Theme 1
Introductory Material

Module T1M2:
The Predictable Universe

Announcements!

1. Lab #1 – currently underway
   - This week, sections L10 – L18
   - Next week, sections L01 – L09

2. "Homework" begins Next Class!
   - One of the first 4 questions from CAPA #1 will be shown in class; you bring paper and write your solution!

3. email contact vs. Avenue email
   - don't use Avenue email!

Labs

- Labs start Monday September 28 (see AtL for schedule)
- Lab sections alternate week by week:
  - L01-L09:
    - Lab#1 week of 05.10.2015
    - Lab#2 week of 19.10.2015
    - Lab#3 week of 02.11.2015
    - Lab#4 week of 16.11.2015
  - L10-L18:
    - Lab#1 week of 28.09.2015
    - Lab#2 week of 26.10.2015
    - Lab#3 week of 09.11.2015
    - Lab#4 week of 23.11.2015
- Lab#5 will be assigned when we start topic on Fluids

Maikel Rheinstadter, #007

R

First name, Last Name, Student Number on top of page

Box with first letter of your last name in right top corner

Your calculations go here

Box with result of your calculation (number and units) in bottom right corner

5.2 m/s

Module Clicker Quiz!

Now that you have had a chance to review the entire first module, T1M2, here is your first

module quiz!

Module Clicker Quiz!

Significant Figures (120 seconds)

- Using the correct number of significant figures, what is the result of calculation

$$\frac{(4.3176 + 8.4)}{(4.8901 - 2.059)}$$

A. 4.5
B. 4.49
C. 4.492
D. 4.4921
E. I don't know

Module Clicker Quiz!

Significant Figures (120 seconds)

- Using the correct number of significant figures, what is the result of calculation

$$\frac{(4.3176 + 8.4)}{(4.8901 - 2.059)} = \frac{12.7176}{2.8311}$$

Keep the least # of digits after the decimal (i.e. 12.7). So numerator has 3 sig figs.

Can only keep 3 digits after the decimal (2.831). So denominator has 4 sig figs

A. 4.5
B. 4.49
C. 4.492
D. 4.4921
E. I don't know

$$\frac{12.7}{2.831} = 4.49$$

With ×/÷, keep the lesser number of sig figs, in this case, that is 3 sig figs.

T1M2 – Learning Objectives

- Recognize that the presentation of a numerical quantity, using ***significant figures*** and ***scientific notation***, reflects the accuracy of a measurement.
- Carry the appropriate significant figures through simple arithmetic calculations.
- Appreciate the importance of ***estimating unknown quantities*** as a means of understanding a system and predicting outcomes.
- Develop the skill of making an estimate and performing '***order of magnitude' approximations***.

Estimation – When 'Close' is good enough!

- We don't always need to exact values in order to appreciate the size of a quantity!
- Consider the statement:

"Within your body there are 2.75×10^{14} ***bacterial cells***"

- The "2.75" is not what impresses us here
- It's the 10^{14} that wows us (i.e. order of magnitude)
- Especially when we put it into context:

"Our bodies only contain 10^{13} of our own cells"

- ***Our* Goals for Estimation**: To develop a logical thought process for estimating values
  - Look at a few techniques and tricks
  - There is no 'one correct way' to estimate!

Estimation Tools

1. Familiarity with unit conversions!
   - We saw this with our Calorie conversion

2. Comfort with scientific notation

3. Estimating plausible ranges for an unknown quantity
   - Helpful when assigning an estimated value
   - The geometric mean can be helpful here

4. Break the problem down into simple steps

Mmm... Donuts

How many donuts would it take to cover a soccer pitch?

What kinds of questions do we need to be asking ourselves?

- How big is a soccer pitch?
- How big is a donut?

Mmm… Donuts

How big is a soccer pitch?

- We came up with 70 m x 100 m (Area = 7×10^3 m^2)

How big is a donut?

a) We looked at a length of 7 cm vs. 10 cm

b) Corresponding areas: 0.0049, 0.01 m^2

c) We also thought of adding an additional 20% to each donut to fill in the centre (a Timbit?)

Number of donuts

- Area of pitch ÷ area of donut = # donuts

We found:

a) Area = 1.4×10^6 m^2

b) Area = 0.7×10^6 m^2

c) Area = 0.84×10^6 m^2 [20% more than b)]

Regardless of the details of donut size, all our *reasonable* estimates give the same order of magnitude – 10^6 donuts!!

(Take home message: Don't sweat the details too much!)

Clicker Quiz

What is the approximate volume of this room?

A. 10^0 m^3
B. 10^1 m^3
C. 10^2 m^3
D. 10^3 m^3
E. 10^4 m^3

Clicker Quiz

What is the approximate volume of this room?

A. 10^0 m^3
B. 10^1 m^3
C. 10^2 m^3
D. 10^3 m^3
E. 10^4 m^3

80% of the class estimated 10^3 m^3 remarkable, given that we used different number!

Put your brain to work!

Estimate the mass of your brain, and the number of cells it contains

What kinds of questions do we need to be asking ourselves?

- What is the size of your brain?
- How do we go from *volume* to *mass*?
- What is the size of a brain cell?

Put your brain to work!

What is the size of your brain?

- 10 cm x 10 cm x 10 cm = 10^{-3} m^3
- This is 1 Litre – think of a bag of milk or 2 pints of beer

How do we go from *volume* to *mass*?

- Density is mass/volume
- Let's use the density of water (10^3 $\mathrm{kg/m}^3$) and trust that we're within 20-30% (don't sweat the details)

What is the size of a brain cell?

- Eukaryotic cells range 5-100 micrometres in size
- let's use 10 microns (10^{-5} m)
- Volume of a cell then is $10^{-15}\mathrm{m}^3$

Number of brain cells

- Volume of brain ÷ volume of cell= # cells

We get 10^{-3} $\mathrm{m}^3 \div 10^{-15}\mathrm{m}^3 = 10^{12}\mathrm{m}^3$ (1 trillion!)

- Student comment: BUT WAIT – earlier we said there are 10^{13} cells in our body – that would mean our brain comprises 10% of our cells.
- The interweb says that there are 10^{12} brain cells, which means one of our etsimates was off – which one do you think it was?

Tim Hortons

How many Tim Hortons coffees do we go through in a year?

What kinds of questions do we need to be asking ourselves?

- How many people are there in Canada?
- How much coffee does the average Canadian drink in a day?
- How much of that coffee is Tim's?

Suppose we stacked all of our cups – how tall of a stack would that be?

How many people are there in Canada?

- 35 million (+ you!)
- we made a reasonable range – more than 1 million (10^6); less than 100 million (10^8)
- Used geometric average $\sqrt{10^6 10^8} = 10^7$ (10 million)
- Close enough!!

How many of them drink coffee?

- We said 1/2 of them: 5×10^6

How much coffee does the average Canadian drink in a day?

- We settled on 2 cups
- BUT – one of those is from Tim's

Number of cups per year:

$$(2.5 \times 10^6)(365) \approx (5 \times 10^6)(300) \approx 1.5 \text{ billion!!}$$

- Tim Horton's website says 2 billion cups per year world wide, and 80% of their stores are in Canada.
- We likely made some over-estimates and under-estimates throughout, but in spite of this we came pretty close!
- Future thought: Should we look separately at roll-up-the-rim time?

Social Media

How many people in the world are on Facebook, right now?

What kinds of questions do we need to be asking ourselves?

- What fraction of your day do you spend on Facebook?
- How many people are there in the world?

What fraction of the day do you spend on facebook?

- 1 hr per day average (in class, some of you looked indignant – others looked down… and updated their status)

How many people are there in the world? 7 billion.

How many of us have a facebook account? 10%?

Now the trick:

- The fraction of your day spent doing something is equal to the fraction of the world doing it right now!

$$\frac{1\text{ hr}}{24\text{ hr}} = \frac{\#\text{ on FB right now}}{7 \times 10^8}$$

- **Think about this:**
  - Assume everyone in the world sleeps for 6 hours per day – that's 25% of your day.
  - This would mean that, at any given time, 25% of the world is asleep!

 # on FB right now = $7 \times 10^8/24 = 2 \times 10^7$ (~10 million people!)

Clicker Quiz

Approximately how many cars are there in Canada?

A. 10^5
B. 10^6
C. 10^7
D. 10^8

Give this a try! I estimated 10 million cars.
Here's what I considered:

- Population of Canada
- How people per household
- How many cars per household

Maybe you have another way to think of this?

T2M1 – Learning Objectives

- Take our day-to-day description of motion and shape these terms into well defined quantities.
- Visually represent motion by translating our spatial observations into a quantitative picture – a graph.
- Extract information from graphs, using our kinematic definitions.
- Define a model for one dimensional motion of an object that experiences a constant acceleration.
- Extend our model to two dimensional motion to see how the vector nature of the kinematic quantities can be used with the kinematic equations.

§

How we define motion

Term	Meaning	Notation
Position	Where is the object?	$\vec{x} \quad (\vec{x}_o, \vec{x}_i, \vec{x}_f, \vec{x}_3)$
Displacement	How far has the object moved from where it was before?	$\triangle\vec{x} = \vec{x}_f - \vec{x}_i$
Velocity	How quickly does the displacement occur?	$\vec{v} = \frac{\triangle\vec{x}}{\triangle t} = \frac{\vec{x}_f - \vec{x}_i}{t_f - t_i}$
Acceleration	Is the motion getting faster or slower?	$\vec{a} = \frac{\triangle\vec{v}}{\triangle t} = \frac{\vec{v}_f - \vec{v}_i}{t_f - t_i}$

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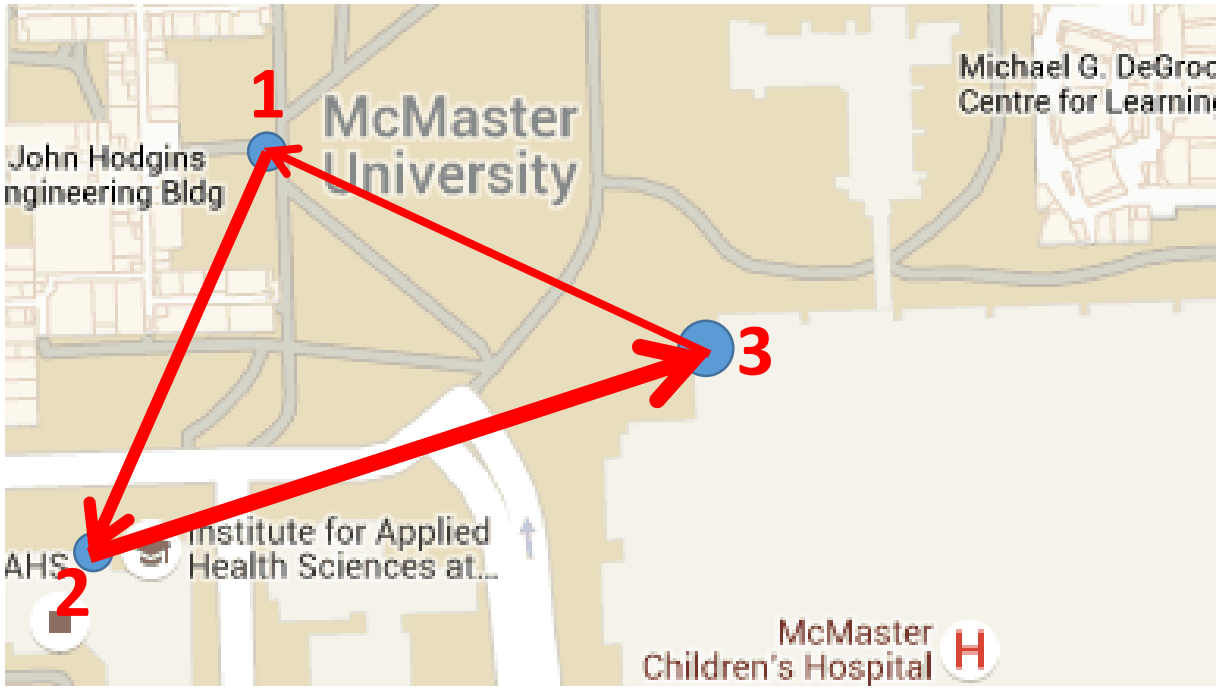
Distance vs Displacement

Take a Hike!: Walk from Health sciences bldg. over to JHE (130 m), then to Tim Hortons in Mo-Mac (120 m), then back to class (180 m)

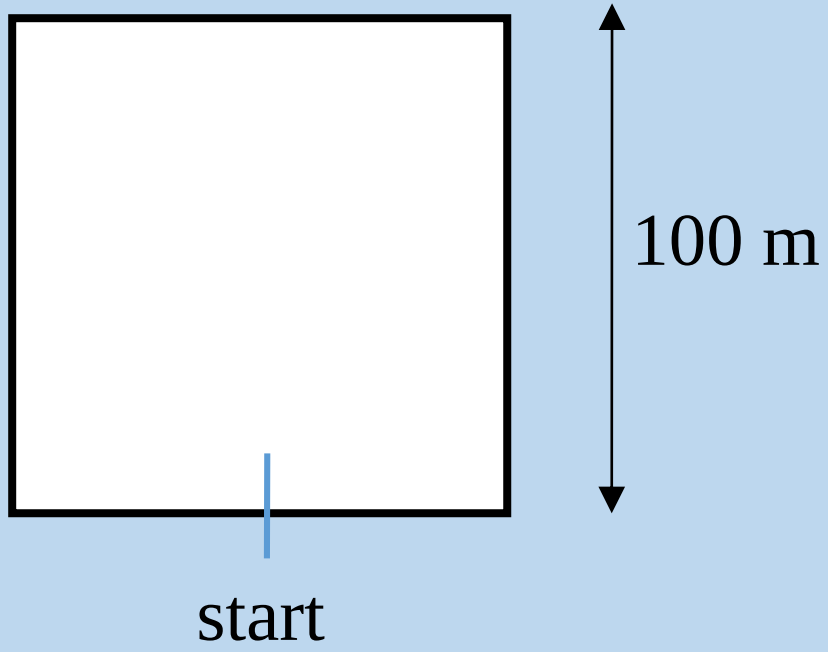
- What total distance did you walk? $\boldsymbol{d = 430\ m}$
- What was your total displacement? $\boldsymbol{\Delta\vec{r} = 0\ m}$



Clicker Quiz – 2D Motion

A jogger runs around a city block that is 100 m between stop signs. Starting at her apartment, she runs one and a half laps. What is her ***displacement*** from her starting point?

A. 0 m
B. 100 m
C. 200 m
D. 500 m
E. 600 m



Clicker Quiz

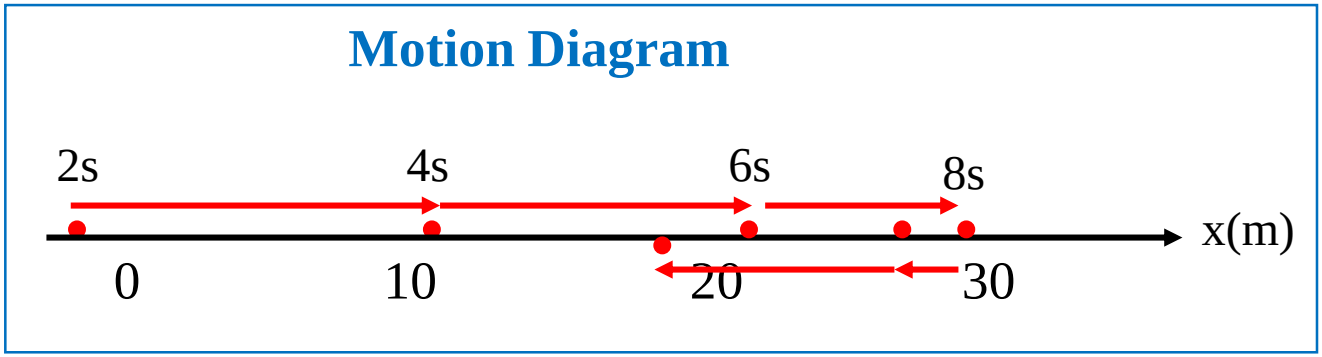
- When an object moves, is there anything that can be said, ***in general***, about distance vs. displacement?

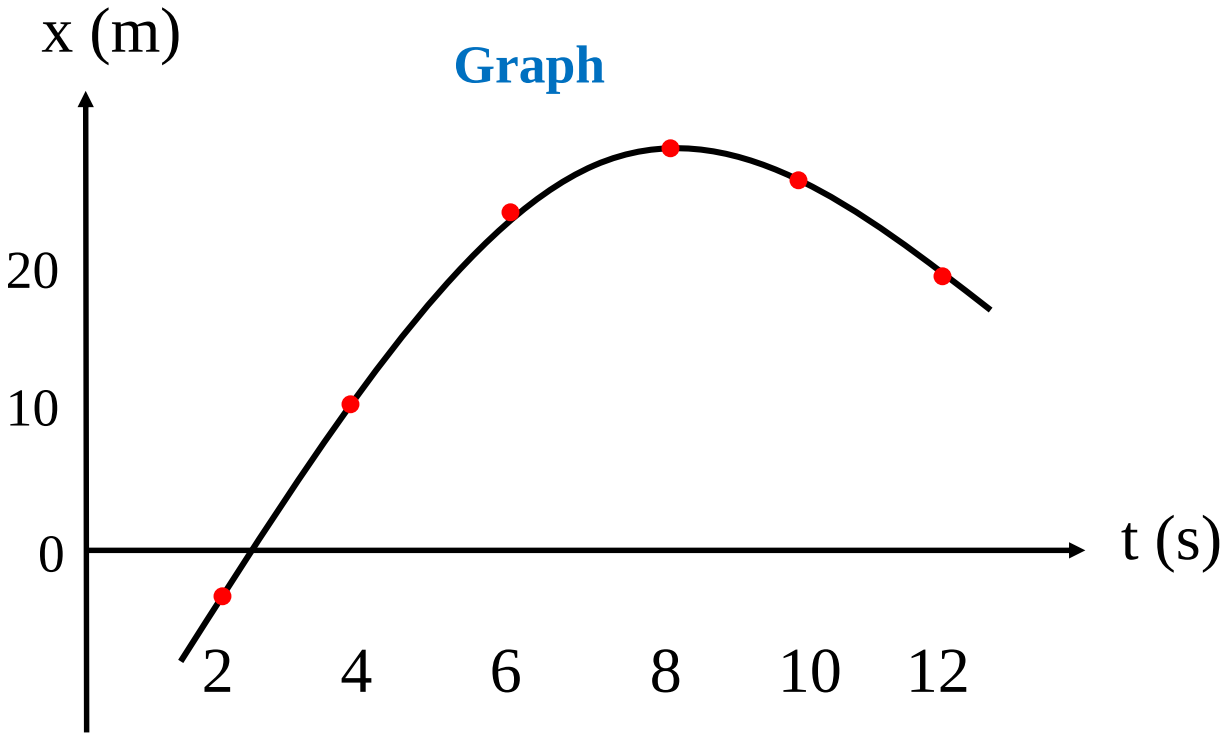
The magnitude of the DISPLACEMENT is ___ the DISTANCE.

A. Either greater than or equal to
B. Always greater than
C. Always equal to
D. Either smaller than or equal to
E. Always smaller than

§ Plotting motion on a position-time graph

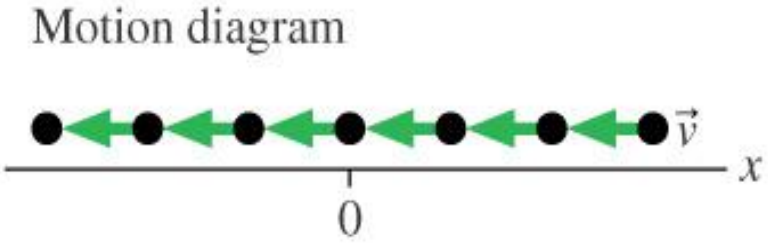
t(s)	x (m)
2	-2
4	10
6	24
8	29
10	27
12	19

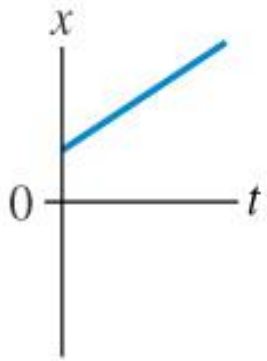




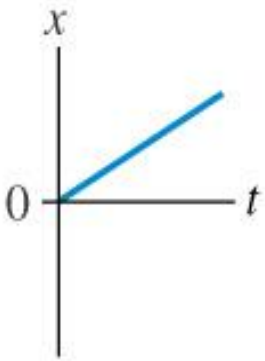
Clicker Quiz

A ***motion diagram*** shows a moving object, with equal time intervals between successive positions. Which graph represents the motion shown in the diagram below?





(a)



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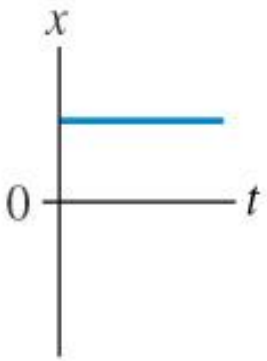

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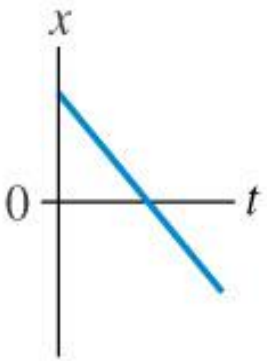

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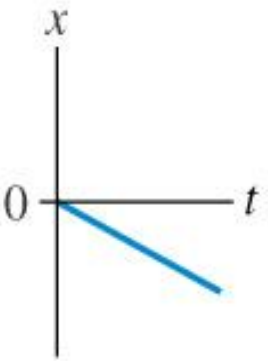

(e)

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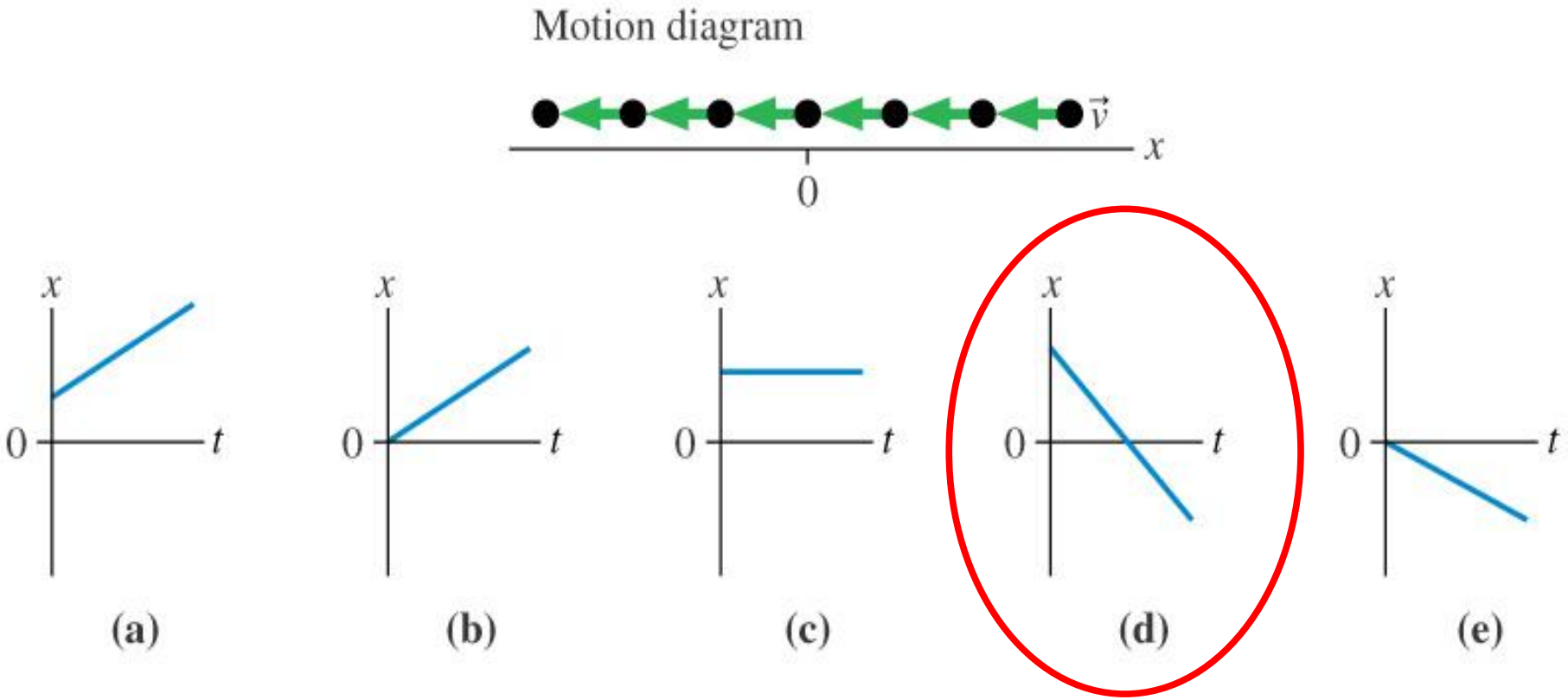
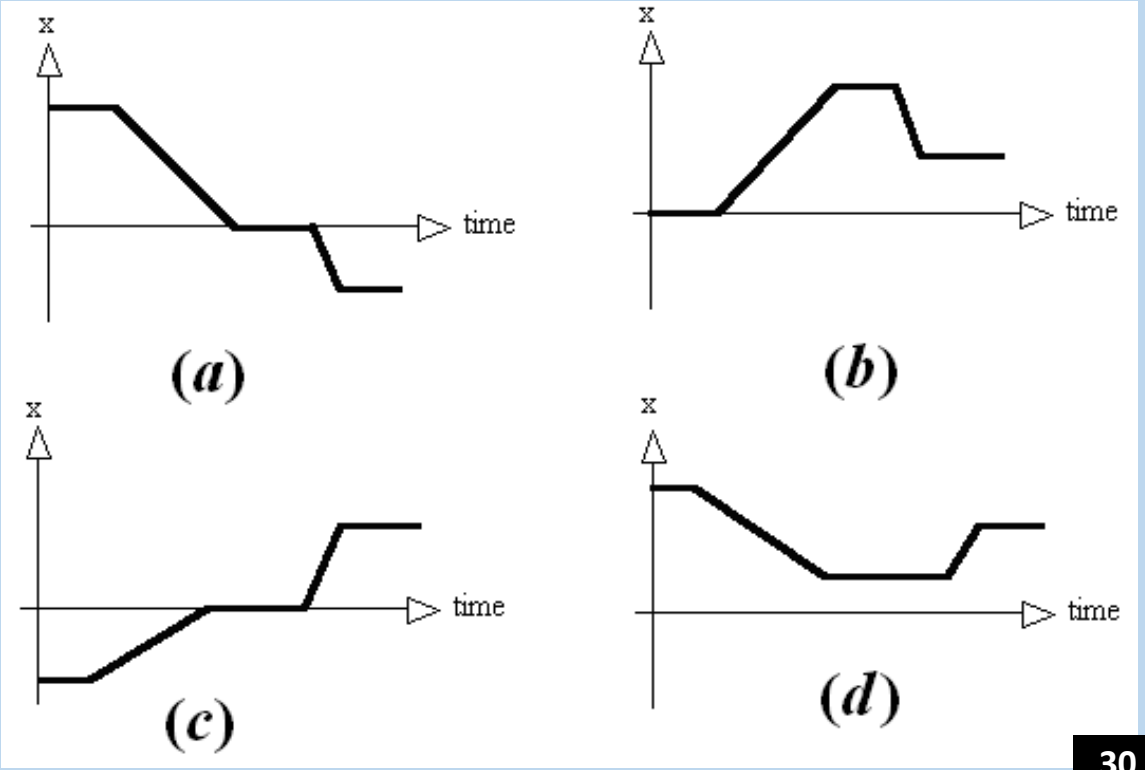


§

Clicker Quiz

- A person initially at point **C** on the x-axis stays there for a little while and then strolls along the x-axis to point **A**, stays there for a moment and then runs to point **B** and remains there.

- **Which graph correctly depicts this motion?**



Clicker Quiz

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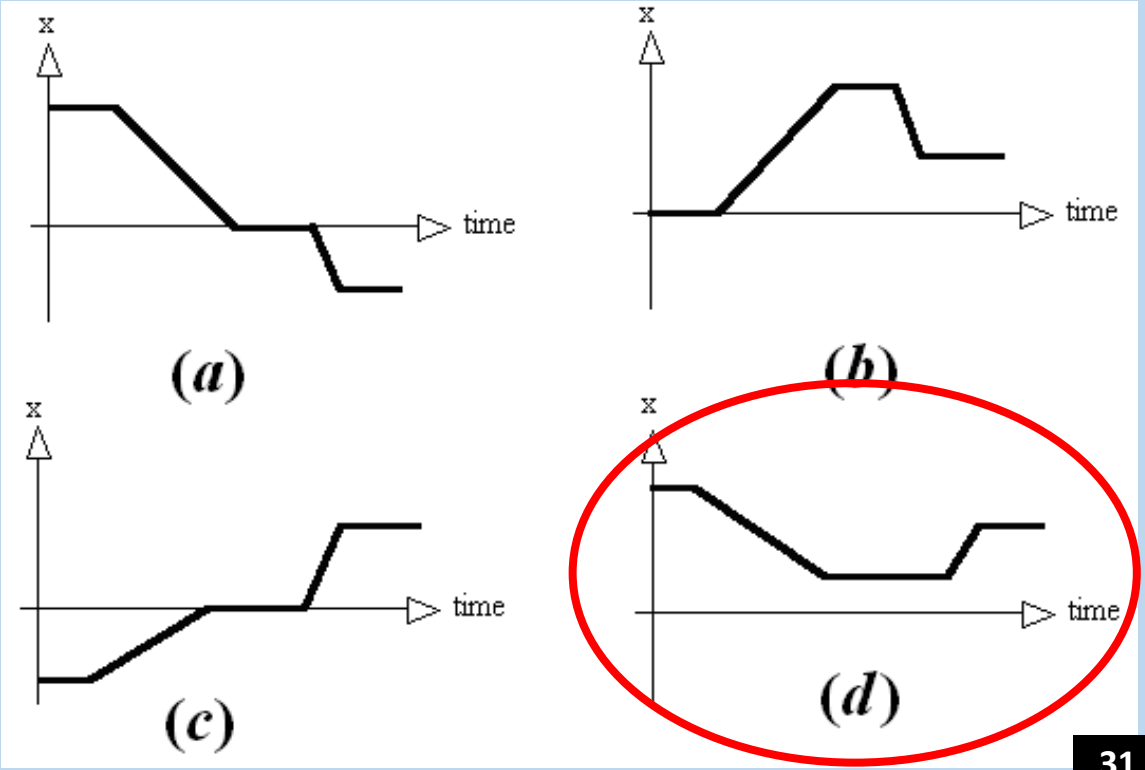


Speed vs Velocity

- Speed = distance/time $$\text{speed}_{avg} = \frac{d}{\triangle t}$$

- Velocity = displacement/time $$\vec{v} = \frac{\triangle \vec{x}}{\triangle t} = \frac{\vec{x}_f - \vec{x}_i}{t_f - t_i}$$

  - “How fast, and in which direction?”

§

Speed vs Velocity

You are walking down Main St. At 1:05 pm, you are 40 m east of campus. At 1:09 pm you are 60 m west of campus. What is your *average* velocity over the trip?

Let's define [east] as the positive direction

$$x_1 = 40\ m\ [\text{east}] = +40\ m \qquad t_1 = 1{:}05$$

$$x_2 = 60\ m\ [\text{west}] = -60\ m \qquad t_2 = 1{:}09$$

$$\vec{v} = \frac{x_2 - x_1}{t_2 - t_1} = \frac{(-60\ m) - (40\ m)}{1{:}09\ - 1{:}05}$$

$$= \frac{-100\ m}{4\ min} = -25\ m/min$$

$$= -0.42\ m/s$$

§

Clicker Quiz

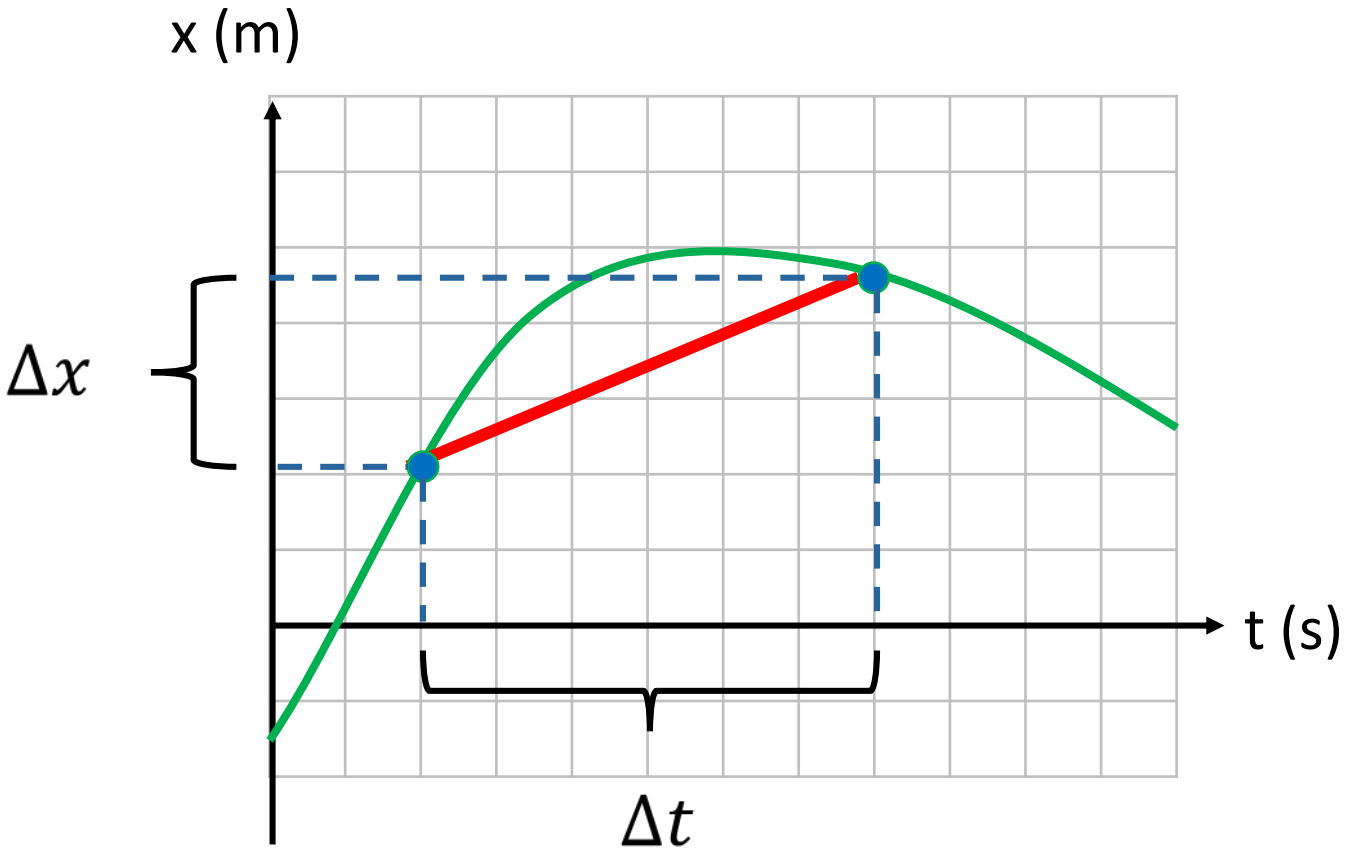
You go out for a jog – you travel at 8 km/h for 2 hours, 6 km/h for 2 hours and then 4 km/h for 1 hour. What is your average speed?

A. 6 km/h
B. Less than 6 km/h
C. Greater than 6 km/h
D. Not enough information

§ Position-time graphs and velocity

- The **SLOPE** of a position-time graph gives us velocity

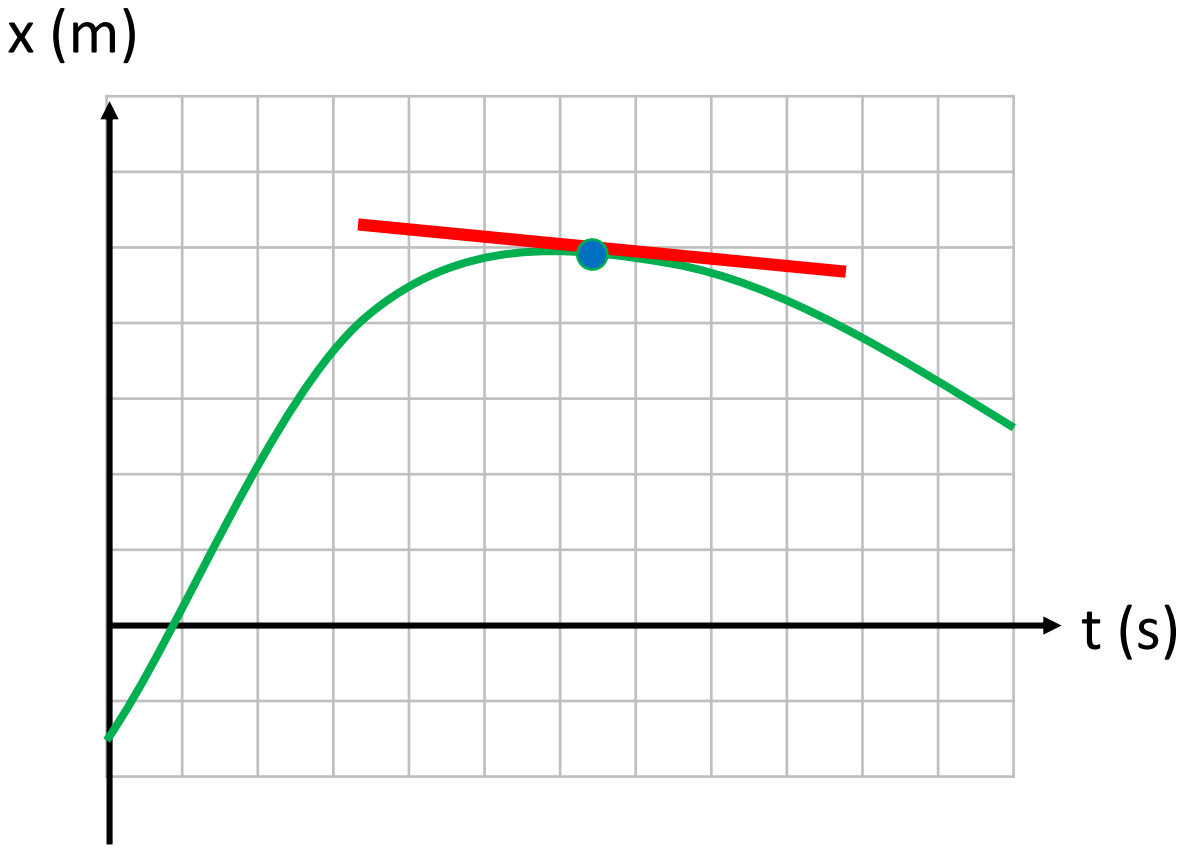
Average velocity: $v_{avg} = \frac{\Delta x}{\Delta t}$



§ Position-time graphs and velocity

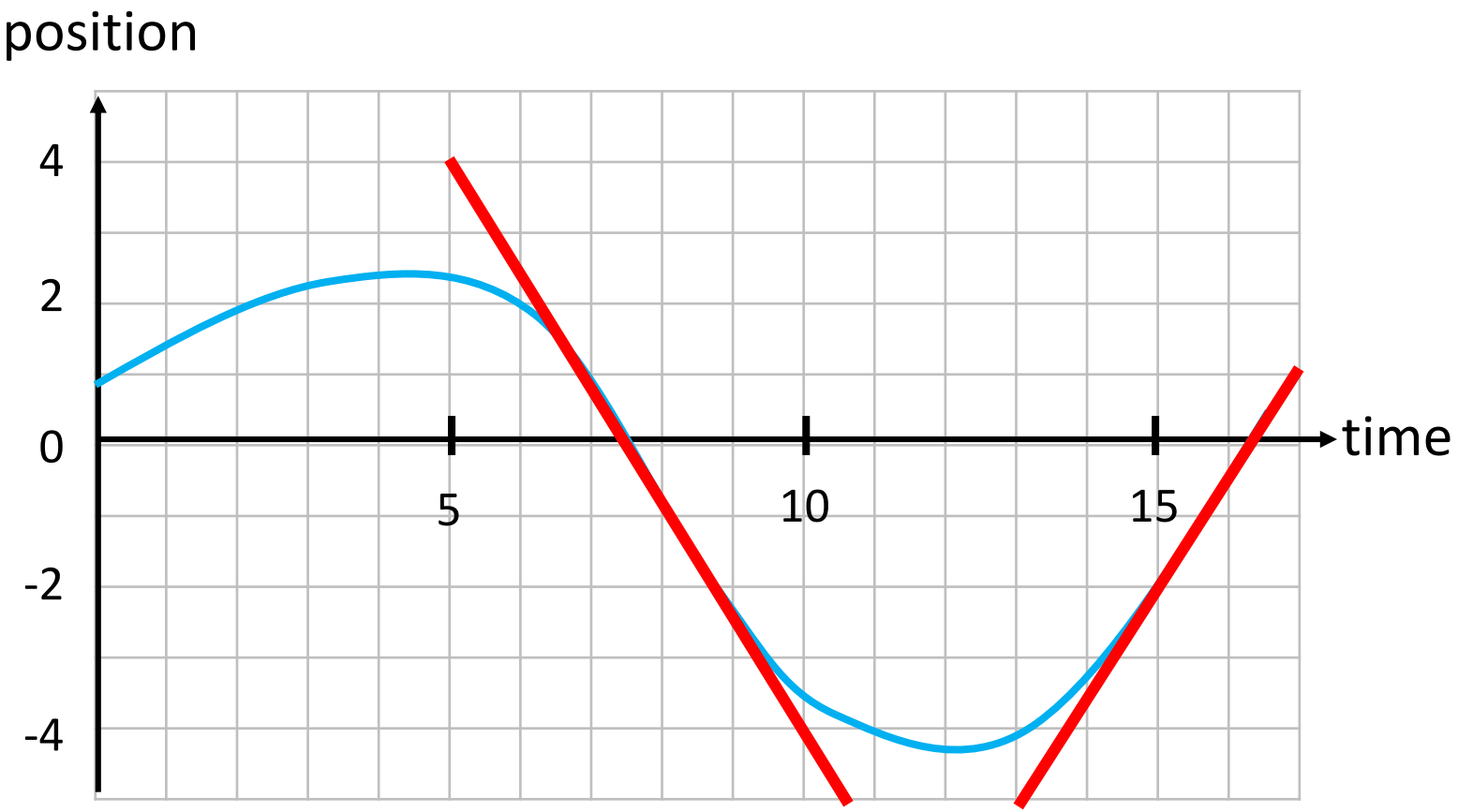
- The **SLOPE** of a position-time graph gives us velocity

Instantaneous velocity: $v_{inst} = \text{slope of tangent} \left(\frac{dx}{dt}\right)$



Average and instantaneous velocity

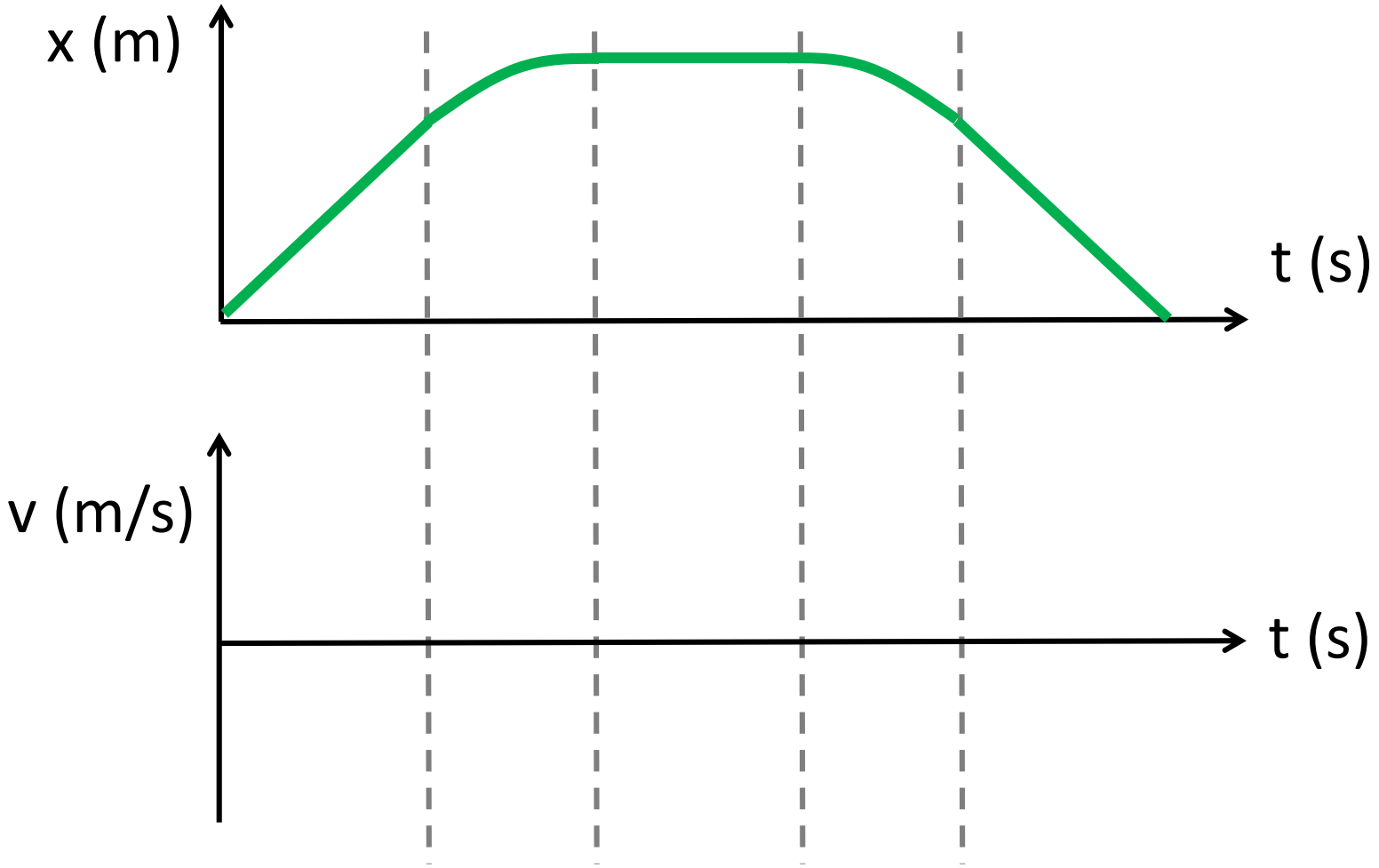
- The **SLOPE** of a position-time graph gives us velocity



1D kinematics in the real world?

Example

- We can evaluate the instantaneous velocity at any point on this graph.
  - Can we use this to make a plot of **velocity vs. time**?



§

Acceleration

- When velocity changes over a time interval ($t_1 \rightarrow t_2$), we define

- **Average acceleration** $$\vec{a}_{avg} = \frac{\Delta \vec{v}}{\Delta t} = \frac{\vec{v}_2 - \vec{v}_1}{t_2 - t_1}$$

- What graphical interpretation will give us acceleration?

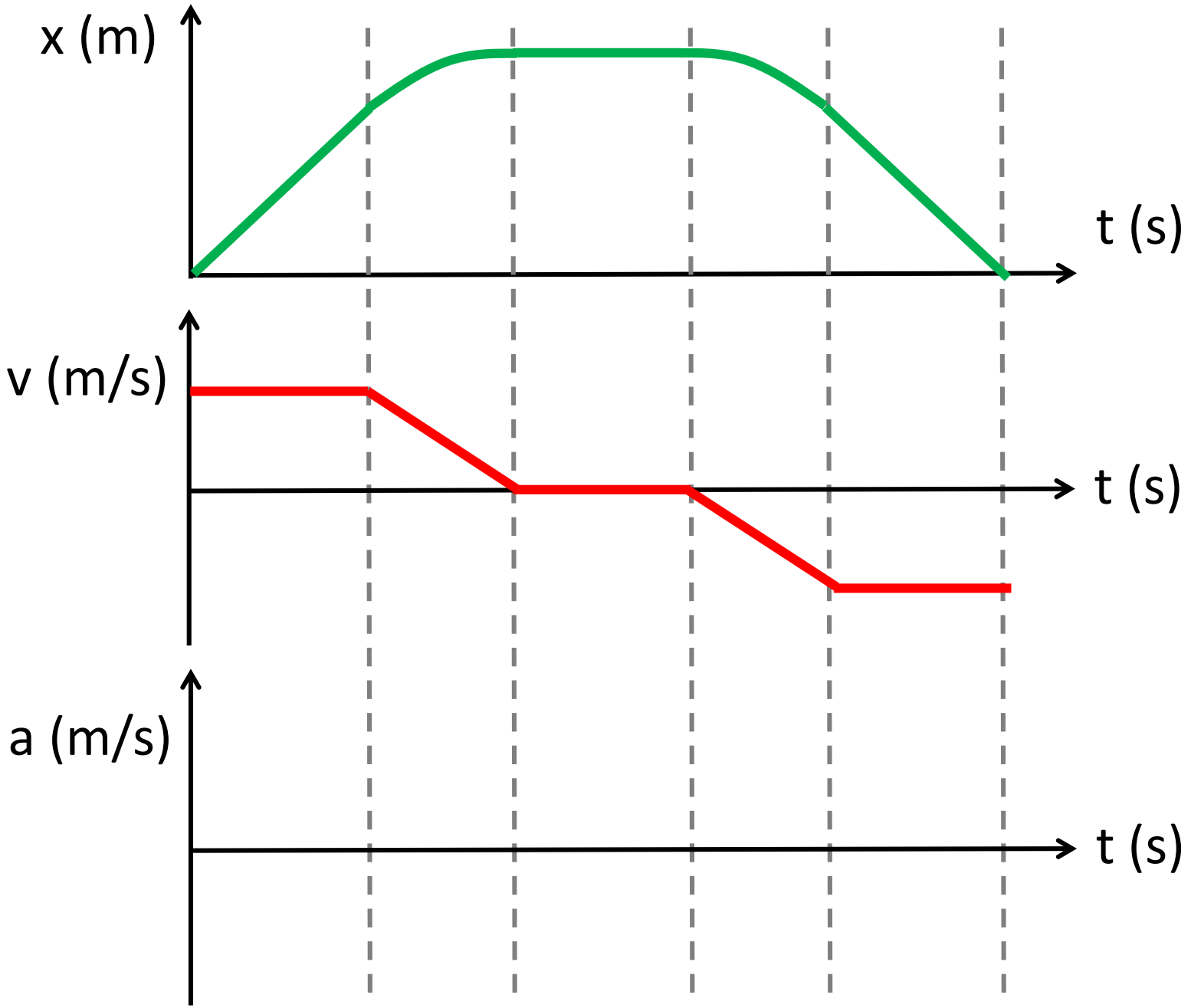
The SLOPE of a velocity-time graph gives acceleration

Determining acceleration from *v* vs. *t* graph

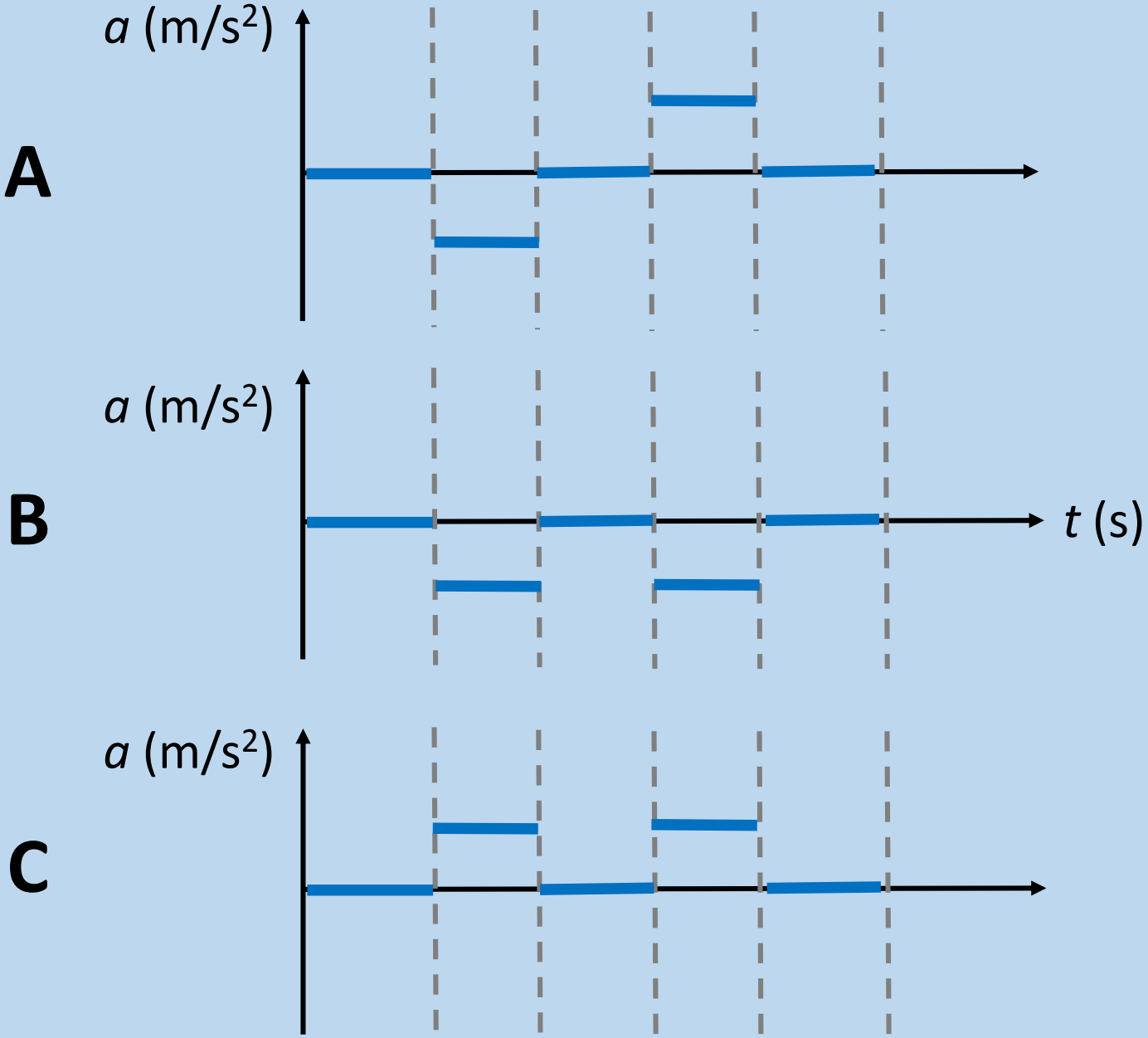
- **Average acceleration**
  - calculated over a finite period, from t_1 to t_2
  - use the slope of the line connecting the two points on the curve at t_1 and t_2.

- **Instantaneous acceleration**
  - calculated at one value of t
  - using the slope of the tangent line at that point.

§ Velocity-time graphs and acceleration



Clicker Quiz



Tricky acceleration!

- In previous example, there are two time intervals over which the object has negative acceleration.

1. **velocity is positive** and acceleration is negative
   - the object is slowing down.

2. **velocity is negative** and acceleration is negative
   - the object is speeding up (in the negative direction).

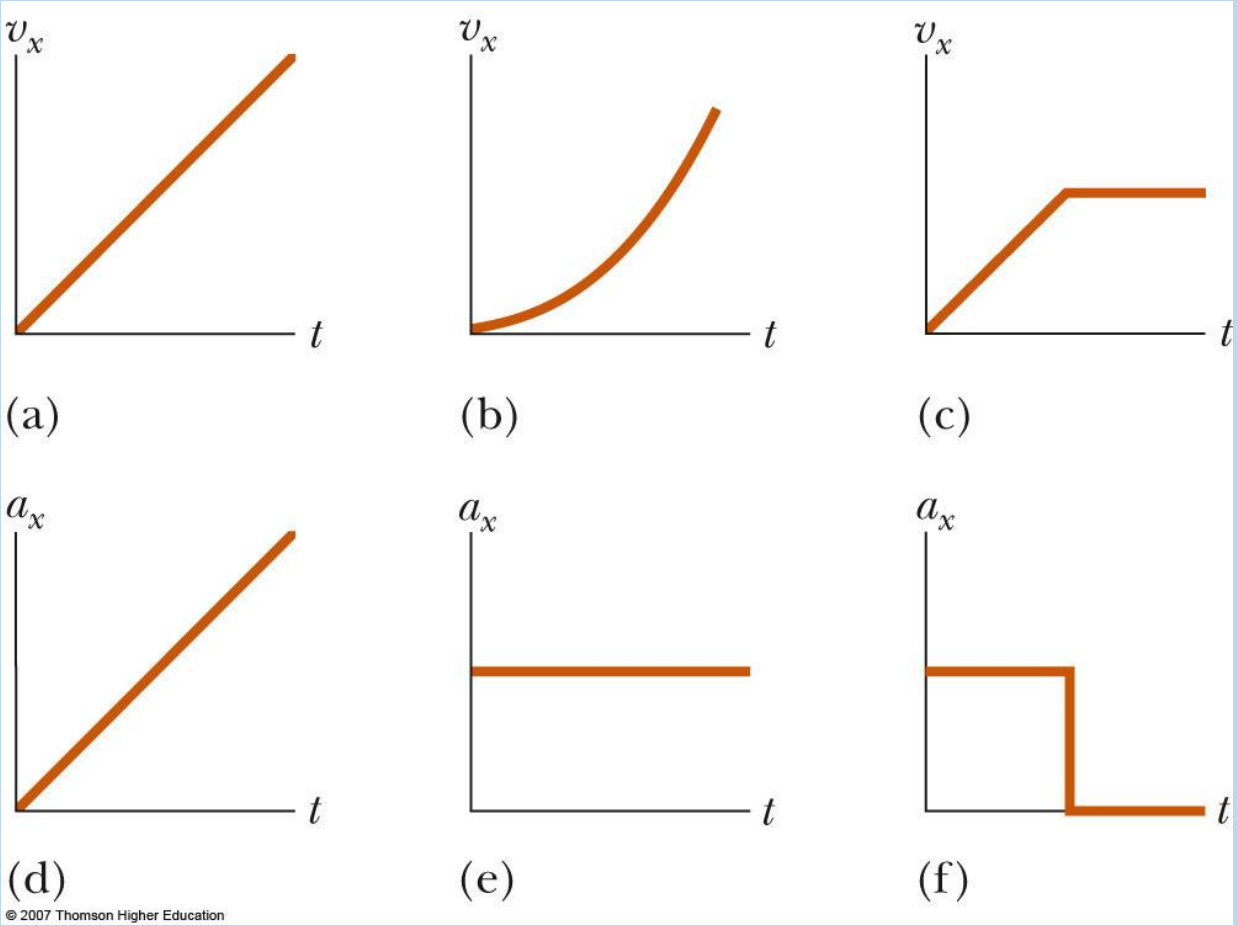
The Big Message:

Negative acceleration is NOT JUST slowing down

Clicker Quiz

- Match a given velocity graph with the corresponding acceleration graph

a. a-d, b-e, c-f
b. a-e, b-f, c-d
c. a-f, b-d, c-e
d. a-e, b-d, c-f
e. a-f, b-e, c-d



Clicker Quiz

- Match a given velocity graph with the corresponding acceleration graph

a. a-d, b-e, c-f

b. a-e, b-f, c-d

c. a-f, b-d, c-e

✔ **a-e, b-d, c-f**

e. a-f, b-e, c-d