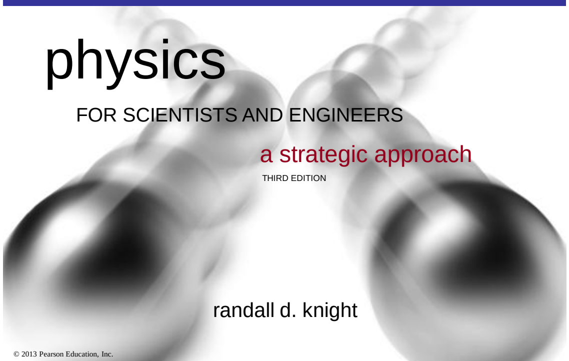
Class 4 – Sections 2.1-2.4, Preclass Notes



physics

FOR SCIENTISTS AND ENGINEERS

a strategic approach

THIRD EDITION

randall d. knight

ALWAYS LEARNING PEARSON

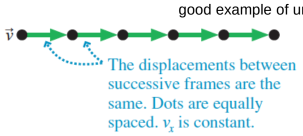
Chapter 2 Goal: To learn how to solve problems about motion in a straight line.

Slide 2-2

Uniform Motion (Constant Speed)

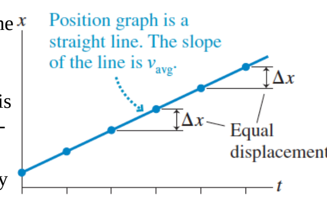
- If you drive your car at a perfectly steady 60 km/hr, this means you *change* your position by 60 km for every *time interval* of 1 hour
- **Uniform motion** is when equal displacements occur during any successive equal-time intervals

Riding steadily over level ground is a good example of uniform motion.



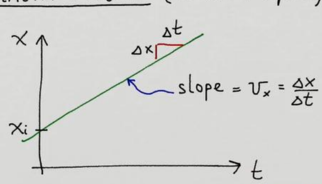
Uniform Motion (Constant Speed)

- For uniform motion, the position-versus-time graph is a straight line
- The **average velocity** is the slope of the position-versus-time graph
- The SI units of velocity are m/s

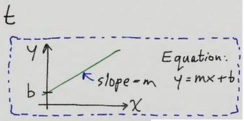


$$v_{avg} \equiv \frac{\Delta x}{\Delta t} \text{ or } \frac{\Delta y}{\Delta t} = \text{slope of the position-versus-time graph}$$

Uniform Motion (Constant Speed)



Recall:



Similarly:

$$x = v_x t + x_i \quad \text{or}$$

$$x = x_i + v_x t$$

Some Vocabulary

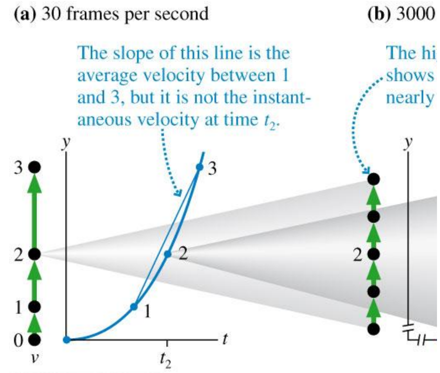
- The **distance** an object travels is a scalar quantity (no direction given, always positive)
- The **displacement** of an object is a vector quantity, equal to the final position minus the initial position
- An object's **speed** v is scalar quantity (no direction given, always positive)
- **Velocity** is a vector quantity that includes direction
- In one dimension, the direction of velocity is specified by the + or – sign

Instantaneous Velocity

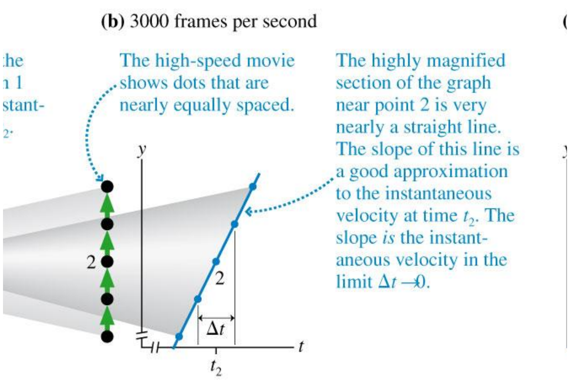
- An object that is speeding up or slowing down is *not* in uniform motion
- In this case, the position-versus-time graph is *not* a straight line
- We can determine the average speed v_{avg} between any two times separated by time interval Δt by finding the slope of the straight-line connection between the two points
- The **instantaneous velocity** is the is the object's velocity at a single *instant* of time *t*
- The average velocity $v_{avg} = \Delta s/\Delta t$ becomes a better and better approximation to the instantaneous velocity as Δt gets smaller and smaller

$$v_s \equiv \lim_{\Delta t \to 0} \frac{\Delta s}{\Delta t} = \frac{ds}{dt}$$

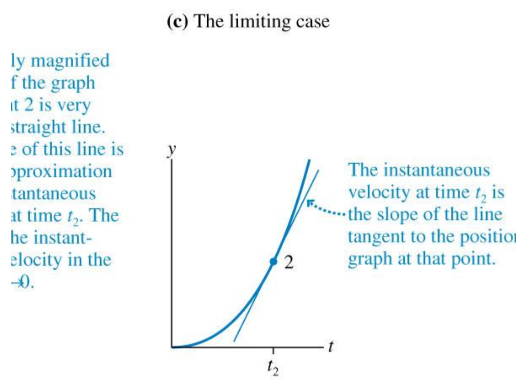
Instantaneous Velocity



Instantaneous Velocity



Instantaneous Velocity



Instantaneous Velocity

- As Δt continues to get smaller, the average velocity $v_{avg} = \Delta s/\Delta t$ reaches a constant or *limiting* value
- The instantaneous velocity at time *t* is the average velocity during a time interval Δt centered on *t*, as Δt approaches zero
- In calculus, this is called *the derivative of s with respect to t*
- Graphically, $\Delta s/\Delta t$ is the slope of a straight line
- In the limit $\Delta t \to 0$, the straight line is tangent to the curve
- The instantaneous velocity at time *t* is the slope of the line that is tangent to the position-versus-time graph at time *t*

v_s = slope of the position-versus-time graph at time *t*

A little calculus on the side...

$\frac{dx}{dt}$ is "the derivative of x with respect to t."

- If the function x(t) is of the form: $x = ct^n$, where c and n are constants, then: $\frac{dx}{dt} = nct^{n-1}$
- If x is a constant, then $\frac{dx}{dt} = 0$.

Example: Suppose the position of an object is $x = 2t^2$, with t in seconds.
(a) What is v_x?
(b) What is the velocity of the object at $t = 3$ s.

$v_x = \frac{dx}{dt} = \frac{d}{dt}(2t^2) = 2 \cdot 2 t^{2-1}$

(a) $v_x = 4t$

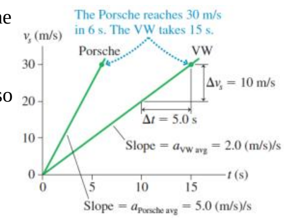
(b) $v_x(3) = 4 \cdot 3 = 12 \frac{m}{s}$

Acceleration

- Imagine a competition between a Volkswagen Beetle and a Porsche to see which can achieve a velocity of 30 m/s in the shortest time
- The table shows the velocity of each car, and the figure shows the velocity-versus-time graphs
- Both cars achieved every velocity between 0 and 30 m/s, so neither is faster
- But for the Porsche, the rate at which the velocity *changed* was

$$\frac{\Delta v_s}{\Delta t} = \frac{30 \text{ m/s}}{6.0 \text{ s}} = 5.0 \text{ (m/s)/s}$$

t(s)	$v_{Porsche}$(m/s)	v_{VW} (m/s)
0.0	0.0	0.0
0.1	0.5	0.2
0.2	1.0	0.4
0.3	1.5	0.6
0.4	2.0	0.8
⋮	⋮	⋮

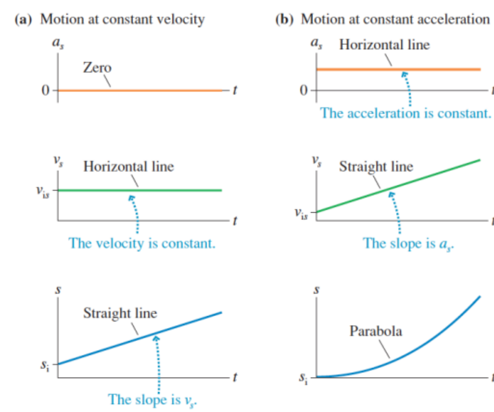


Motion with Constant Acceleration

- The SI units of acceleration are (m/s)/s, or m/s^2
- It is the rate of change of velocity, and measures how quickly or slowly an object's velocity changes
- The **average acceleration** during a time interval Δt is

$$a_{avg} \equiv \frac{\Delta v_s}{\Delta t}$$

- Graphically, a_{avg} is the *slope* of a straight-line velocity-versus-time graph
- If acceleration is constant, the acceleration a_s is the same as a_{avg}
- Acceleration, like velocity, is a vector quantity and has both magnitude and direction



The Kinematic Equations of Constant Acceleration

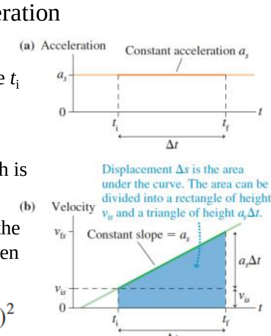
- Suppose we know an object's velocity to be v_{is} at an initial time t_i
- We also know the object has a constant acceleration of a_s over the time interval $\Delta t = t_f - t_i$
- We can then find the object's velocity at the later time t_f as

$$v_{fs} = v_{is} + a_s \Delta t$$

The Kinematic Equations of Constant Acceleration

- Suppose we know an object's position to be s_i at an initial time t_i
- It's constant acceleration a_s is shown in graph (a)
- The velocity-versus-time graph is shown in graph (b)
- The final position s_f is s_i plus the area under the curve of v_s between t_i and t_f:

$$s_f = s_i + v_{is}\Delta t + \tfrac{1}{2}a_s(\Delta t)^2$$



The Kinematic Equations of Constant Acceleration

- Suppose we know an object's velocity to be v_{is} at an initial position s_i
- We also know the object has a constant acceleration of a_s while it travels a total displacement of $\Delta s = s_f - s_i$
- We can then find the object's velocity at the final position s_f

$$v_{fs}^2 = v_{is}^2 + 2a_s \Delta s$$

The Kinematic Equations of Constant Acceleration

$$v_{fs} = v_{is} + a_s \Delta t$$

$$s_f = s_i + v_{is} \Delta t + \frac{1}{2} a_s (\Delta t)^2$$

$$v_{fs}^2 = v_{is}^2 + 2a_s \Delta s$$