PHY131H1F Summer – Class 4

Today:
- Circular Motion
- Forces
- Free Body Diagrams
- Newton's Second Law
- Newton's First Law

Pre-class Reading Quiz. (Chapter 4)

$$\frac{d\omega}{dt} = \alpha$$

The time derivative of ω is α. What are the S.I. units of α ?

A. m/s^2
B. N
C. N/m
D. rad
E. rad $/s^2$

Pre-class Reading Quiz. (Chapter 5)

Knight prefers to group the **causes** on the right hand side of the equals sign, and **effects** on the left hand side of the equals sign.

This author's preferred way of writing Newton's Second Law of motion is:

A. $a = \frac{F_{net}}{m}$

B. $F_{net} = ma$

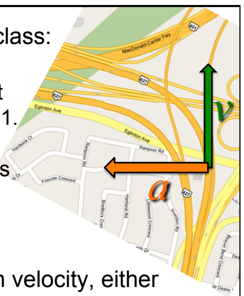
C. $m = \frac{F_{net}}{a}$

Test on June 2 evening – 1 week from today!

- Test will be Thursday, June 2 from 6:10pm to 8:00pm in EX100.
- There are no practicals that day, nor is there a class in BA1160.
- Test will cover Chs.1-6, the Error Analysis Document and Practicals Sessions 1-4 Material.
- Please bring a non-communicating calculator and a single 2-sided 8.5”x11” **aid sheet** which **you** have prepared yourself with helpful equations, etc.
- I will provide any numerical constants you may need on the test.

Last day I asked at the end of class:

- You are driving North Highway 427, on the smoothly curving part that will join to the Westbound 401. Your speedometer is constant at 115 km/hr. Your steering wheel is not rotating, but it is turned to the left to follow the curve of the highway. Are you accelerating?



- ANSWER: YES! Any change in velocity, either magnitude or speed, implies you are accelerating.
- If so, in what direction?
- ANSWER: West. If your speed is constant, acceleration is always perpendicular to the velocity, toward the centre of circular path.

FIGURE 4.32 A particle in uniform circular motion.

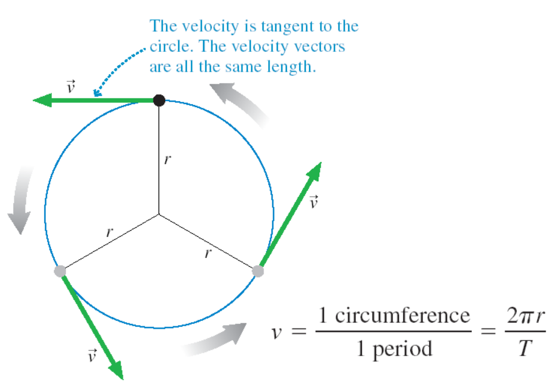
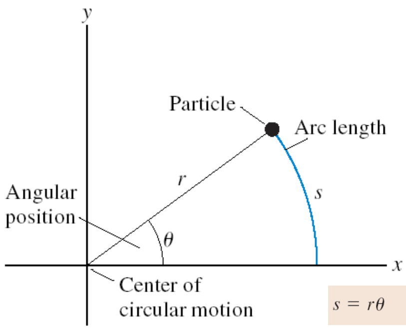
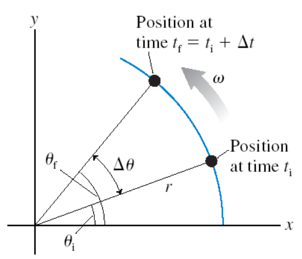


FIGURE 4.33 A particle's position is described by distance r and angle θ.



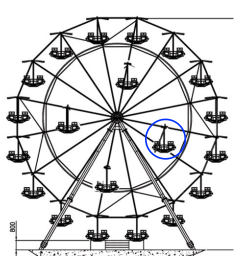
$s = r\theta$ (with θ in rad)

FIGURE 4.34 A particle moves with angular velocity ω.



$$\omega \equiv \lim_{\Delta t \to 0} \frac{\Delta\theta}{\Delta t} = \frac{d\theta}{dt} \quad \text{(angular velocity)}$$

$$\theta_f = \theta_i + \omega \Delta t \quad \text{(uniform circular motion)}$$



In-Class Discussion Question :

A carnival has a Ferris wheel where some seats are located halfway between the center and the outside rim. Compared with the seats on the outside rim, the inner cars have

A. Smaller angular speed and greater tangential speed
B. Greater angular speed and smaller tangential speed
C. The same angular speed and smaller tangential speed
D. Smaller angular speed and the same tangential speed
E. The same angular speed and the same tangential speed

A ball rolls along a frictionless track on a horizontal table, as seen from above in the figure. The track is curved in ¾ of a circle. The ball rolls clockwise around this track and then emerges onto the flat, frictionless table. Which dashed line most closely represents the path of the ball when it emerges from the track?

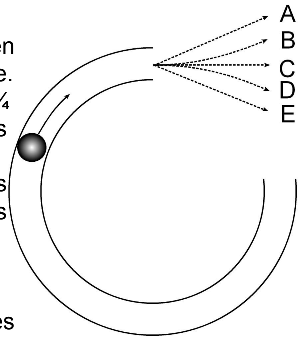
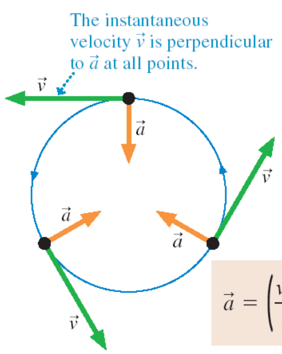


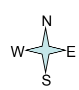
FIGURE 4.40 For uniform circular motion, the acceleration $\vec{a}$ always points to the center.

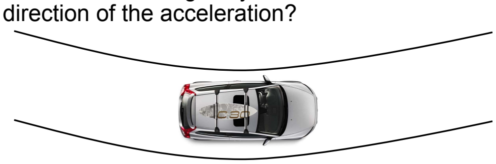


Centripetal Acceleration, also known as Radial Acceleration:

$$\vec{a} = \left(\frac{v^2}{r}, \text{toward center of circle}\right)$$

A car is traveling East at a constant speed of 100 km/hr. Without speeding up of slowing down, it is turning left, following the curve in the highway. What is the direction of the acceleration?





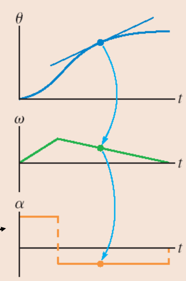
A. North
B. East
C. North-East
D. North-West
E. None; the acceleration is zero.

Centripetal Acceleration example

- A bike wheel of diameter 1.0 m turns 20 times per second. What is the magnitude of the centripetal acceleration of a yellow dot on the rim?

Angle, angular velocity, and angular acceleration are related graphically.

- The angular velocity is the slope of the angular position graph.
- The angular acceleration is the slope of the angular velocity graph.



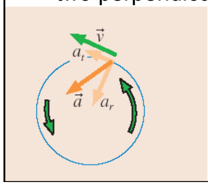
Determines the *Tangential* acceleration, **NOT** centripetal acceleration!

Summary of definitions:

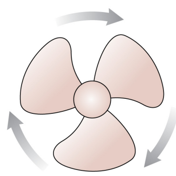
- θ is angular position. The S.I. Unit is radians, where 2π radians = 360°.
- ω is angular velocity. The S.I. Unit is rad/sec.
- α is angular acceleration. The S.I. Unit is rad/sec^2.
- s is the path length along the curve: $s = \theta r$ when θ is in [rad].
- v_t is the tangential speed: $v_t = \omega r$ when ω is in [rad/s].
- a_t is the tangential acceleration: $a_t = \alpha r$ when α is in [rad/s^2].

Nonuniform Circular Motion

- Any object traveling along a curved path has **centripetal acceleration**, equal to v^2/r.
- If, as it is traveling in a circle, it is speeding up or slowing down, it also has **tangential acceleration**, equal to $r\alpha$
- The total acceleration is the vector sum of these two perpendicular components



The fan blade is slowing down. What are the signs of ω and α?
[Let's define, as Knight often does, positive to be counter-clockwise.]



A. ω is positive and α is positive.
B. ω is negative and α is positive.
C. ω is positive and α is negative.
D. ω is negative and α is negative.

Moving on to Chapters 5 and 6..

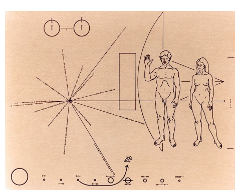
- Up until now, we have been studying **kinematics**, a description of HOW things move and how to describe this.
- In Chapter 5 we begin to study WHY things move the way they do: This is **dynamics**, which includes the important concepts of **Force** and **Energy**.

Isaac Newton

- Born in 1643, the year Galileo died.
- Was a "physicist, mathematician, astronomer, natural philosopher, alchemist, and theologian and one of the most influential people in human history." (http://en.wikipedia.org/wiki/Isaac_Newton)
- In *Philosophiæ Naturalis Principia Mathematica*, published 1687, he described **universal gravitation** and the **three laws of motion**, laying the groundwork for classical mechanics.

1 Newton's First Law

The natural state of an object with no net external force on it is to either remain at rest or continue to move in a straight line with a constant velocity.



What is a force?

- A force is a push or a pull on an object.
- A force is a vector. It has both a magnitude and a direction.
- A force requires an agent and a recipient. Something does the pushing or pulling, and something else gets pushed or pulled.
- A force is either a contact force or a long-range force. **Gravity** is the only long-range force we will deal with in PHY131.
- Important contact forces are: **Normal**, **Tension, Kinetic Friction** and **Static Friction**.

What is Mass?

Mass is a scalar quantity that describes an object's inertia. Loosely speaking, it also describes the amount of matter in an object. **Mass is an intrinsic property of an object.** It tells us something about the object, regardless of where the object is, what it's doing, or whatever forces may be acting on it.

2 Newton's Second Law

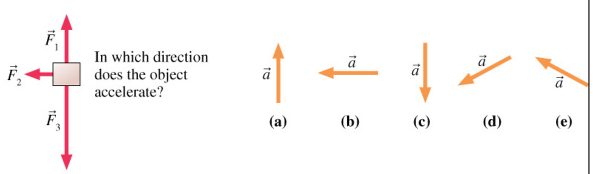
The acceleration of an object is directly proportional to the net force acting on it, and inversely proportional to its mass.

$$\vec{a} = \frac{\vec{F}_{\text{net}}}{m}$$

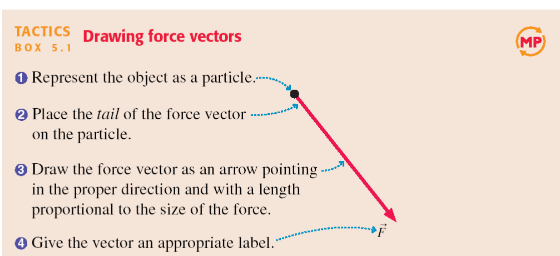
A fan attached to a cart causes it to accelerate at 2 m/s^2.
Suppose the same fan is attached to a second cart with smaller mass.
The mass of the second cart plus fan is half the mass of the first cart plus fan.
The acceleration of the second cart is

A. 16 m/s^2.
B. 8 m/s^2.
C. 4 m/s^2.
D. 2 m/s^2.
E. 1 m/s^2.

Three forces act on an object. In which direction does the object accelerate?

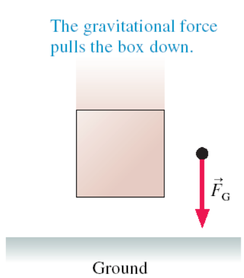


Tactics: Drawing force vectors



A Short Catalog of Forces

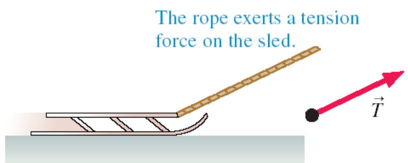
FIGURE 5.3 Gravity.



$\vec{F}_G = m\vec{g}$ when the object is close to the surface of the Earth. vector-g is 9.8 m/s^2, toward the centre of the Earth (down).

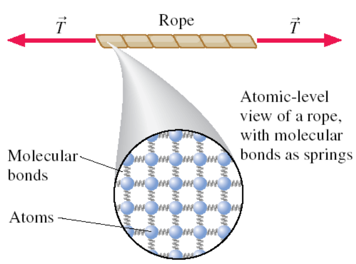
A Short Catalog of Forces

FIGURE 5.5 Tension.



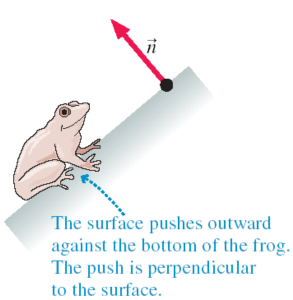
A Short Catalog of Forces

FIGURE 5.6 An atomic model of tension.



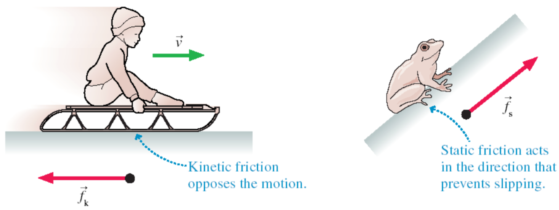
A Short Catalog of Forces

FIGURE 5.9 The normal force.



A Short Catalog of Forces

FIGURE 5.10 Kinetic and static friction.



Example

- A 1500 kg car is traveling North at 115 km/hr. The road is curving West, and the radius of curvature is 500 m.

a) If the road is perfectly slippery, what will happen to the car?

b) What is the required force of static friction of the road on the car to cause the car to stay on the curve of the road?

The "Fine Print"

- WARNING: Newton's Laws only apply in a "inertial reference frames". They are not valid if your reference frame is accelerating!
- An inertial reference frame is one that is not accelerating.
- The surface of the Earth can be treated as an inertial reference frame because A) it is not moving B) it is not accelerating, or C) it's acceleration is very small.
- NOTE: The Earth rotates once every 24 hours, which give us a steady acceleration towards the axis of less than 0.03 m/s^2. Also, its orbit gives the entire Earth a steady acceleration of 0.006 m/s^2 toward the Sun.

- A car is driving at a steady speed on a straight and level road.

Quick quiz [1/4]: inside the car, is it…

A: Inertial Reference Frame

B: Not an inertial reference frame

- A car is driving at a steady speed up a 10° incline.

Quick quiz [2/4]: inside the car, is it…

A: Inertial Reference Frame

B: Not an inertial reference frame

- A car is speeding up after leaving a stop sign, on a straight and level road.

Quick quiz [3/4]: inside the car, is it…

A: Inertial Reference Frame

B: Not an inertial reference frame

- A car is driving at a steady speed around a curve on a level road.

Quick quiz [4/4]: inside the car, is it…

A: Inertial Reference Frame

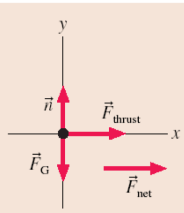
B: Not an inertial reference frame

Summary

- Acceleration is the link between dynamics and kinematics.
- From F_{net}, find a.
- From a and initial conditions, find v_x, v_y, x, y.
- $a = 0$ is the condition for equilibrium.
  - "static equilibrium" is when $a = 0$ and $v = 0$.
  - "dynamic equilibrium" is when $a = 0$ and $v \neq 0$.
- Equilibrium occurs if and only if $F_{net} = 0$.

Free-Body Diagrams

A free-body diagram represents the object as a particle at the origin of a coordinate system. Force vectors are drawn with their tails on the particle. The net force vector is drawn beside the diagram.



Before Next Class:

- Read Chapter 6 of Knight.
- Complete MasteringPhysics.com Problem Set 3 due by May 30 at 11:59pm
- Something to think about: A basketball and a tennis ball are in freefall.
  1. Which, if either, has the larger **mass**?
  2. Which, if either, experiences the larger **force of gravity**?
  3. Which, if either, experiences the larger **acceleration**?
  4. Which, if either, has the larger **weight**?