LINEAR AND ANGULAR KINEMATICS

Readings: McGinnis Chapters 2 and 6

DISTANCE, DISPLACEMENT, SPEED, VELOCITY, AND ACCELERATION:

How far?

Describing change in linear or angular position

Distance (Scalar quantity)—Length of path traveled with no concern for direction (magnitude only)

Displacement (Vector quantity)—Difference between starting and finishing positions; independent of path followed (magnitude and direction)

Symbols: linear - ℓ, d angular - ϕ, θ

Examples - Linear distance and displacement

Describing race distances:

100 m Sprint ℓ = 100 m

Indy 500 (auto race) ℓ = 500 mi

4000 km Tour de France (bike race)

ℓ = 4000 km

Characterizing performance:

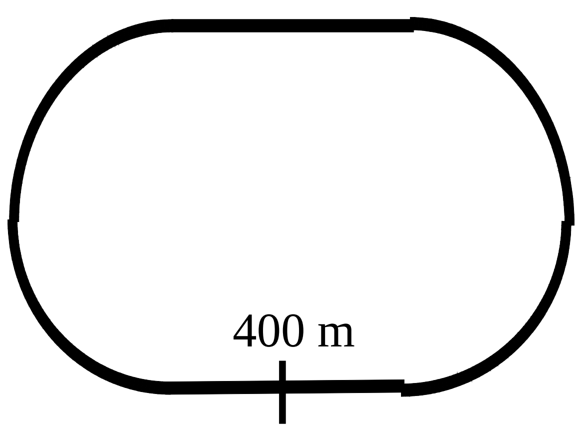
Shot put, Long jump, High jump

long jump of 8.89 m ℓ = 8.89 m

Typical units of measurement: m, km, ft, mile

Distinguishing distance and displacement

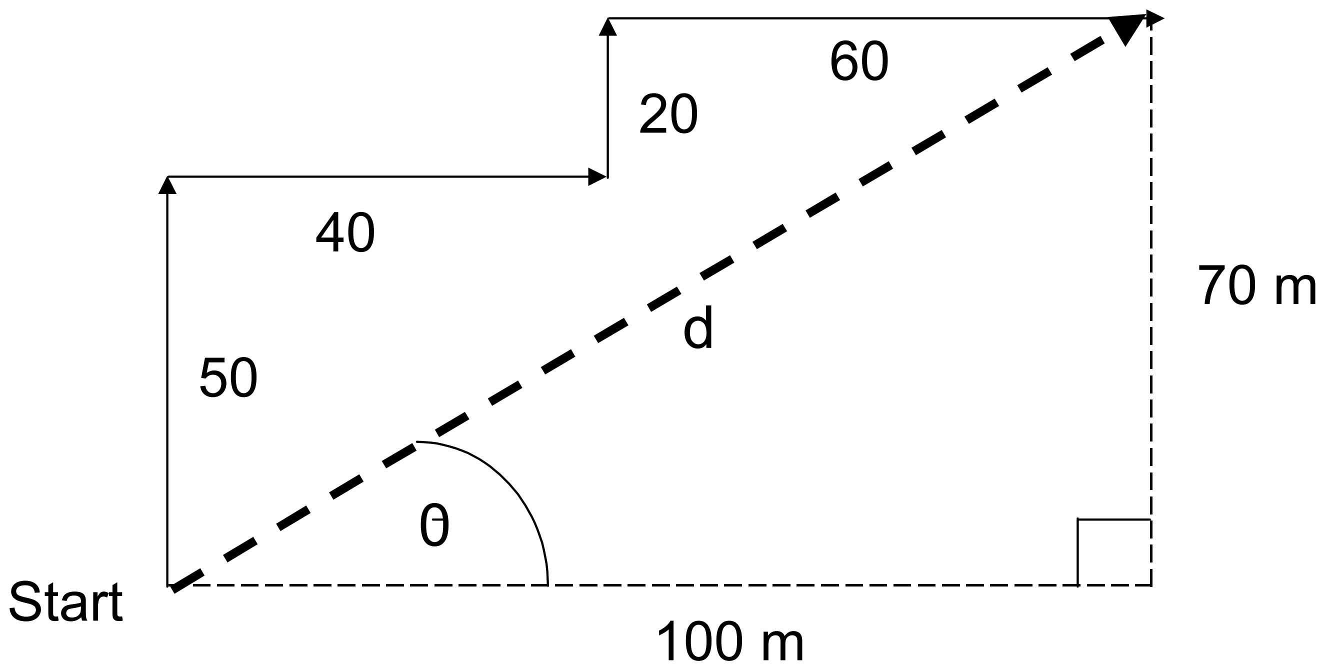
Example: 400 m run (one lap around track)



Distance?

Displacement?

Example: Walking north and east, then north and east again:



Overall distance traveled? ℓ

Displacement ("as the crow flies")?

Magnitude d

Direction θ

Examples - Angular distance and displacement.

Diving, gymnastics:
"triple somersault with a full twist"
3.0 revolutions about a transverse axis (somersaulting axis) combined with 1 rev about a longitudinal axis (twisting axis)
transverse axis ϕ =____ θ=_____
long. axis ϕ = _____ θ=______

Discus throw:
Body rotates through ____ rotations prior to discus release.
ϕ = ____ rev θ = ____ rev

Joint range of motion:
The elbow and knee have ROM's of approximately 150 degrees.
ϕ = _______ θ = _______

Typical units - 3 used commonly:
revolutions, radians, degrees

1 rev = 2π rad (i.e., 6.28 rad) = 360 deg
1 rad = 57.3 deg

How fast?

Describing rate of change of linear or angular position with respect to (wrt) time

Speed or Velocity: Rate at which a body moves from one position to another

Speed (scalar)   Velocity (vector)

Note: *There will be times when it is important to use velocity because of its vector characteristic.*

Linear: Angular:

$$\bar{v} = \frac{d}{\Delta t} \qquad \bar{\omega} = \frac{\theta}{\Delta t}$$

Examples of linear speed or velocity:

Tennis: 125 mph (55.9 m/s) serve
v = 125 mph = 55.9 m/s
Pitching: 90 mph (40.2 m/s) fastball
v = 90 mph = 40.2 m/s

Running:

Marathon (26.2 mi) - 2 hr 10 min
(2.17 hr)

$\bar{v}$ = 12.1 mph (5.4 m/s; 4:57 per mile)

Sprinting - 100 m in 9.86 s

$\bar{v}$ = 10.14 m/s = 22.7 mph

Football – “4.6” speed (40 yd in 4.6 s)

$\bar{v}$ = 7.95 m/s = 17.8 mph

Typical units of measurement for v:
m/s, km/hr (kph), ft/s, mph

Examples of angular speed or velocity:

Auto engine speed - 3000 rpm

ω = 3000 rpm

CD ROM drive - 400 rpm

ω = 400 rpm

Cycling cadence - 90 rpm

ω = 90 rpm

Isokinetic dynamometer (Cybex and others) -
e.g., 60 deg/s

ω = 60 deg/s

Body segment ω's -

e.g., peak ω of soccer player's knee...

2400 deg/s . 6.7 rev/s

Typical units of measurement for ω:

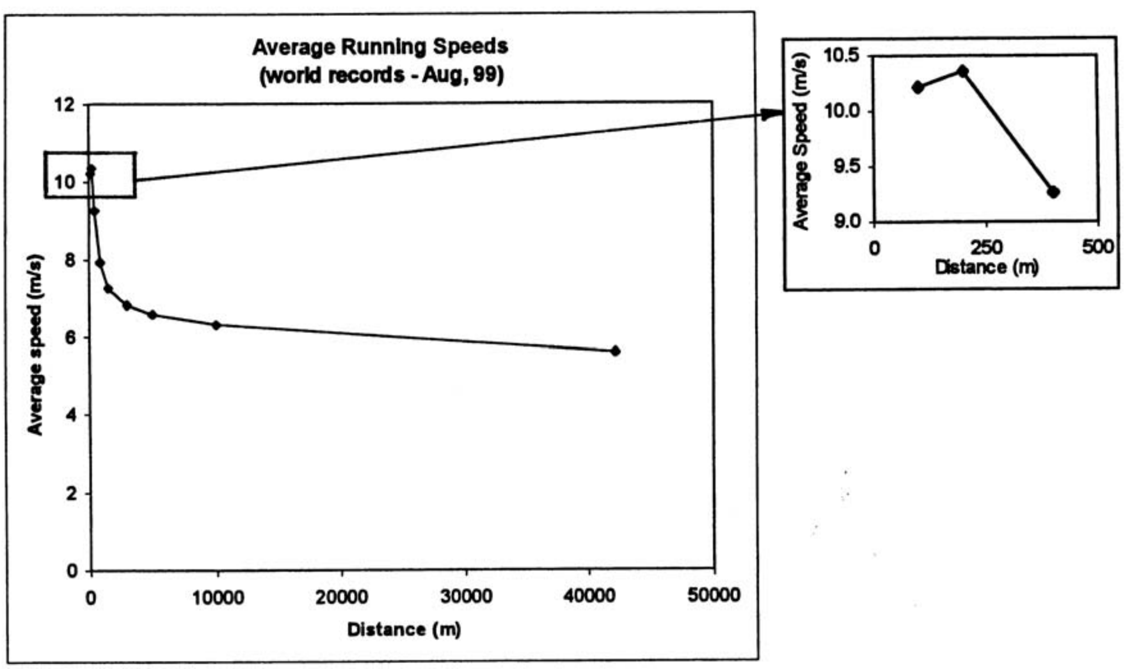
rpm, deg/s, rad/s

Average vs. Instantaneous Velocities

Average speed per race distance:

100 m...marathon

Race that produces highest average speed?



Sometimes $\bar{v}$ over relatively long t is not very informative - reflects need for a "kinematic profile" for more detailed information about performance

e.g., distance running - split times

e.g., sprinting - 1987 T&F World Champ.

Johnson vs. Lewis

9.83 s   9.93 s Δ = 0.100 s

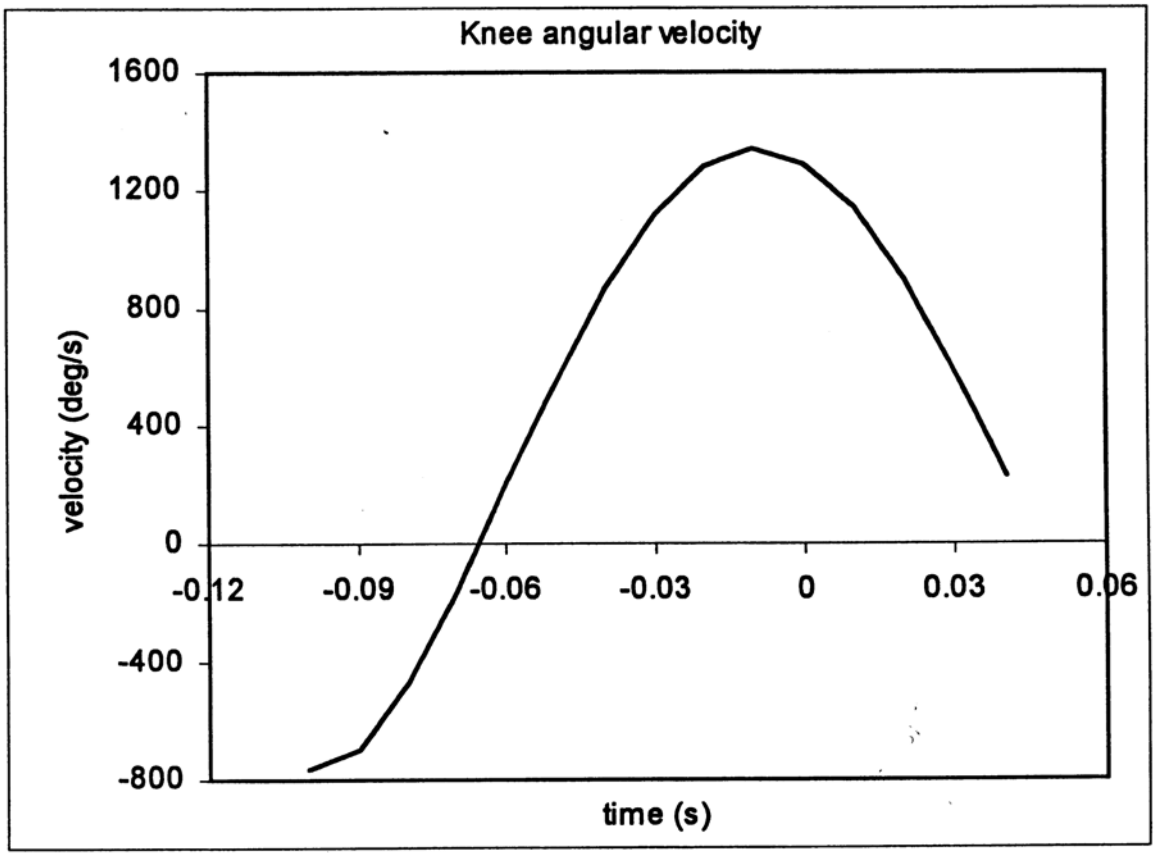
Where was race won or lost?

Reaction time: Δ = 0.067 s

After 10 m: Δ = 0.100 s

By decreasing t over which we examine velocity and other kinematic information, we approach *instantaneous* estimates of performance - gives more detail about performance.

e.g., during a soccer kick (next page):



Acceleration

Describing the rate of change of linear or angular velocity wrt time

Vector only - no scalar equivalent

Linear:

Angular:

Typical units of measurement for acceleration:

Linear - m/s^2, ft/s^2

Angular - deg/s^2, rad/s^2

Example - linear

An athlete described as being “quick” or having “good acceleration” - same as being fast?

No, acceleration describes a person’s ability to change speed or direction; doesn’t describe top speed.

Example - angular

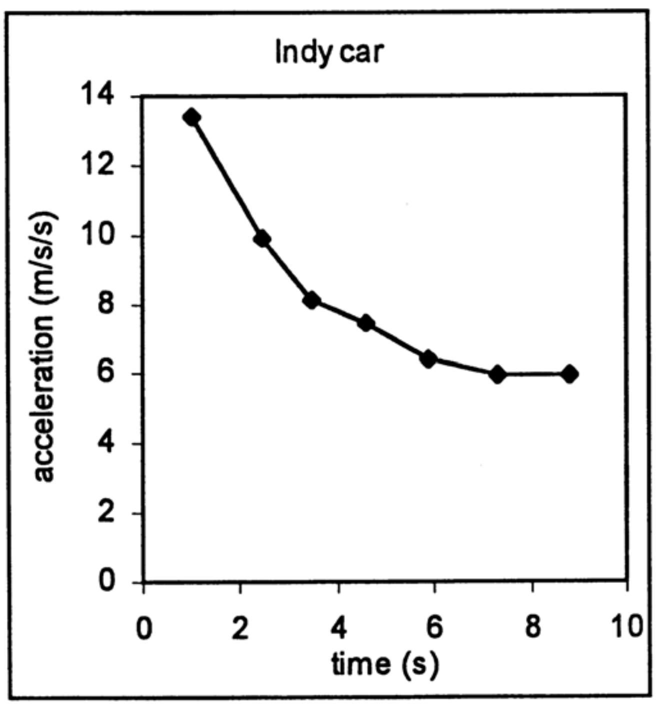
Throwing a baseball

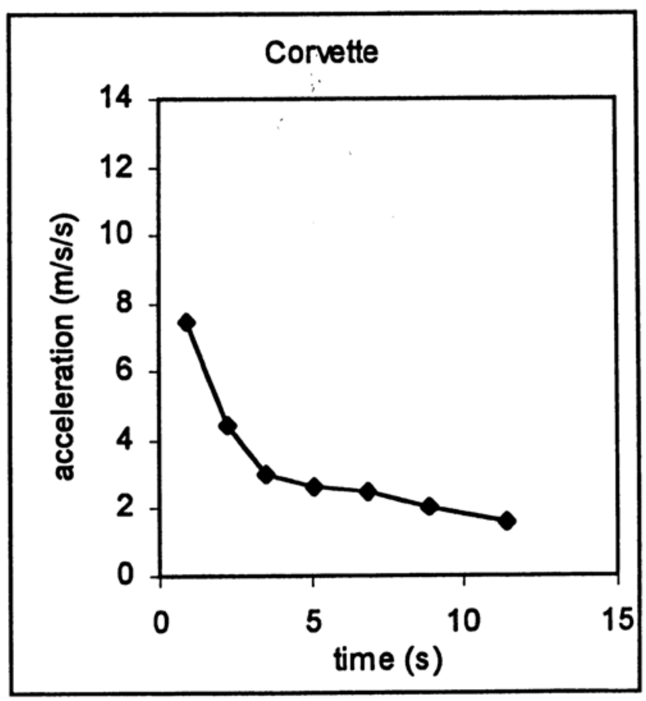
Angular speed of shoulder internal rotation increases from zero to 1800 deg/s in 26 ms just prior to release...

Ball velocity at release correlates strongly (r=.75) with shoulder internal rotation speed at release (Sherwood, 1995).

Example – linear:
Auto accelerations - Indy car vs. Corvette

Indy car				Corvette			
Δmph	Δm/s	Δt (s)	$\bar{a}$ (m/s^2)	Δmph	Δm/s	Δt (s)	$\bar{a}$ (m/s^2)
0-60	0-26.8	2.0	13.42	0-30	0-13.4	1.8	7.45
60-80	26-8-35.8	0.9	9.94	30-40	13.4-17.9	1.0	4.47
80-100	35.8-44.7	1.1	8.13	40-50	17.9-22.4	1.5	2.98
100-120	44.7-53.7	1.2	7.45	50-60	22.4-26.8	1.7	2.63
120-140	53.7-62.6	1.4	6.39	60-70	26.8-31.3	1.8	2.48
140-160	62.6-71.6	1.5	5.96	70-80	31.3-35.8	2.2	2.03
160-180	71.6-80.5	1.5	5.96	80-90	35.8-40.3	2.8	1.60





_____When is speed or velocity highest for Indy car?

_____When is acceleration highest for Indy car?

_____Is the speed or velocity of the Indy car changing approximately 6-8 seconds after the start?

<u>Link between position, velocity, and acceleration</u>:

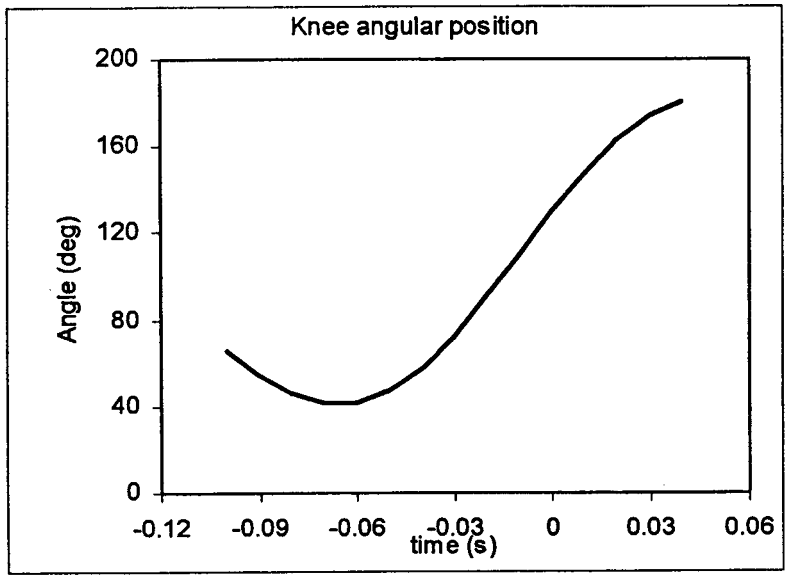
<u>Velocity</u> - rate of change of <u>position</u> wrt time

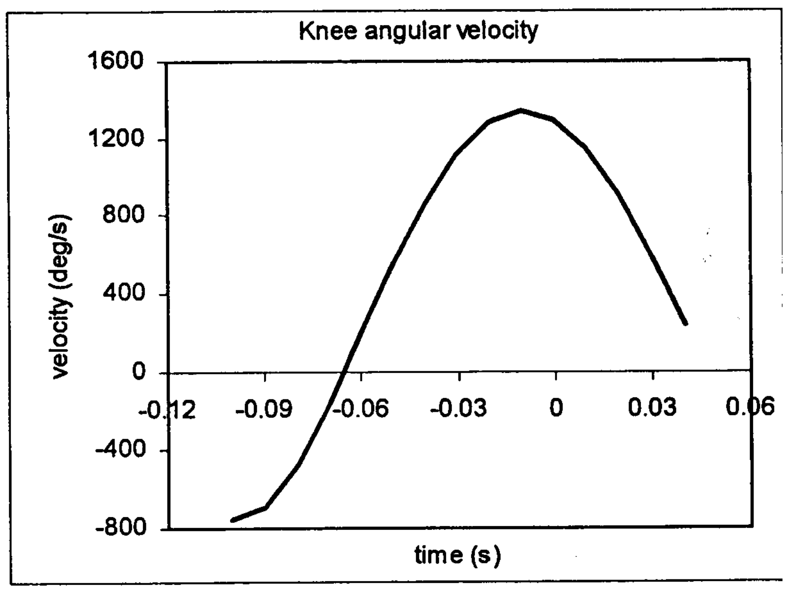
<u>Acceleration</u> - rate of change of <u>velocity</u> wrt time

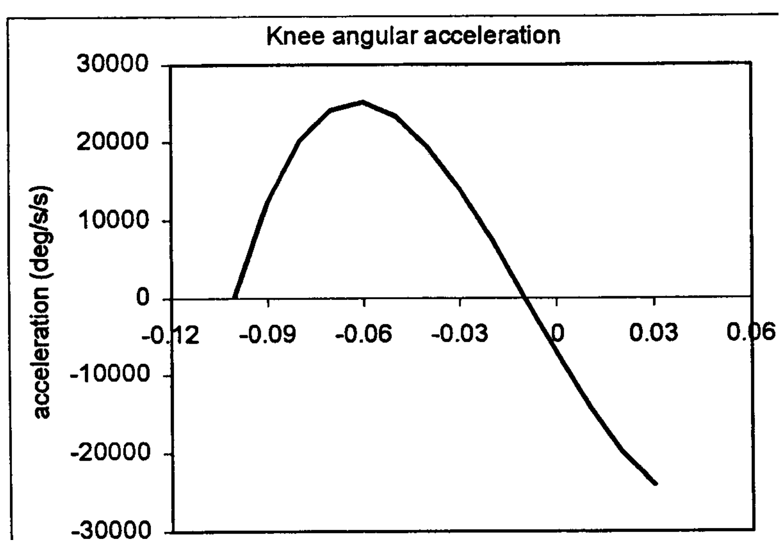
- Instantaneous <u>velocity</u> is reflected by the *slope* of the <u>position</u> curve at some instant in time.
- Instantaneous <u>acceleration</u> is reflected by the *slope* of the <u>velocity</u> curve at some instant in time.

See soccer kick - angular position, velocity, and acceleration graphs next page

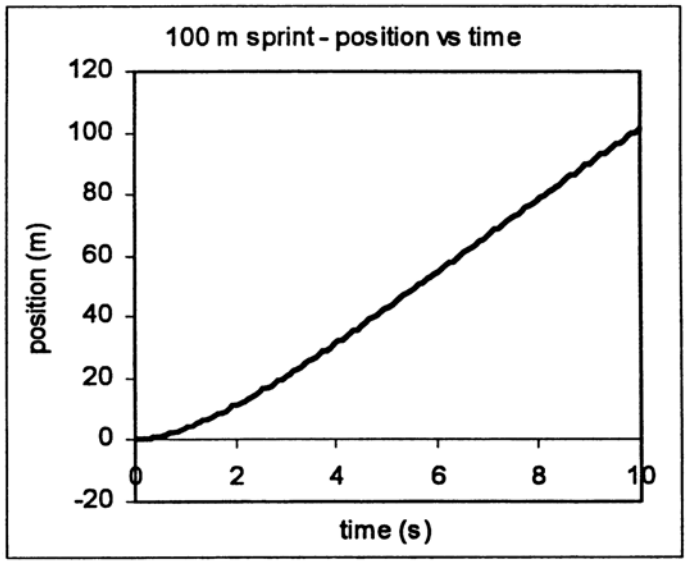
Knee angular kinematic profile (soccer kick)





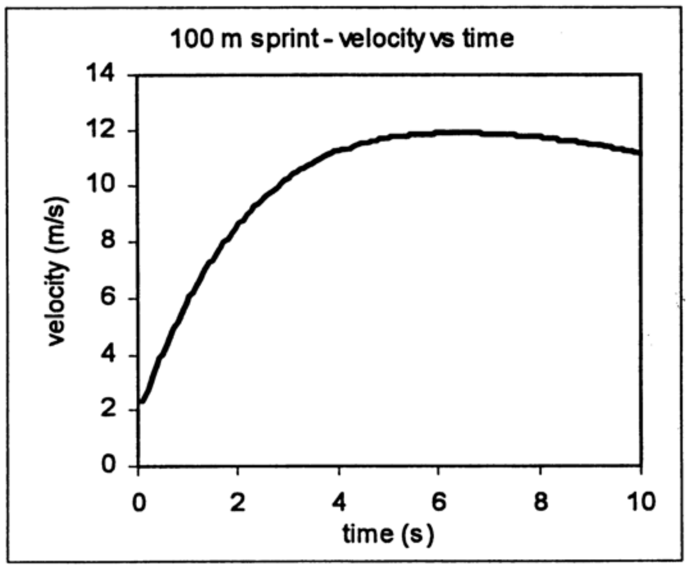


100 m dash linear kinematic profile (highly skilled sprinter)

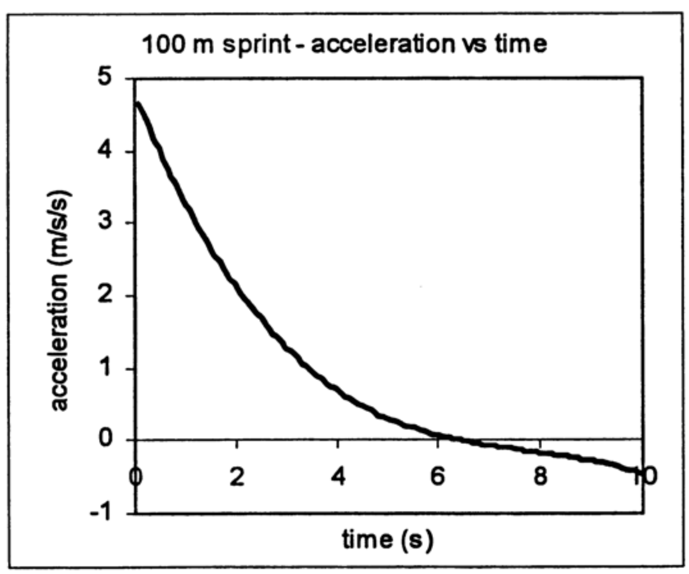


When is maximum velocity achieved?

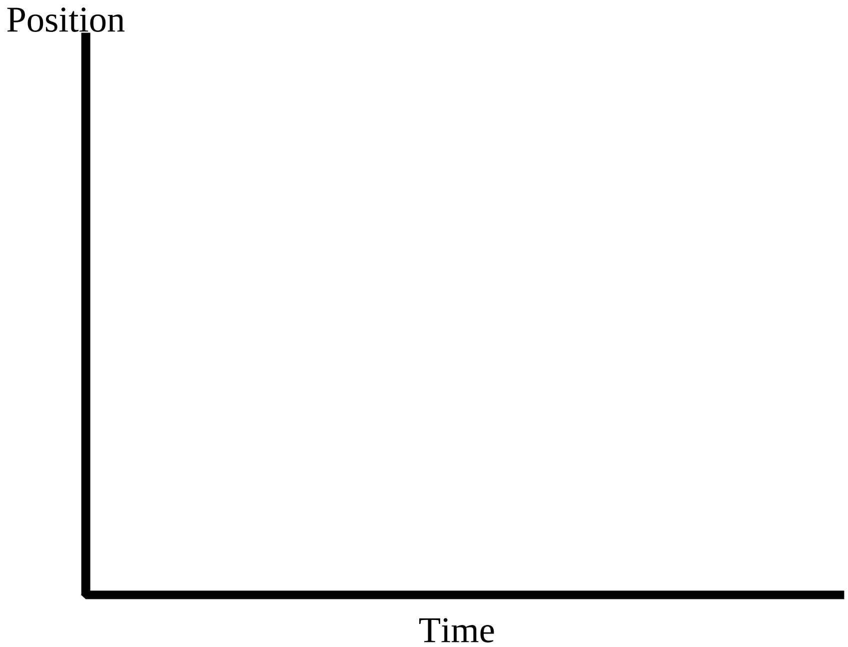
When is acceleration highest?

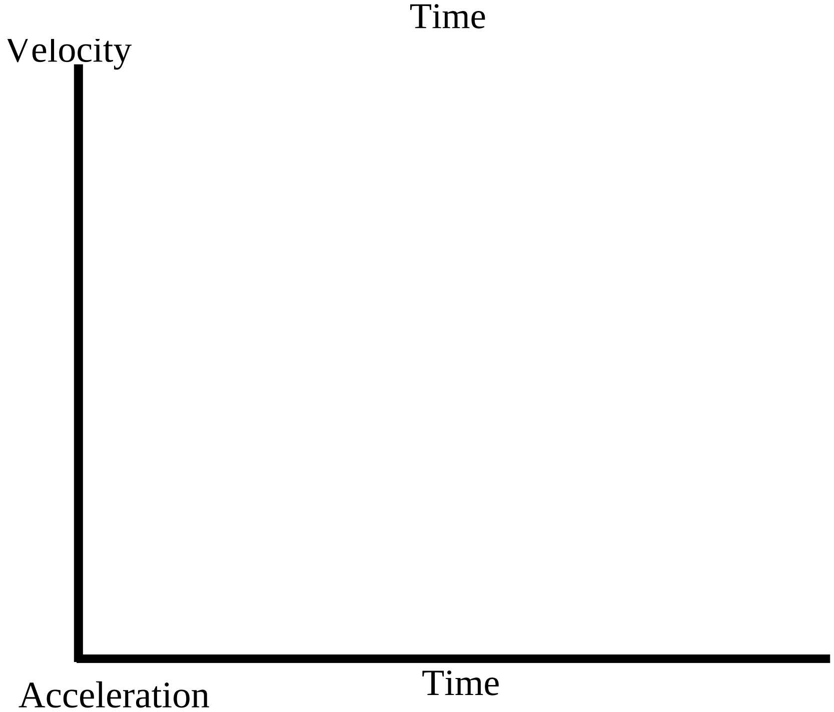


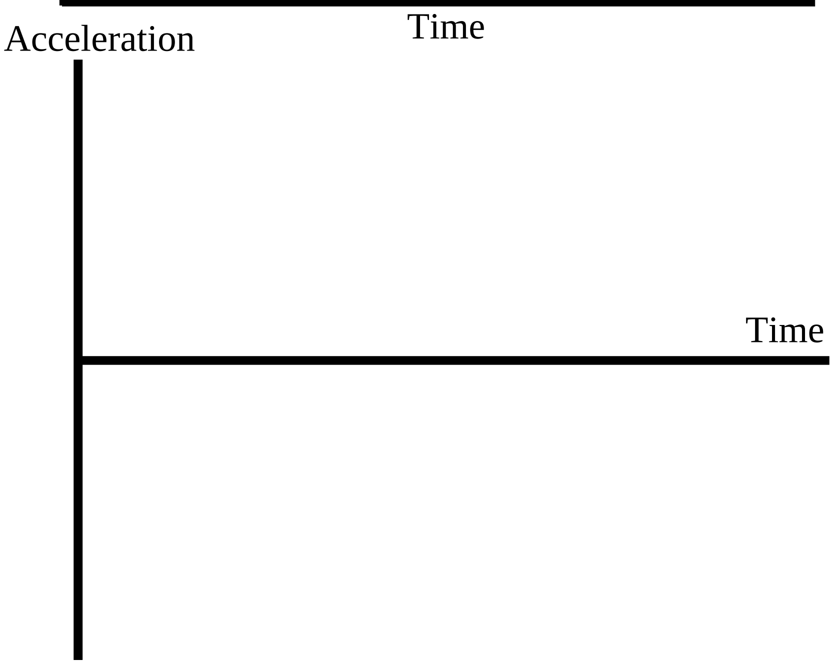
What is the approximate acceleration of sprinter 6 seconds into the race?



Can you deduce the position vs. time and acceleration vs. time profiles based on the velocity profile of a hand reaching for a glass of water?







Six Cases of Acceleration					
Case	Change in Speed	Starting Direction	Ending Direction	Δv	Accel. ($\Delta v/\Delta t$)
1	Speeding up				
2	Slowing down				
3	Speeding up				
4	Slowing down				
5	Reversing directions				
6	Reversing directions				

Notes:

1. Speeding up in the positive direction =______ acceleration
2. Slowing down in the positive direction = ______ acceleration
3. Speeding up in the negative direction = ______ acceleration
4. Slowing down in the negative direction = ______ acceleration
5. *Reversing directions* from positive to negative = ______ acceleration
6. *Reversing directions* from negative to positive = ______ acceleration.