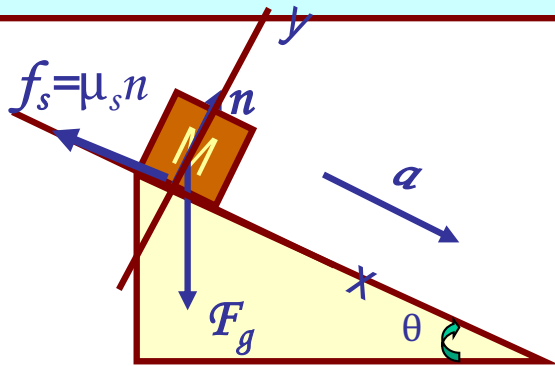
Steps for solving mechanics problems using Newton's Laws

1. Identify all the forces acting on the object of interest in the problem.
2. Establish a vector sum equation using all identified forces.
 - Note that the vector sum of all forces are the net force that provides the acceleration to the object's motion
3. Set the coordinates so that one axis aligns with the anticipated direction of motion (=direction of the net force!).
4. Identify all components of the forces in each coordinate.
5. Establish the force equation for each component, whose right hand-side is the mass of the object times the acceleration in that particular direction.
6. Solve each equation of component for the the quantities of interests.
7. If any further equation of motion is of interest, use combinations of kinematic equations to obtain the answers.

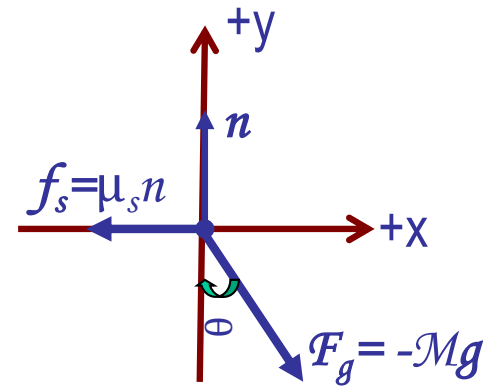


Example w/ Friction

Suppose a block is placed on a rough surface inclined relative to the horizontal. The inclination angle is increased till the block starts to move. Show that by measuring this critical angle, θ_c , one can determine coefficient of static friction, μ_s .



Free-body
Diagram



Net force eq.

$$\vec{F} = M\vec{a} = \vec{F}_g + \vec{n} + \vec{f}_s$$

x comp.

$$F_x = F_{gx} - f_s = Mg \sin \theta - f_s = 0 \quad f_s = \mu n = Mg \sin \theta_c$$

y comp.

$$F_y = Ma_y = n - F_{gy} = n - Mg \cos \theta_c = 0 \quad n = F_{gy} = Mg \cos \theta_c$$

$$\mu_s = \frac{Mg \sin \theta_c}{n} = \frac{Mg \sin \theta_c}{Mg \cos \theta_c} = \tan \theta_c$$

Motion in Resistive Force

A medium can exert resistive forces on an object moving through it due to viscosity or other types frictional properties of the medium.

Some examples?

Air resistance, viscous force of liquid, etc

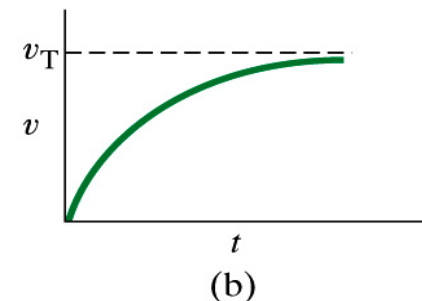
These forces are exerted on moving objects in the opposite direction to the movement.

These forces are proportional to such factors as speed. They almost always increase with increasing speed.

Two different cases of proportionality:

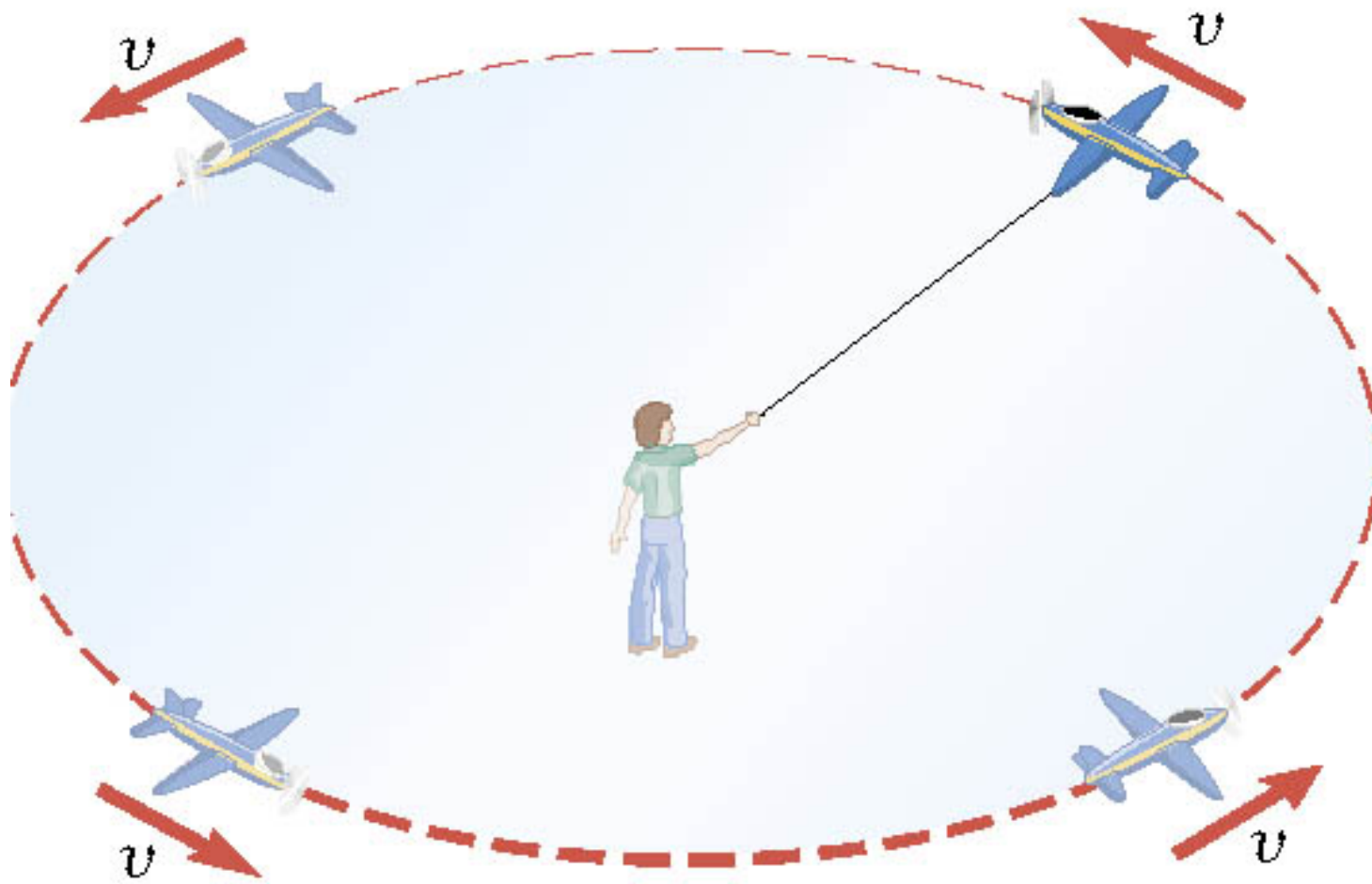
1. Forces linearly proportional to speed:
Slowly moving or very small objects
2. Forces proportional to square of speed:
Large objects w/ reasonable speed

$$\mathbf{F}_D = -b\mathbf{v}$$



Definition of the Uniform Circular Motion

Uniform circular motion is the motion of an object traveling at a **constant speed** on a circular path.



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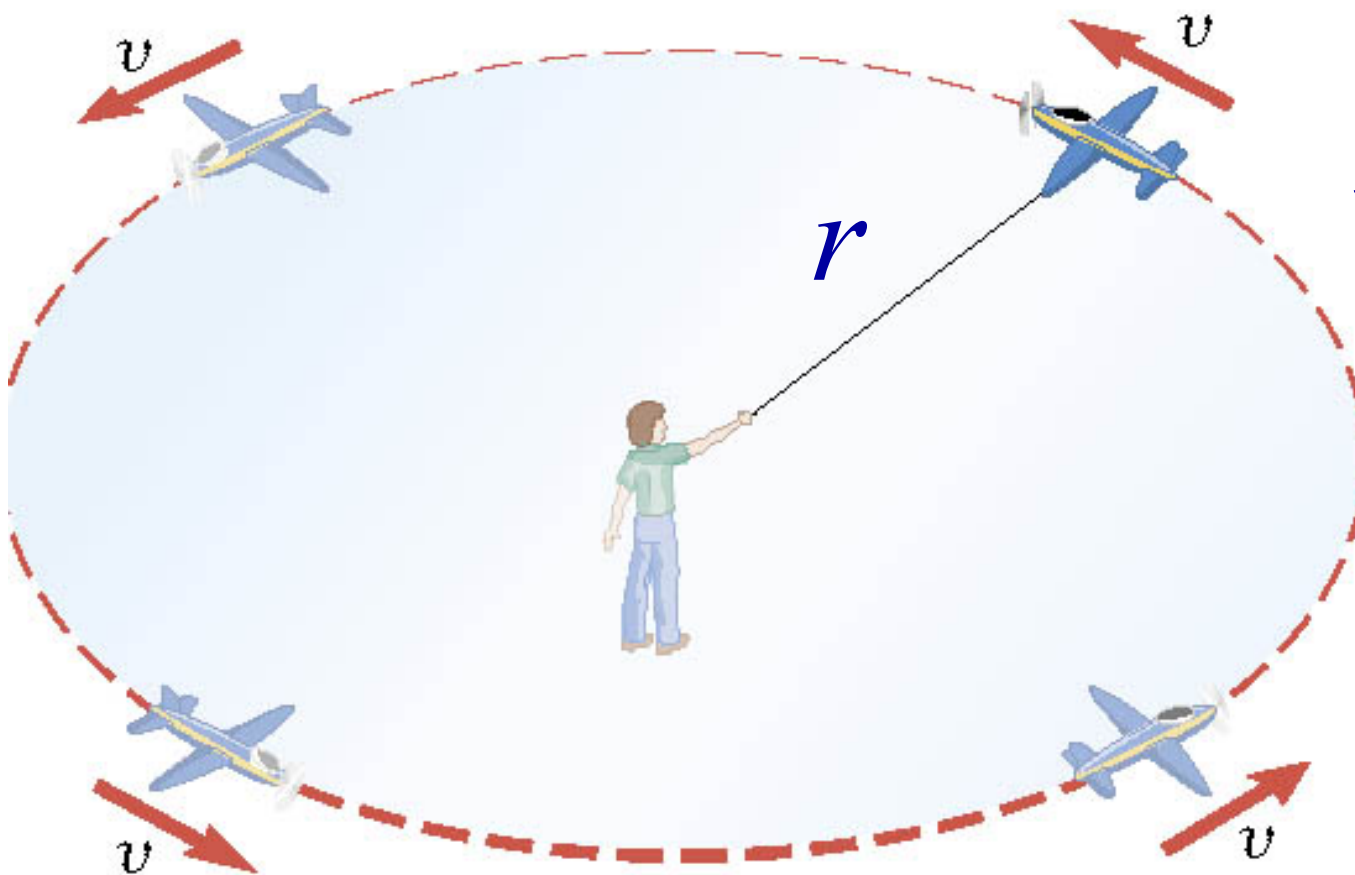


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Speed of a uniform circular motion?

Let T be the period of this motion, the time it takes for the object to travel once around the complete circle whose radius is r is



$$v = \frac{\text{distance}}{\text{time}} \\ = \frac{2\pi r}{T}$$

Ex. : A Tire-Balancing Machine

The wheel of a car has a radius of 0.29m and is being rotated at 830 revolutions per minute on a tire-balancing machine.

Determine the speed at which the outer edge of the wheel is moving.

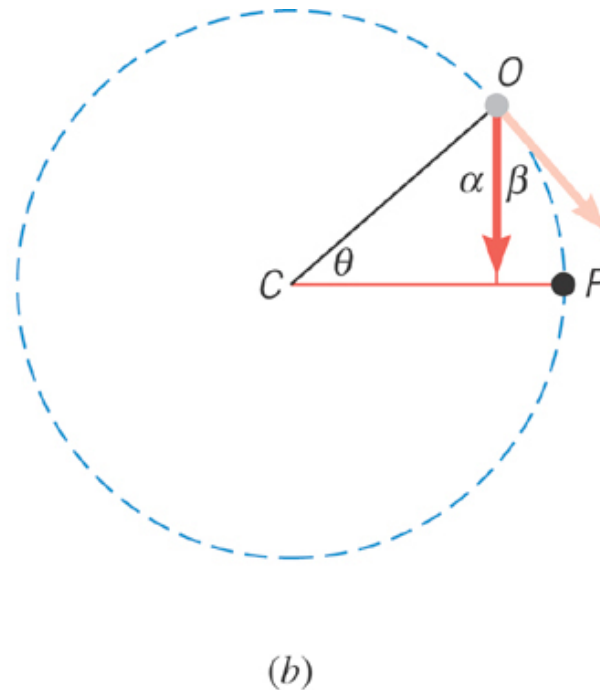
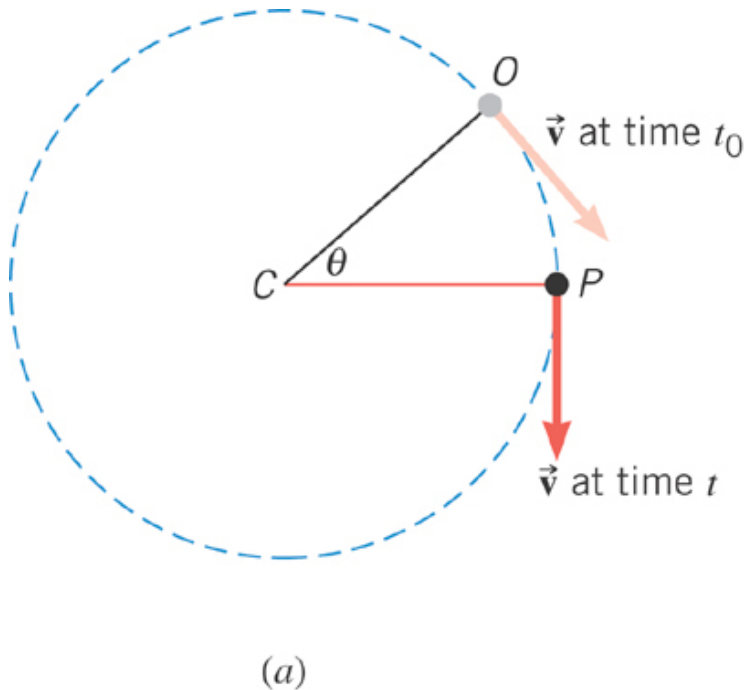
$$\frac{1}{830 \text{ revolutions/min}} = 1.2 \times 10^{-3} \text{ min/revolution}$$

$$T = 1.2 \times 10^{-3} \text{ min} = 0.072 \text{ s}$$

$$v = \frac{2\pi r}{T} = \frac{2\pi(0.29 \text{ m})}{0.072 \text{ s}} = 25 \text{ m/s}$$

Centripetal Acceleration

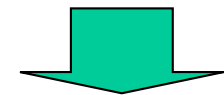
In a uniform circular motion, the speed is constant, but the direction of the velocity vector is *not constant*.



$$\alpha + \beta = 90^\circ$$

$$\alpha + \theta = 90^\circ$$

$$\beta - \theta = 0$$



$$\beta = \theta$$

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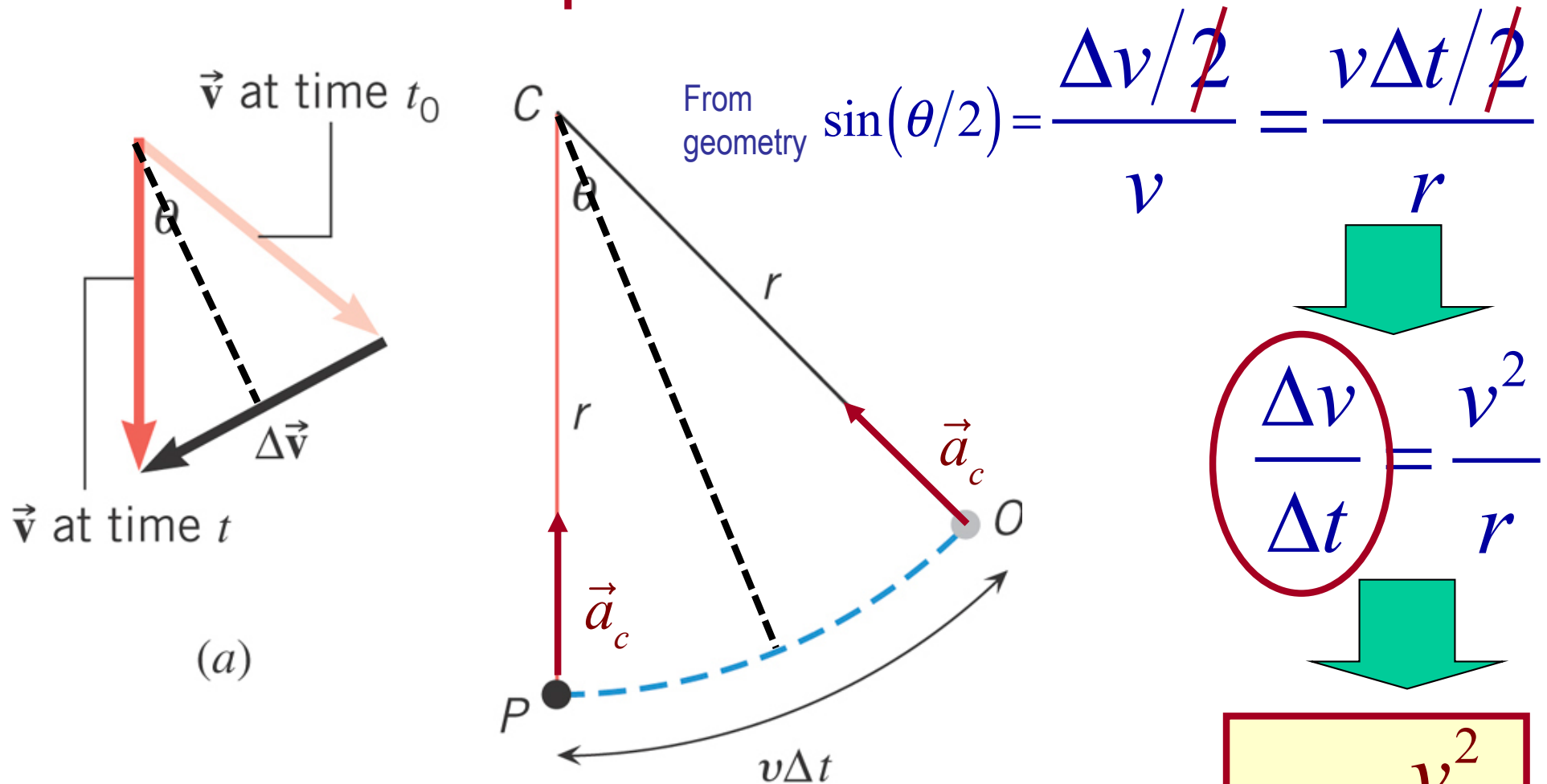


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The change of direction of the velocity is the same as the change of the angle in the circular motion!

Dr. Saadoun Fa

Centripetal Acceleration

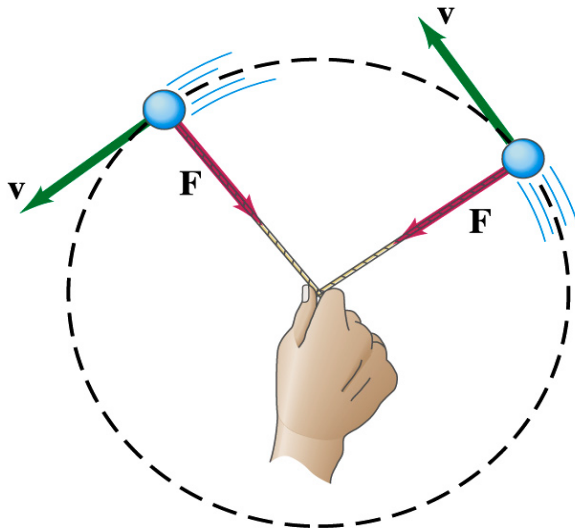


What is the direction of a_c ?

Always toward the center of the circle!

Centripetal Acceleration

Newton's Second Law & Uniform Circular Motion



The centripetal ^{*} acceleration is always perpendicular to the velocity vector, $\mathbf{v}$, and points to the center of the axis (radial direction) in a uniform circular motion.

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

Are there forces in this motion? If so, what do they do?

The force that causes the centripetal acceleration acts toward the center of the circular path and causes the change in the direction of the velocity vector. This force is called the centripetal force.

$$\sum F_r = ma_r = m \frac{v^2}{r}$$

What do you think will happen to the ball if the string that holds the ball breaks?

The external force no longer exist. Therefore, based on Newton's 1st law, the ball will continue its motion without changing its velocity and will fly away along the tangential direction to the circle.

***Mirriam Webster: Proceeding or acting in the direction toward the center or axis**

Ex. For Uniform Circular Motion

A ball of mass 0.500kg is attached to the end of a 1.50m long cord. The ball is moving in a horizontal circle. If the string can withstand the maximum tension of 50.0 N, what is the maximum speed the ball can attain before the cord breaks?

Centripetal
acceleration:

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

When does the
string break?

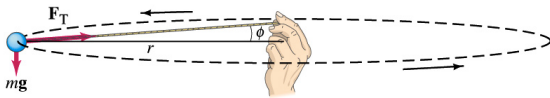
$$\sum F_r = ma_r = m \frac{v^2}{r} > T$$

when the required centripetal force is greater than the sustainable tension.

$$m \frac{v^2}{r} = T \quad v = \sqrt{\frac{Tr}{m}} = \sqrt{\frac{50.0 \times 1.5}{0.500}} = 12.2 (m/s)$$

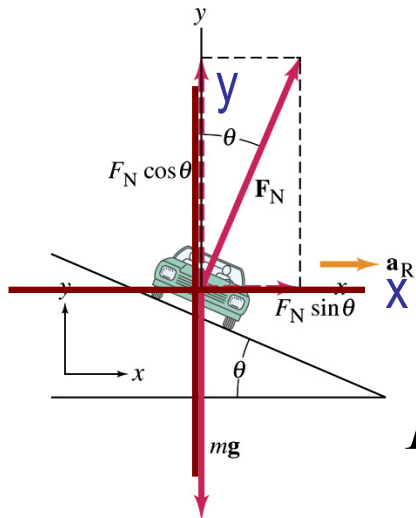
Calculate the tension of the cord
when speed of the ball is 5.00m/s.

$$T = m \frac{v^2}{r} = 0.500 \times \frac{(5.00)^2}{1.5} = 8.33 (N)$$



Example: Banked Highway

(a) For a car traveling with speed v around a curve of radius r , determine the formula for the angle at which the road should be banked so that no friction is required to keep the car from skidding.



x comp. $\sum F_x = F_N \sin \theta = ma_r = \frac{mv^2}{r}$

$$F_N \sin \theta = \frac{mv^2}{r}$$

y comp. $\sum F_y = F_N \cos \theta - mg = 0 \quad F_N \cos \theta = mg$

$$F_N = \frac{mg}{\cos \theta} \quad F_N \sin \theta = \frac{mg \sin \theta}{\cos \theta} = mg \tan \theta = \frac{mv^2}{r}$$

$$\tan \theta = \frac{v^2}{gr}$$

(b) What is this angle for an expressway off-ramp curve of radius 50m at a design speed of 50km/h?

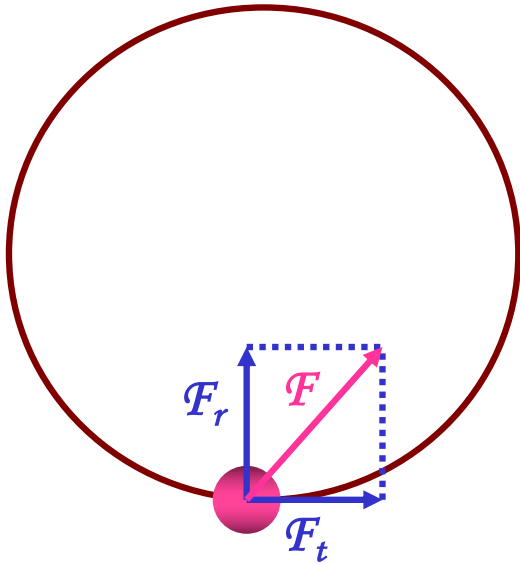
$$v = 50 \text{ km/hr} = 14 \text{ m/s} \quad \tan \theta = \frac{(14)^2}{50 \times 9.8} = 0.4 \quad \theta = \tan^{-1}(0.4) = 22^\circ$$

Forces in Non-uniform Circular Motion

The object has both tangential and radial accelerations.

What does this statement mean?

The object is moving under both tangential and radial forces.



$$\vec{F} = \vec{F}_r + \vec{F}_t$$

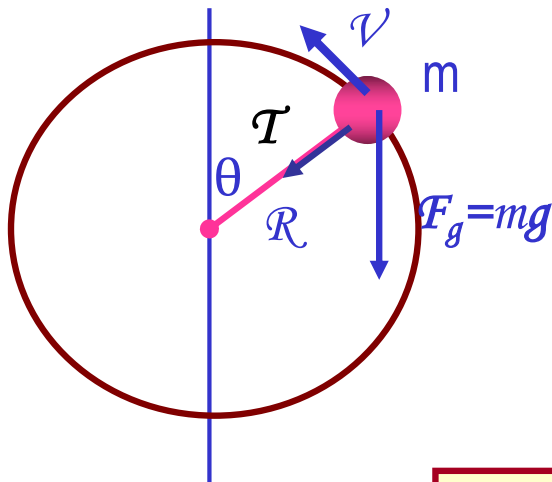
These forces cause not only the velocity but also the speed of the ball to change. The object undergoes a curved motion in the absence of constraints, such as a string.

What is the magnitude of the net acceleration?

$$a = \sqrt{a_r^2 + a_t^2}$$

Ex. for Non-Uniform Circular Motion

A ball of mass m is attached to the end of a cord of length R . The ball is moving in a vertical circle. Determine the tension of the cord at any instance in which the speed of the ball is v and the cord makes an angle θ with vertical.



What are the forces involved in this motion?

- The gravitational force F_g
- The radial force, T , providing the tension.

tangential
comp.

$$\sum F_t = mg \sin \theta = ma_t$$

$$a_t = g \sin \theta$$

Radial
comp.

$$\sum F_r = T + mg \cos \theta = ma_r = m \frac{v^2}{R}$$

$$T = m \left(\frac{v^2}{R} - g \cos \theta \right)$$

At what angles the tension becomes the maximum and the minimum. What are the tensions?

