Kinematics: Circular Motion
Mechanics: Forces

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Last time

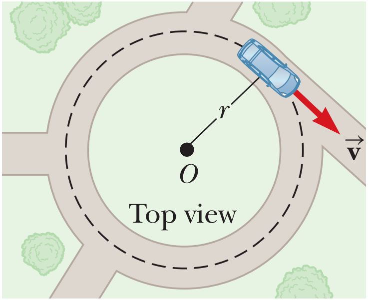
- projectile trajectory equation
- projectile examples
- projectile motion and relative motion

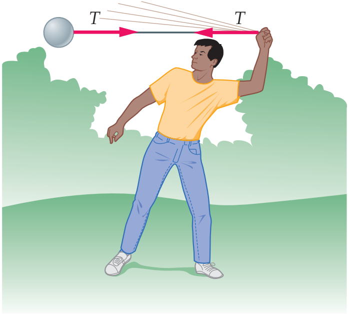
Overview

- circular motion
- force
- net force

Circular motion

Objects that move along an arc of a circle are said to be undergoing circular motion.





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[1]Left Figure: from Serway & Jewett, 9th ed. Right Figure: from Walker.

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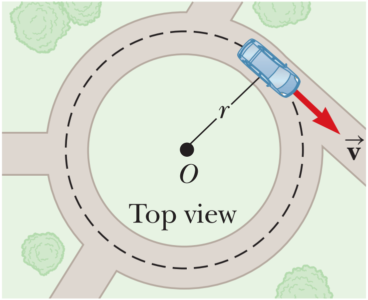

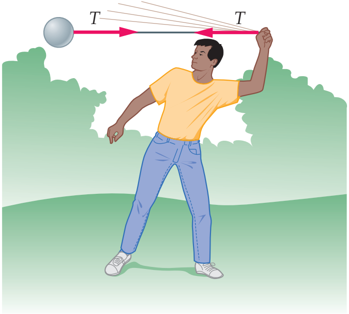

It is possible that such an object moves with constant speed. But does it move with constant velocity? No!

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Circular Motion

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It should depend on:

Circular Motion

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It should depend on:

- the **speed** of the object - in this case, a higher the speed means a larger acceleration
- the **radius** of the path - the tighter the turn, the smaller the radius, the larger the acceleration

Centripetal Acceleration

Centripetal acceleration

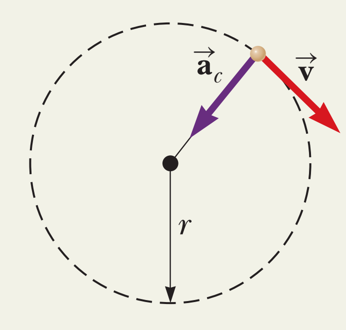
The acceleration of an object that follows a circular arc of radius, r, at constant speed v. Its magnitude is

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

(See page 71 of textbook for the proof.)

Uniform Circular Motion

The velocity vector points along a tangent to the circle



For uniform circular motion:

- the radius is constant
- the speed is constant
- the *magnitude* of the acceleration is constant

Period

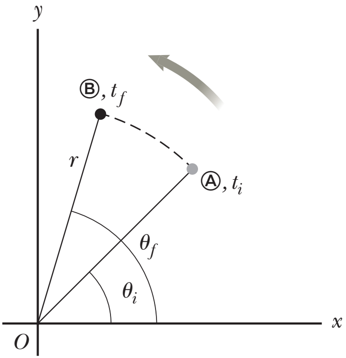
Period

The time for one complete orbit of an object that follows a circular arc of radius, r, at constant speed v. Its magnitude is

$$T = \frac{2\pi r}{v}$$

Uniform Circular Motion

We can also consider the rate at which the angular coordinate is changing:



$$\Delta\theta = \theta_f - \theta_i$$

Then we can define the **angular speed**, ω, as

$$\omega = \frac{d\theta}{dt} \qquad \text{where } \theta \text{ is measured in radians}$$

Uniform Circular Motion

ω gives the amount by which the angle θ advances in radians, per unit time. Therefore,

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where T is the period (time for one revolution).

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Putting in the expression for T ($T = \frac{2\pi r}{v}$):

$$\begin{aligned} \omega &= 2\pi \frac{v}{2\pi r} \\ \omega &= \frac{v}{r} \end{aligned}$$

Uniform Circular Motion

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Putting in the expression for T ($T = \frac{2\pi r}{v}$):

$$\omega = 2\pi \frac{v}{2\pi r}$$

$$\omega = \frac{v}{r}$$

This gives us another expression for the centripetal acceleration:

$$a = \omega^2 r$$

Circular Motion

Quick Quiz 4.4[1] A particle moves in a circular path of radius r with speed v. It then increases its speed to $2v$ while traveling along the same circular path.

(i) The centripetal acceleration of the particle has changed by what factor? Choose one:

A 0.25

B 0.5

C 2

D 4

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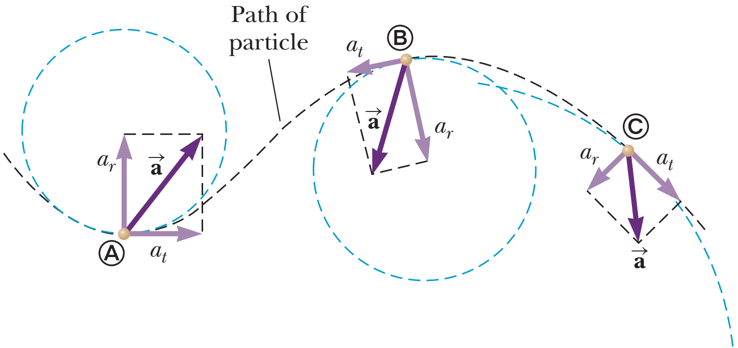
Non-Uniform Circular Motion



a_r is the centripetal acceleration. It changes the direction of the particle's velocity.

The tangential acceleration a_t speeds up or slows down the particle.

Public Service Announcement

Vote!

https://registertovote.ca.gov/

If you are eligible, and you haven't registered, do it this week!

Election day: Tuesday, Nov 6.

Taylor Swift wants You to Vote!

> “For a lot of us, we may never find a candidate or party with whom we agree 100% on every issue, but we have to vote anyway.
>
> “So many intelligent, thoughtful, self-possessed people have turned 18 in the past two years and now have the right and privilege to make their vote count. But first you need to register, which is quick and easy to do. [...] Go to vote.org and you can find all the info. Happy Voting! 🗳😃🌈 ”
>
> – Taylor Swift, Instagram post

Forces

Up until now we have predicted the motion of objects from knowledge of their motional quantities, *eg.* their initial velocities, accelerations, *etc.*

We did not consider what the causes of this motion might be. We now will think about that.

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Up until now we have predicted the motion of objects from knowledge of their motional quantities, *eg.* their initial velocities, accelerations, *etc.*

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We will understand **forces** as the cause of changes in the motion of objects.

Forces are a "push" or "pull" that an object experiences because of an interaction.

Forces are **vectors**.

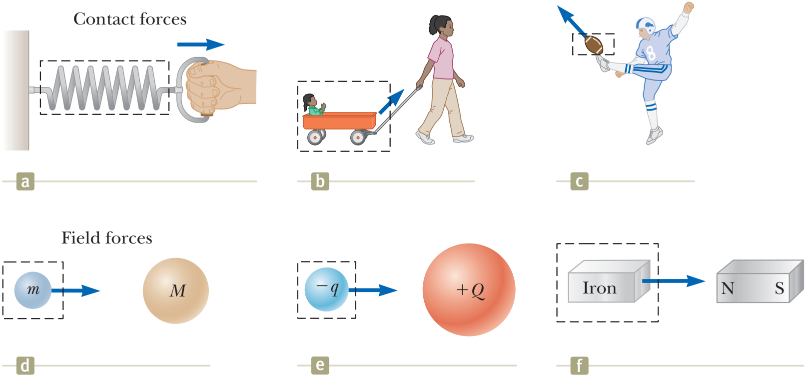
Forces

Two types of forces

- contact forces
  another object came into contact with the object
- field forces
  a kind of interaction between objects without them touching each other

Forces

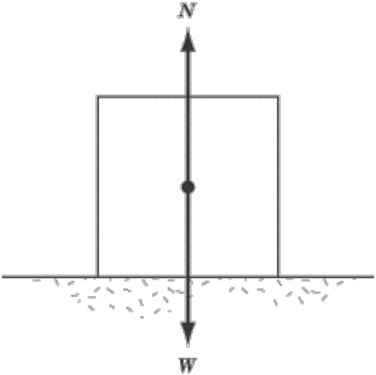
Force type examples:



[1] Serway & Jewett, “Physics for Scientists and Engineers”.

Forces are Vectors

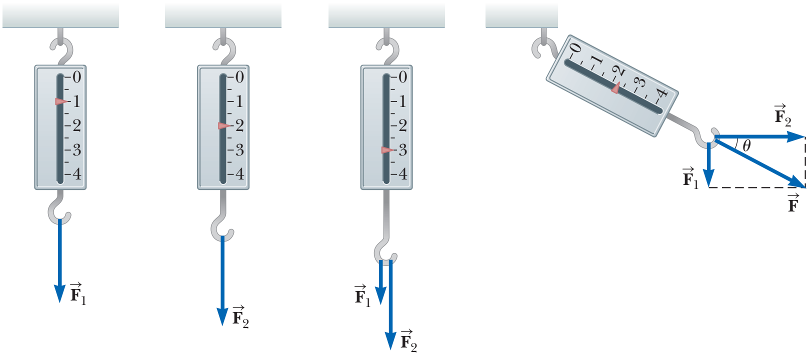
We typically draw them like this[2]:



The block is the object that experiences the forces. There are two forces here, **N** and **W**, they are drawn as arrows to indicate their direction.

[1]Figure from www.sparknotes.com

Forces are Vectors



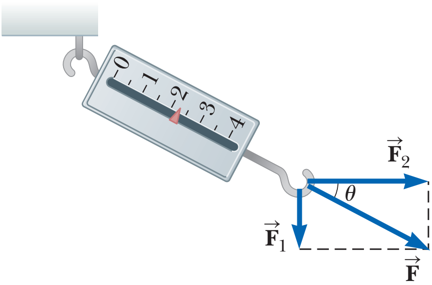
[1]Figure from Serway & Jewett.

Net Force

Net Force

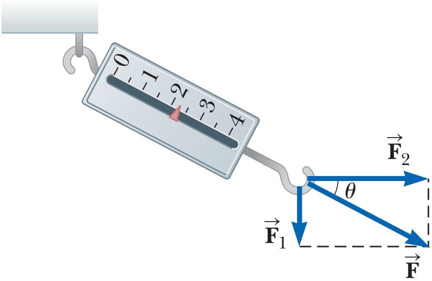
the vector sum of all forces acting on an object.

$$\mathbf{F}_{\text{net}} = \sum_i \mathbf{F}_i$$



In the diagram $\mathbf{F} = \mathbf{F}_1 + \mathbf{F}_2$.

Net Force



In the diagram $\mathbf{F} = \mathbf{F}_1 + \mathbf{F}_2$.

The magnitude of **F** is

$$F = \sqrt{F_1^2 + F_2^2} = \sqrt{1^2 + 2^2} = 2.23 \text{ N}$$

The direction of **F** is

$$\theta = \tan^{-1}(F_1/F_2) = 26.6^\circ$$

Summary

- circular motion
- forces
- net force

Homework

- new: Ch 4 Probs: 57, 59, 67 (circular motion)
- read ahead in Ch 5