3D Time:
From Transportation to Physics
Part 3: Kinematics I

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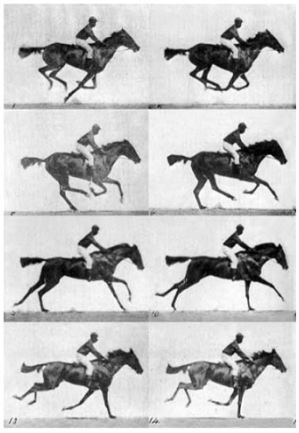
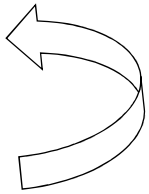
What is kinematics?

- The study of motion: what is it?
  - Describing, not explaining
  - No forces – that's dynamics
- Speed, velocity, acceleration
- Corresponding terms in 3D time



What is motion?



- Begin with motion – a primitive concept
- Define space and time in terms of motion
- Compare motion to a reference motion
- Space: asynchronous comparison to a reference motion
  - comparing with a ruler
- Time: synchronous comparison to a reference motion
  - comparing with a clock

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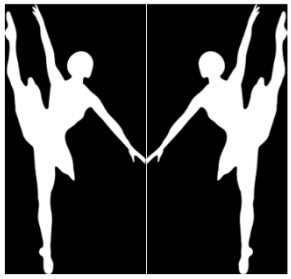
Space and time

- Space is observed asynchronously
  - as with a picture, sculpture
- Time is experienced synchronously
  - as with music, dance
- Space direction: relative to a place
  - dancers converging at a place on the stage
- Time direction: relative to an event
  - dancers converging at a point in time



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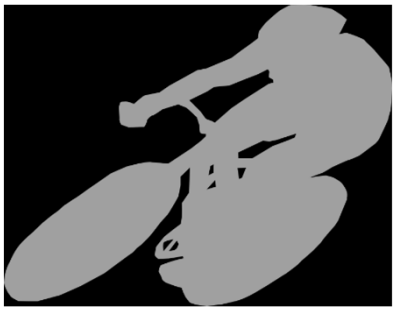
What is speed?

- Change of distance per unit time
  - average speed, $v = \Delta s/\Delta t$
  - instantaneous speed, $v = \mathrm{d}s/\mathrm{d}t$
  - a magnitude, $v \geq 0$
- Units
  - m/s, kph, mph
- Independent variable is time
  - dependent variable is distance
- Switch distance and time?



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What is pace?

- Change of time per unit distance
  - average pace, $u = \Delta t/\Delta s$
  - instantaneous pace, $u = \mathrm{d}t/\mathrm{d}s$
  - a magnitude, $u \geq 0$
- Walking, running, cycling
  - e.g., min per km, min per mile
- Independent variable is distance
  - e.g., track length is fixed
  - dependent variable is time
- Lower numbers mean faster

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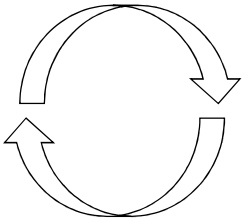
Speed and pace

- Inverses
  - pace = 1/speed, $u = 1/v$
  - so u and v cannot be zero
  - speed & pace equivalent
- Zero speed
  - no motion but time changes
- Zero pace
  - no motion but distance changes
  - because distance is independent



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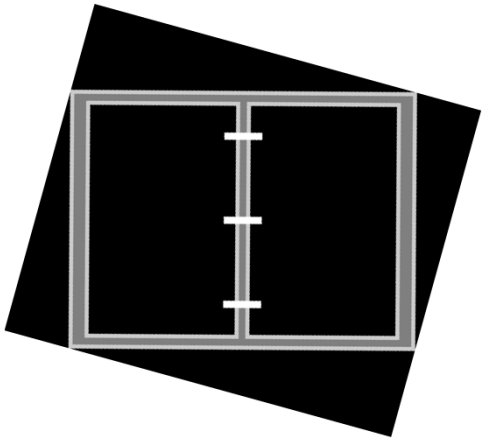
Pre-trip planning

- E.g., have an appointment
  - destination is fixed
  - independent variable is length
- Want to get there on time
- What route takes the least time?
- What time to depart?
- Time questions: pace, 3D time



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Circular and cyclic motion

- Clock angle from 12 to 3
  - angle in space or time? both
- Circle
  - θ, *s*, R
  - angle in space, θ = *s* / R
- Cycle
  - ϕ, *t*, Q
  - angle in time, ϕ = *t* / Q

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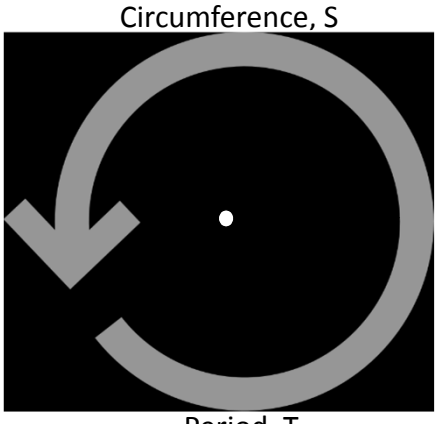
Angular speed

- Angular distance per unit time, *v*
  - frequency, *f*
  - time rate of rotation, *ω*
- Angular speed, *v* = S/T = R/Q
  - If S = 1, then 1/T = *f*
  - If R = 1, then 1/Q = *ω*
- Units: m/s, rpm, cps, Hz
- Independent variable is time
  - dependent variable is angle in space



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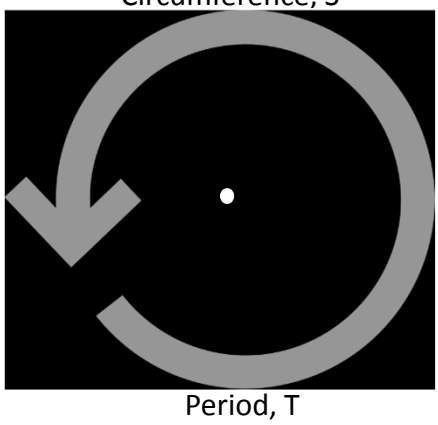
Angular pace

- Period angle per unit length, *u*
  - periodicity, *h*
  - space rate of rotation, *ψ*
- Angular pace, *u* = T/S = Q/R
  - If T = 1, then 1/S = *h*
  - If Q = 1, then 1/R = *ψ*
- Units: s/m, cycles/m
- Independent variable is length
  - dependent variable is angle in time



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Kinematics 1 conclusion

- Began with motion
- Defined space and time
  - reference motion
  - asynchronous and synchronous
- Defined speed and pace
  - angle in space and time
  - angular speed and pace
- Continued with *Part 4: Kinematics II*

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