

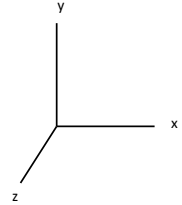
Kinematics

John A. Mercer, Ph.D.

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Kinematics

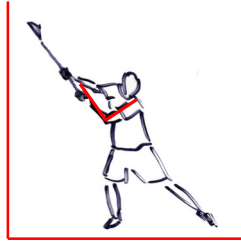
- The study of motion without regards to the forces causing motion.
- Movement (or motion)
 - Mechanical definition
 - Change in space
 - Change in time
 - Reference Frame
 - Cartesian coordinates
 - (x, y, z)
 - Axes 90° from each other



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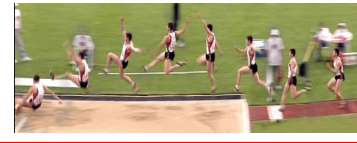
Reference Frame

- Global (or Laboratory)
 - Fixed reference frame
 - Does not move
- Local
 - Moves relative to a global reference frame.
 - Origin is set at a joint



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Reference Frame



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Types of Motion

1. Linear
2. Angular
3. General

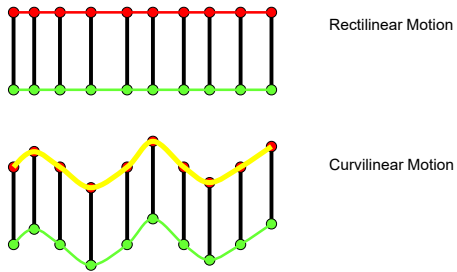
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Types of Motion

- Linear
 - Rectilinear
 - All points of an object travel the same distance in a straight line.
 - Distance
 - » Total change in position
 - Curvilinear
 - All points of an object travel the same linear distance along a curved path.

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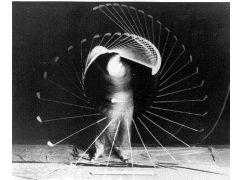
Linear Kinematics



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Types of Motion

- Angular
 - Movement of a segment about an axis.
 - Rotational motion.



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Types of Motion

- General
 - Combination of Linear and Angular motion
 - Human movements are typically general motion



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Types of Motion

- General
 - Combination of Linear and Angular motion
 - Human movements are typically general motion



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Summary: Types of Motion

- Kinematics
- Movement
- Reference Frame
 - Global
 - Local
- Types of Motion
 - Linear
 - rectilinear
 - curvilinear
 - Angular
 - General

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Kinematics

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Types of Motion

- Linear
- Angular
- General
 - Combination of Linear and Angular motion
 - Human movements are typically general motion



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Kinematic Analysis

- To study General Motion, a kinematic analysis will typically approach the problem by studying each type of motion independent of each other.
 - Linear analysis
 - x, y, and/or z
 - Angular analysis
 - Joint angles
 - Segment angles
- Different analyses are put together to understand General Motion.

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Kinematics

- Semester Plan
 - Linear Kinematics
 - Description of linear motion
 - Angular Kinematics
 - Description of angular motion
- Understand the parameters
 - Position, velocity, acceleration

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Linear Kinematic Parameters

- Position
 - Location of point in space at some point in time
 - Used to determine
 - Distance: total change in position
 - Units: length
 - » Meters, feet, miles,
 - scalar
 - Displacement: straight line distance between two points
 - $\Delta p = p_f - p_i$
 - Units: length
 - » Meters, feet, miles,
 - vector

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Vectors vs. Scalars

- Vectors
 - Parameters that are represented by
 - Magnitude
 - Direction
- Scalars
 - Parameters that are represented by
 - Magnitude
- Math of dealing with vectors and scalars is different.

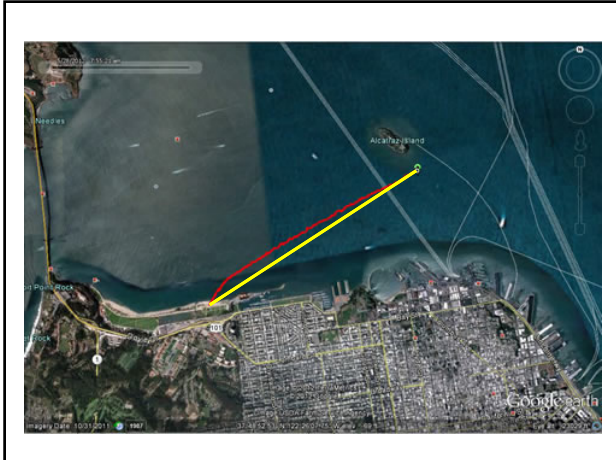
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Position

- Distance
 - total change in position of object
- Displacement
 - Straight line change in position



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Linear Kinematic Parameters

- Velocity
 - Time rate of change of position (displacement)
 - $v = \Delta p / \Delta t$
 - Units:
 - Units of length / units of time
 - m/s, ft/s, ...
 - vector
- Speed
 - Time rate of change of distance
 - Units:
 - Units of length / units of time
 - m/s, ft/s, ...
 - scalar

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Linear Kinematic Parameters

- Acceleration
 - Time rate of change of velocity
 - $a = \Delta v / \Delta t$
 - Units:
 - Units of velocity / units of time
 - m/s/s, ft/s/s, mph/s, ...
 - Vector

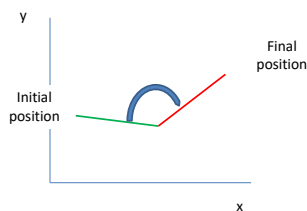
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Angular Kinematic Parameters

- Angular Distance
 - Total change in angular position
 - Units: degrees, radians, revolutions
 - Scalar
- Angular Displacement
 - Change in angular position.
 - $\theta = \theta_f - \theta_i$
 - Units: degrees, radians, ~revolutions~
 - Vector

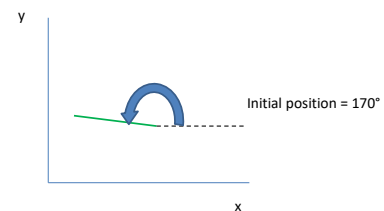
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Angular Position



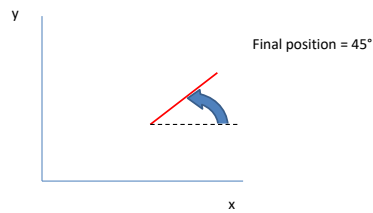
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Angular Position



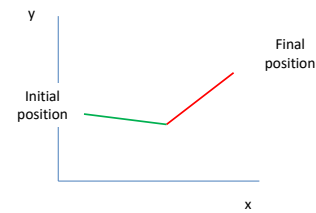
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Angular Position



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Angular Position

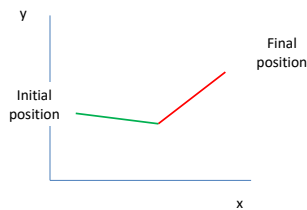


$$\text{Angular Displacement} = 45^\circ - 170^\circ = -125^\circ$$

A negative sign means that the rotation was clockwise.
The +/- sign indicates direction of rotation.

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Angular Position



$$\text{Angular Distance} = 125^\circ$$

- Typically, negative signs are not used for angular distance.
- Multiple rotations will mean that angular distance can be greater than 360° .
- Angular Displacement will always be less than 360° .

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Angular Velocity

- Angular Velocity
 - Time rate of change of angular displacement
 - $\omega = \Delta\theta / \Delta t$
 - Units:
 - Units of angular displacement / units of time
 - Rad/s, degrees/s
 - vector
- Angular Speed
 - Time rate of change of angular distance
 - Units:
 - Units of angular distance / units of time
 - Rad/s, degrees/s, RPM
 - scalar

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Angular Acceleration

- Angular Acceleration
 - Time rate of change of angular velocity
 - $\alpha = \Delta\omega / \Delta t$
 - Units:
 - Units of angular velocity / units of time
 - deg/s/s, rad/s/s ...
 - Vector

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Kinematics

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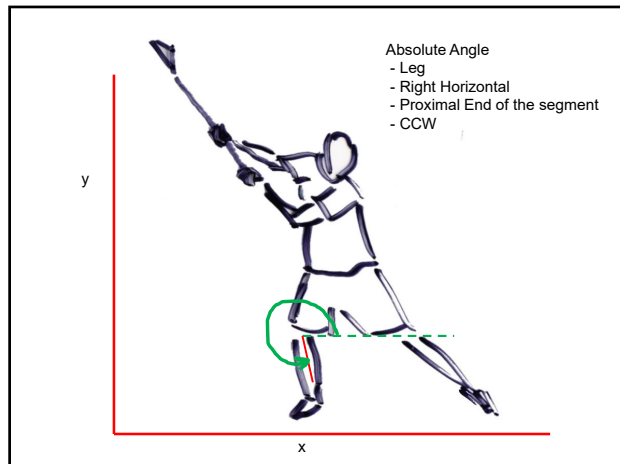
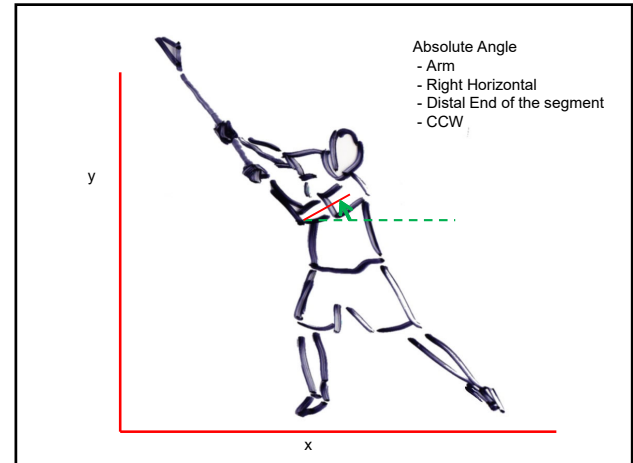
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Angular Position

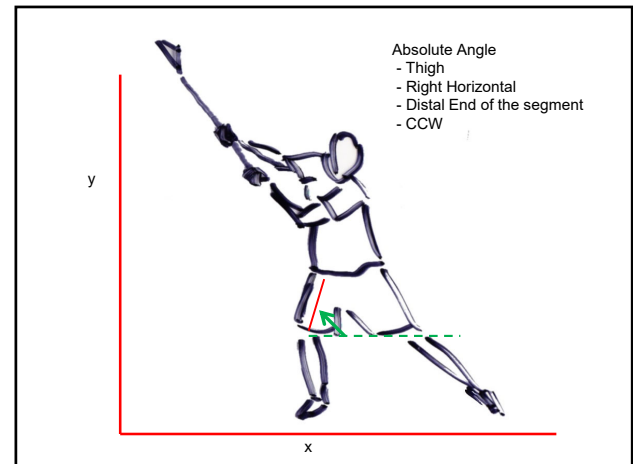
- Absolute Angle
 - aka segment angle
 - The angle between an anatomical segment and a fixed reference line.
- Relative Angle
 - aka joint angle
 - The angle between two anatomical segments, both have the potential to move.

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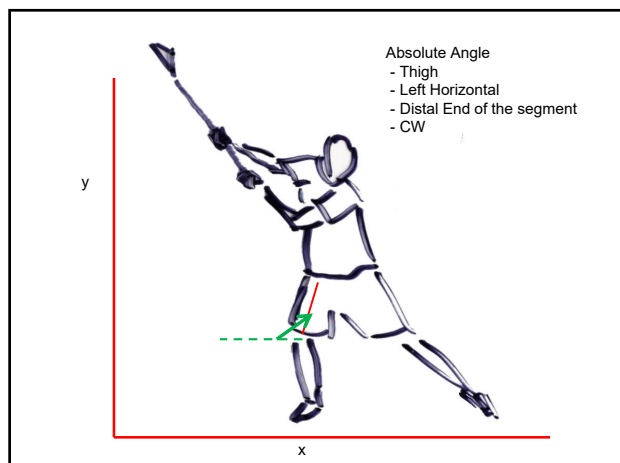
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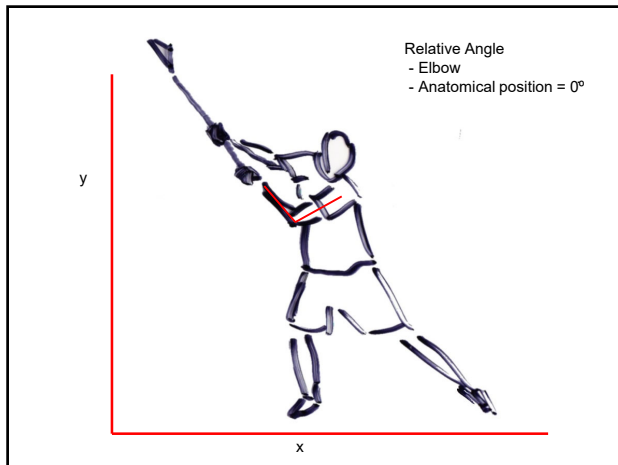


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Absolute Angle

- The angle between an anatomical segment (e.g., leg, thigh, foot, arm, trunk, ...) and a fixed reference line in space.
- All segment angles are absolute angles.

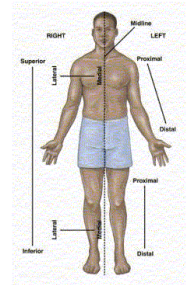
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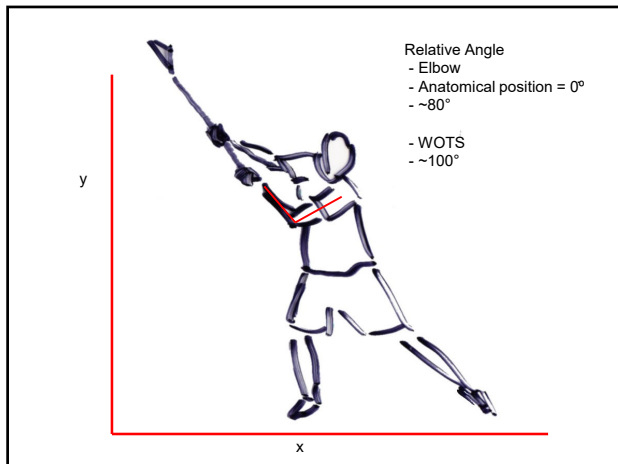
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Relative Angle Reference System

- Anatomical Position
 - Joint angles set to 0°
 - Flexion angles increasing
- Word on the Street
 - Joint angles = 180°
 - Flexion angles decreasing

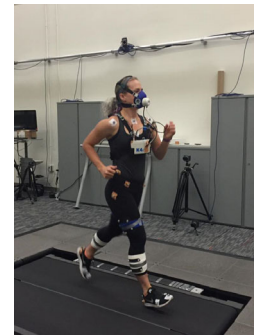


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- Right Knee angle
 - Relative Angle
 - AP = 0°
 - $\sim 10^\circ$ of Flexion
 - WOTS = 180°
 - $\sim 170^\circ$



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Relative Angle

- Angle between two anatomical segments, both have the potential to move.
- All joint angles (e.g., wrist, elbow, shoulder, hip, knee, ...) are relative angles.

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Summary

- Absolute Angle
 - Describe location of reference line.
 - Indicate direction (i.e., CCW, CW).
- Relative Angle
 - Identify joint (and two segments).
 - Indicate reference system
 - Anatomical Position
 - WOTS

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Summary: Kinematics

- Kinematic Parameters
 - Position
 - distance
 - displacement
 - Velocity
 - Speed
 - Acceleration
- Vectors
- Scalars