Physics 4A
Lecture 1: Jan. 6, 2015

Sunil Sinha

UCSD Physics

PHYSICS 4A
Classical Mechanics
Winter Quarter 2015

Instructor: Sunil Sinha ssinha@physics.ucsd.edu

Lecture: Tue/Thu 2:00 PM - 3:20 PM YORK 2622

Discussion: Wed. 8:00 AM - 8:50 AM PCYNH 122

Weekly Quizzes: Fri. 9:00 AM – 9:50 AM HSS 1330 Starting Jan. 16

NO MAKEUP QUIZZES !! But your 2 lowest scores will be dropped.
IF YOU ARE GOING TO MISS 3 OR MORE QUIZZES
DO NOT TAKE THIS COURSE.
Professor Sinha's Office: MHA 4681 858-822-5537

Office Hours: Thu. 11 AM – 12 Noon or by appointment

PHYSICS 4A
Classical Mechanics
Winter Quarter 2015

TA: Animesh Gupta animesh@physics.ucsd.edu

TA Office Hours: Thu. 6 PM – 7 PM Physics Tutorial Center

Web Page: http://physics.ucsd.edu/students/courses/winter2015/physics4a/

Text: Wolfson and Pasachoff, *Physics for Scientists and Engineers* Vol. I UCSD Custom Edition

Final: Thursday March 19, 2015 3:00 PM – 6:00 PM

NO EARLY OR LATE FINAL GIVEN –PLEASE CHECK YOUR SCHEDULE NOW!
Homework will be assigned weekly, but will not be collected or graded.
Solutions to odd-numbered problems are in the textbook. Answers to even-numbered problems will be posted.

The Quiz and Final Exam Problems will be of the same level of difficulty as the Homework Problems, so the best way to prepare for them is to work all the homework problems, preferably on your own. Quizzes will be multiple-choice/machine graded.

PHYSICS 4A

- This is the first quarter of a 4 quarter calculus based sequence on introductory physics for Physics Majors.
- You will need to know some calculus, e.g. Math 20A and should be enrolled in Math 20B.
- We will use Trigonometry and Algebra; Vectors (addition, cross-product, dot-product, components); simple differentiation and integration.

Why do we need Physics?

- Underlies how the world (and the Universe) works—foundation of all Science and Engineering.
- Physics concepts needed for everything from designing bridges, autos, planes, rockets, spacecraft and satellites, to wireless, TV, iphones, ipads, to medical instrumentation such as X-Rays, MRI, ……
- That's why your major requires it!!

This course: PHYS 4A

- We will study Classical Mechanics, which is the study of the motion of macroscopic objects … baseballs, cars, rockets, planets, etc. (differs from Quantum Mechanics which operates at subatomic scale, and Relativistic Mechanics which operates when things move comparable to the speed of light).
- We will discuss how to measure things and how to describe motion in one or more dimensions.

This course : PHYS 4A

- We will then learn Newton's Laws and discuss what happens in terms of particles and forces.
- We will introduce the ideas of momentum and energy and the great conservation laws, and how they can be used to understand the motion of everyday objects.
- We will go on to discuss other applications, e.g. rotational motion and angular momentum; theory of gravity; oscillatory motion; equilibrium of structures, etc.

PHYS 4A

- Learning Physics will help you to

(a) think analytically

(b) solve all kinds of problems

(c) Learn how the world works

(d) Realize how amazing and beautiful the laws governing the universe and all matter in it are!

It can be demanding, so you need to work hard!

(even though you are bright enough to have gotten in to UCSD!)

PHYS 4A

- This is the Foundation Course. If you do well here, you can go on to excel in your coming courses, e.g. Physics 4B, 4C, 4D,4E or possibly other majors in science and engineering.
- Improves your prospects of finding employment in industry.

Course Grading

Will be on an Absolute Scale (no curve!)

A	B	C	D	F
>75	>60	>45	>30	< 30

Quizzes count 60%

Final Exam counts 40%

Quizzes will all be multiple choice/machine-graded

Home Work

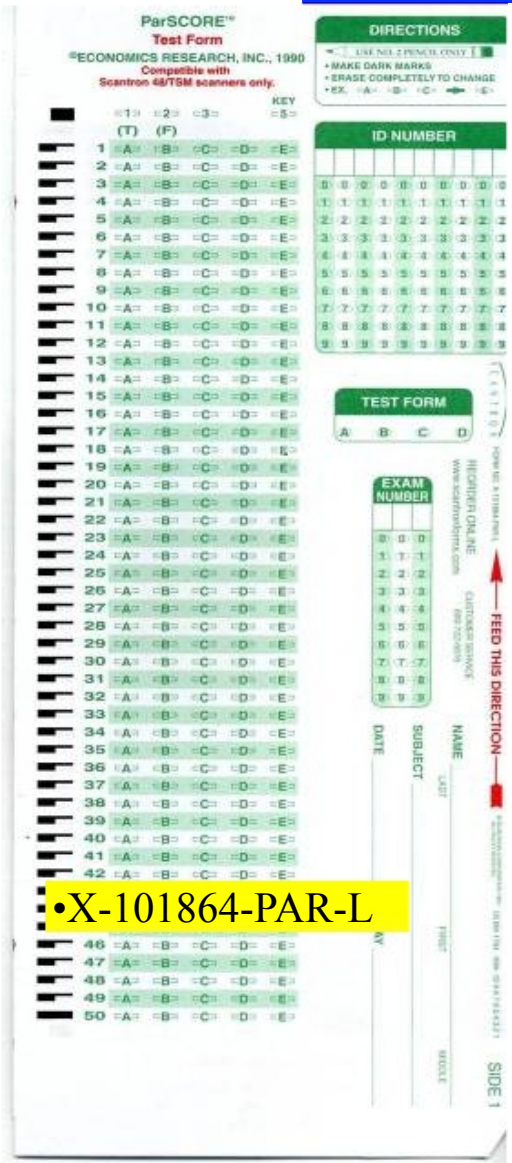
- Home work problem sets will be assigned on class web site on Friday.
- Will typically contain a dozen end-of-chapter problems from book
- Solutions will be posted the following Wednesday.
- Very important that you diligently attempt the HW YOURSELF. If you can **do** the HW problems, quiz will be a cakewalk!

- HW will not be collected or graded but will be discussed in the Discussion session. Be there.
- Follow these guidelines before/while attempting HW problems
  - Attend lectures and take notes (print out the lecture slides from website)
  - Study the relevant text & the solved problems in the book one-by-one
  - Close the book, recall the problem and now try to solve it yourself. **If you can't after few attempts, visit the TA/Prof for help.**
  - Problem solving skills are acquired by doing them. Its like learning how to drive. Cant learn to drive by simply looking at your friend drive !
  - Do not look at the posted HW solution till you have spent fair amount of time attempting the problems yourself. Don't give up early ! Time spent doing HW is the best way to prepare for the quiz!
  - After you look at the HW solutions, "hide it" and try to do problems by yourself by reconstructing the logic used.

Quizzes

- 8 weekly quizzes starting **Friday Jan.16.**
- Will take best 6 scores towards final grade
- There will be no makeup Quiz for **ANY** reason
- Quizzes will be multiple choice, will last 40 minutes
- You must bring a scantron card (#X101864) & #2 pencil
- You must write your course code # on the Scantron card
- You may use a calculator, bring paper to workout quiz problem before entering the final answer in scantron card
- Closed book exam, You may bring a 5"x7" "cheat-card"
- Bring your ID card, proctors will be checking identity

At Every Exam Bring These



Check Battery!

Sheets of Blank paper

UCSD ID CARD

A 5x7 inch

Cheat-card

Ok to write on both sides

A clear mind

Final Exam

- *Preliminary* date of the final exam is now available but location is TBA. Pl. note that the date and venue of the exam *may yet* change in the next two weeks.
- We will confirm the *final* Finals schedule as soon as we get it from the registrar's office. It will be posted on the class announcements page.
- Do not schedule end-of-quarter travel BEFORE the exam schedule is finalized. There will be **no makeup final** for any reason.
- The final exam will cover the material from all 14 chapters. You may bring a double sided full page cheat-sheet to the final exam.

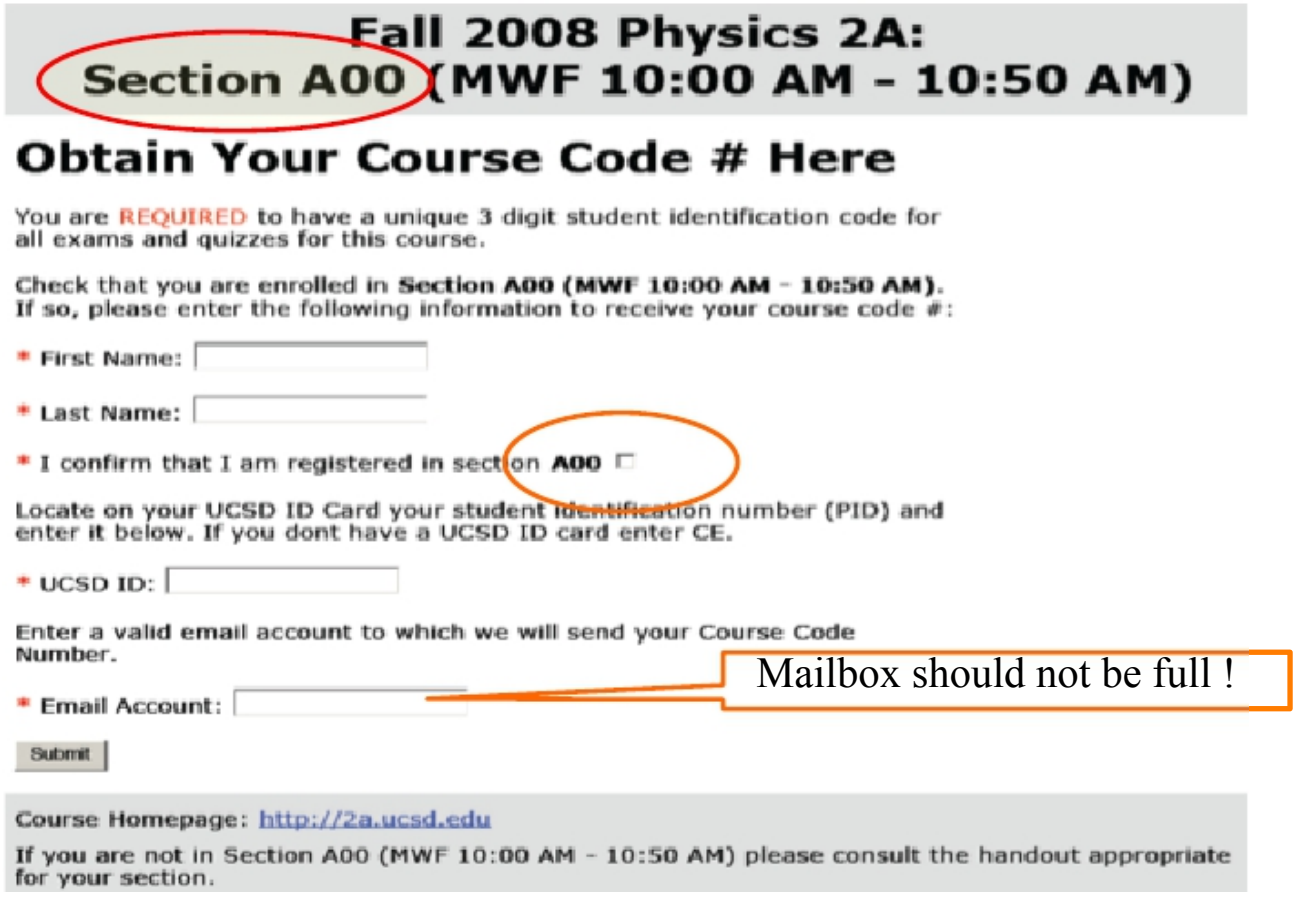
Registration & Obtaining Your Course Code

You **must** obtain a secret course code by registering on the course web site. This code will be your primary identifier for this course. You will need/use it for Quiz & final exam. See class website for registration details

Deadline for obtaining course code # is 15:00 hrs Thursday Jan 15 !

Obtaining Your SECRET Course Code

The Registration page looks like this



Fall 2008 Physics 2A:
Section A00 (MWF 10:00 AM - 10:50 AM)

Obtain Your Course Code # Here

You are REQUIRED to have a unique 3 digit student identification code for all exams and quizzes for this course.

Check that you are enrolled in **Section A00 (MWF 10:00 AM - 10:50 AM).**
If so, please enter the following information to receive your course code #:

* First Name:

* Last Name:

* I confirm that I am registered in section **A00**

Locate on your UCSD ID Card your student identification number (PID) and enter it below. If you dont have a UCSD ID card enter CE.

* UCSD ID:

Enter a valid email account to which we will send your Course Code Number.

* Email Account:

Mailbox should not be full !

Submit

Course Homepage: http://2a.ucsd.edu

If you are not in Section A00 (MWF 10:00 AM - 10:50 AM) please consult the handout appropriate for your section.

Academic Dishonesty Policy

- Pl. read the UCSD policy on *integrity of Scholarship* at http://www.ucsd.edu/catalog/front/AcadRegu.html
- Do not engage in any activity that involves attempting to receive a grade by means other than your honest effort. UCSD rules will be rigidly enforced.
- For this course academic dishonesty includes, among others: submitting another person's work as your own for grade consideration, any alteration for reconsideration, copying from another student, and the use of any unauthorized materials during the exam.

  Please do not cheat and do not encourage cheating. The consequences of being caught are very harsh and we will be very vigilant in our enforcement.

How to Do Well In PHYS4A

- This is a hard course, it will require substantial investment of your time. Consider taking this course another time if you are overloaded with other commitments.
- Read the assigned text from book before and after lectures. Attending lectures is not enough !

How to Do Well In PHYS4A

- Don't accept any concept without understanding the logic. Ask questions in lectures, discussion and PB session
- Do your homework on time, don't rush it. Do as many end of chapter problems as possible.
- Don't be shy, come to my or TA office hours and get the help you need. **I am at your command even on weekends, make an appointment !**
- Be sure to attend the first quizzes, they are the easiest !

Physics Tutorial Center in Mayer Hall

Wonderful resource for students, located at 2101/2106, Mayer Hall in the Revelle campus

- Manned by caring, intelligent and enthusiastic tutors who are there to help you with concepts, problems solving methods etc for free !

http://physics.ucsd.edu/students/courses/tutorialcenter/

- Remember: HW should be done by Thursday, Quiz is on Friday. These guys are available to help with HW when you need them !
  - **Sunday through Thursday 15:00-20:00 hrs !**
- **Check them out! You will be very happy you did.**

Solved ! : Learn Problem Solving From Pros

- Past 4A student input:
  - solved problems in the book are simple
  - home work problems are much harder !
- Solution:
  - Custom made set of (2 x 13 = 26) **hard** problems solved step by step : helps enhance your problem solving skills
  - available on web as narrated and animated videos
  - designed by some of the best Physics TAs at UCSD
  - See http://solved.ucsd.edu/
    - Quicktime movie
    - Can download to your computer for offline viewing

http://solved.ucsd.edu/

Ryan Kelley

Matt Lebourgeois

UCSD *Physics*

Solved!: Methods in Mechanics

Home *Problems*

Course Review Sessions

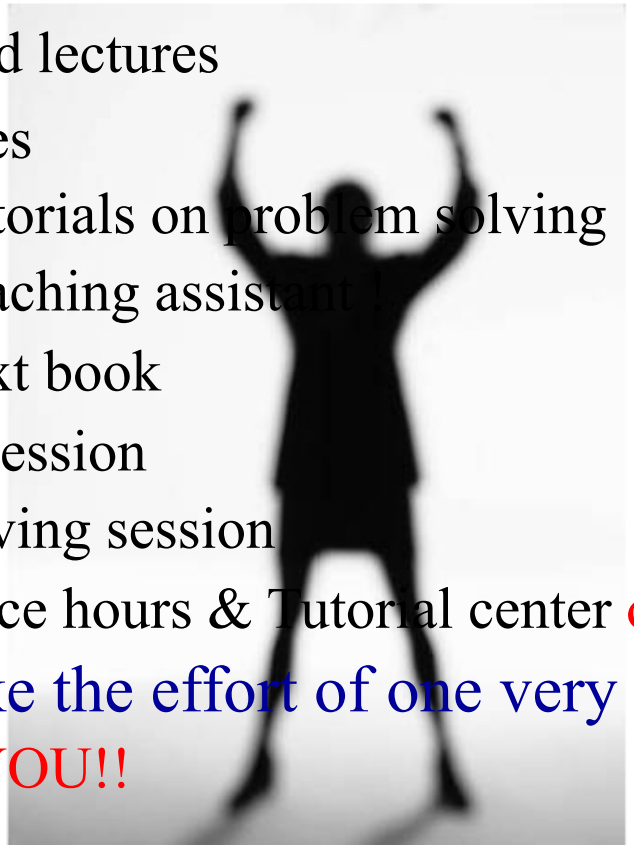
Problem	Topic	QuickTime	iPod
Review Session Tape 1	Vectors		

Problem List

Problem	Topic	QuickTime	iPod
Scoring a Touchdown!	Vectors		
Canoeing on a Lake	Vectors		
Dropping Eggs on the Prof	1-D Motion		
Newton's Crazy Apple	1-D Motion		
Tanks at War	2-D Motion		
Romeo Saves Juliet	2-D Motion		
Stunt Plane	Circular Motion		
Oil Tanker Crash	Newton's Laws I		
Chain Link Fun	Newton's Laws I		
Crazy Block System!	Newton's Laws II		
Even More Blocks!	Newton's Laws II		
Blocks and Frictions	Work-Energy Theorem		
College Books	Work-Energy Theorem		
Tarzan and Jane	Conservation of Energy		
Spring and Block	Conservation of Energy		
Car Collision	Conservation of Momentum		
Baseball and Basketball	Conservation of Momentum		
Racing Truck	Rotational Kinematics		
Torquing Discs	Rotational Energy/Kinematics		
The YoYo	Rotational Dynamics		
Lancelot and Guinevere	Equilibrium		
Barnyard Gate	Equilibrium		
Binary Stars	Gravitation		
Mechanical Bull	Harmonic Motion		
Mechanical Pendulum	Harmonic Motion		

What Does It Take to Excel ?

- We will provide lots of resources for you to succeed in this course
  - Well prepared lectures
  - Lecture slides
  - 24/7 Web tutorials on problem solving
  - Excellent teaching assistant !
  - Excellent text book
  - Discussion session
  - Problem solving session
  - Flexible office hours & Tutorial center open on weekends
- But it will take the effort of one very important person to succeed .. YOU!!

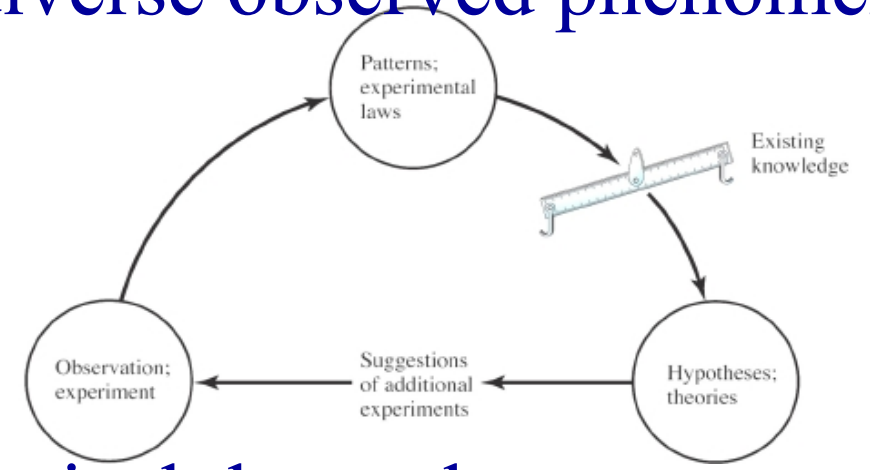


Next: Start Gathering Tools

- Nature of Physics
- Idealized Models
- Standard & Units
- Measurement Error
- Order of magnitude
- Significant figures
- Scalars & Vectors

Nature of Physics

- Physics is an experiment driven science
- Observe phenomena, find patterns & principles (physical theory) that relate and explain diverse observed phenomena



- Every physical theory has a range of validity outside which it is not applicable

Models in Physics

- A **model** is a simplified version of a physical system that would be too complicated to analyze in full detail
- In a model, we overlook the minor effects to concentrate on the most important feature of the system it describes, e.g. analyzing motion of a baseball thrown in air
- The predictions based on a model are only as good as the features present in the model
- Will use models of phenomena throughout the course to learn about its essential features

Unit of Physical Quantities

- Physics is an experimental science, experiments require measurements
- A number used to describe a physical phenomenon quantitatively are called *physical quantities*. e.g. your height and weight
- When measuring a quantity, we compare it with some reference standard. Such a standard defines a unit of the quantity
  - –e.g: SI Units

Length	Time	Mass
Meter(m)	Second(s)	Kilogram(kg)

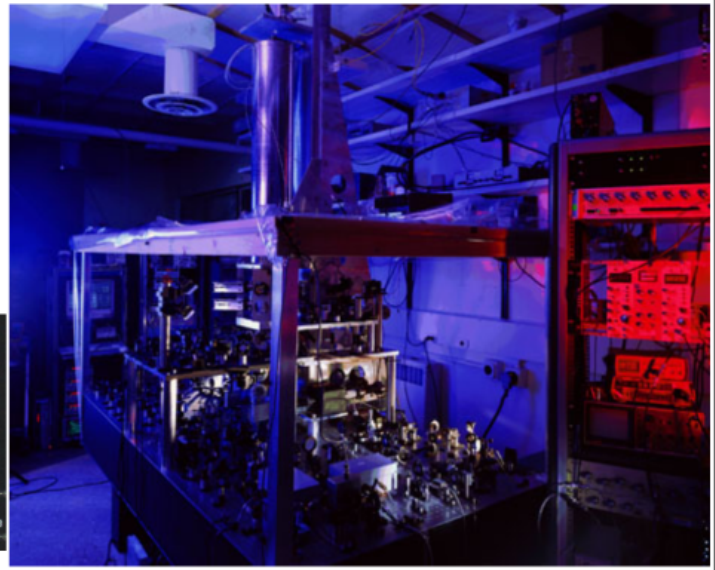
  - –units of measurements must be calibrated:
    - ⇒ exactly the same in all parts of the universe !

Measurement Standards

- Worldwide, in science we use the SI or metric units, its definitions have evolved with gains in technology
- Second (s) is 9192631770 vibrations of ^{133}Cs atom

NIST-F1 Cesium atom "Fountain" atomic clock in Colorado

Internet needs a standard time else the WEB would collapse as would many other networks



Systeme International (SI) Standards

- Meter (m) is the distance traveled by light in vacuum in $\frac{1}{299792458}$ s $\simeq 3.3$ ns
- Kilog[illegible]erence kilogram is a cylinder made of platinum–iridium alloy and kept in the International Bureau of Weights and Measures in France. A search continues for a suitable atomic or natural standard for mass

speed of light is a fundamental constant of this universe; could be different in other (parallel?) universes

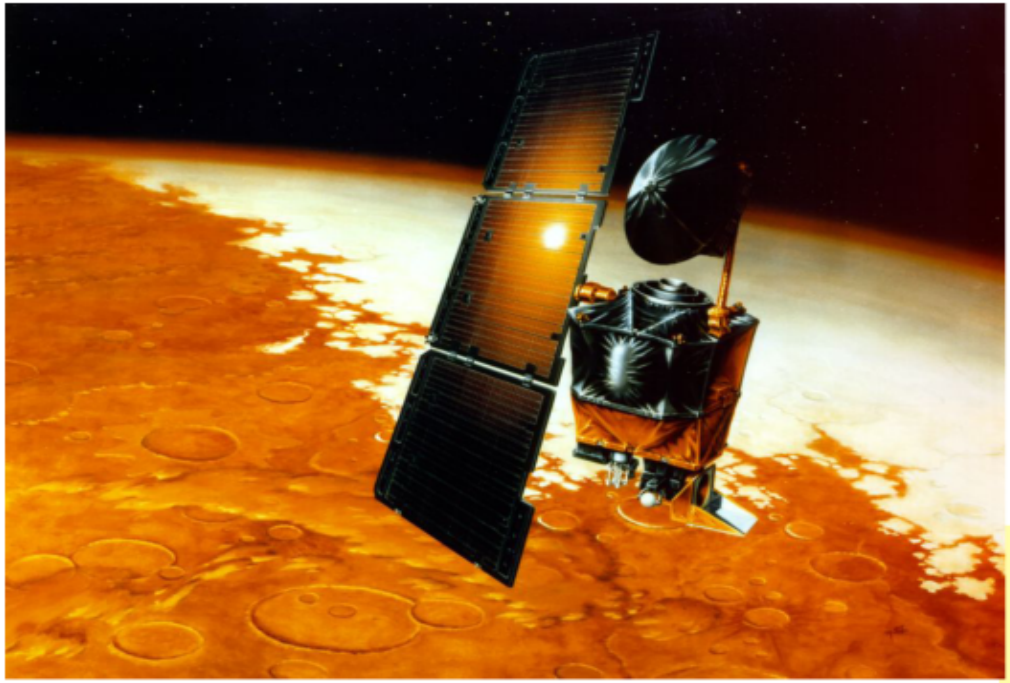
Other (archaic) Units of Measure

- CGS units:second, gram(10^{-3}kg), cm (10^{-2} m)
- British/US: Defined in terms of SI units
  - second
  - inch =2.54cm
  - pound =0.4535 kg at sea level

- In physics we will only use SI (metric units)
- See appendix E of your book for conversion factors.
  - Inconsistent usage of units can be recipe for disaster ! e.g: NASA's Mars mission

Unit Inconsistency Disaster !

NASA crashed a $80M Mars Orbiter in 1999 because of usage of mismatched units in navigation software: Metric Vs British units !!



The space probe vanished soon after reaching Mars after a nine and a half month journey - all because NASA scientists overlooked a conversion of measurements from **british** to metric.

The Mars Climate Orbiter had successfully flown 760 million miles with the error unnoticed but as soon as it began circling the planet the probe vanished.

The mistake in calculations caused the satellite to burn up or break apart by moving too close to Mars.

NASA were apparently given the units for acceleration in pounds of force (imperial) instead of newtons (metric).

For those of you who are interested this is how to convert between the two units:

1 pound of force = 0.225 newtons
4.448 pounds of force= 1 newton

The result was that the changes made to the spacecraft's trajectory were actually 4.4 times greater than what the JPL navigation team believed.

Unit Prefixes To Quantify Small & Big

- With Standard (Metric) units in hand, can define convenient smaller & larger units for the same quantities….in the powers of 10

Prefix	Symbol	Multiple
Exa†	E	10^{18}
Peta†	P	10^{15}
Tera	T	10^{12}
Giga	G	10^{9}

Prefix	Symbol	Multiple
Deci†	d	10^{-1}
Centi	c	10^{-2}
Milli	m	10^{-3}
Micro	μ	10^{-6}

Prefix	Symbol	Multiple
Mega	M	10^{6}
Kilo	k	10^{3}
Hecto†	h	10^{2}
Deka†	da	10^{1}

Prefix	Symbol	Multiple
Nano	n	10^{-9}
Pico	p	10^{-12}
Femto†	f	10^{-15}
Atto†	a	10^{-18}

The Scale of Things

TABLE 1.5 Some approximate lengths

	Length (m)
Circumference of the earth	4×10^{7}
New York to Los Angeles	5×10^{6}
Distance you can drive in 1 hour	1×10^{5}
Altitude of jet planes	1×10^{4}
Distance across a college campus	1000
Length of a football field	100
Length of a classroom	10
Length of your arm	1
Width of a textbook	0.1
Length of your little fingernail	0.01
Diameter of a pencil lead	1×10^{-3}
Thickness of a sheet of paper	1×10^{-4}
Diameter of a dust particle	1×10^{-5}

TABLE 1.6 Some approximate masses

	Mass (kg)
Large airliner	1×10^{5}
Small car	1000
Large human	100
Medium-size dog	10
Science textbook	1
Apple	0.1
Pencil	0.01
Raisin	1×10^{-3}
Fly	1×10^{-4}

Units and Conversion Factors are given in the Appendices in the Textbook.

Estimates: A Little Reasoning Goes a Long Way !

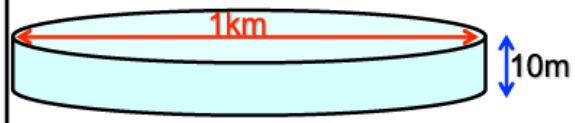
- We sometimes want to make a quick & calculation on the "back of an envelope". We may not have access to all the data needed, so only an estimate, or a very rough approximation, is possible
  Order of Magnitude (OOM) calculation:
  - variables are rounded off to nearest power of 10 or some other convenient number
  - final result of a calculation with variables so dramatically rounded off is accurate only to within a factor of 10-20 yet such estimates can be very useful
- Every budding Scientist/Engineer/Businessperson must know how to do such estimates !

How Much Water In This Lake ?

Estimate how much water there is in the Lake Rae which is circular, about 1km across and, I am guessing, has a depth of 10m

No lake is a perfect circle, nor do lakes always have a perfectly flat bottom !

But for OOM estimate purpose, model the lake as a cylinder !



Volume of a cylinder V

V= height × area of base

$$V = h \times \pi r^2 = 10m \times 3 \times (500m)^2$$

$$= 8 \times 10^6 m^3 \simeq 10^7 m^3$$

Approximately Ten Million cubic meters of water in lake Rae

Estimate no. of times a heart beats in a lifetime

Average Lifetime t ~ 70 years

Av. Heartbeats/ min f ~ 60

1 year = 365 X 24 X 60 = 525, 600 minutes

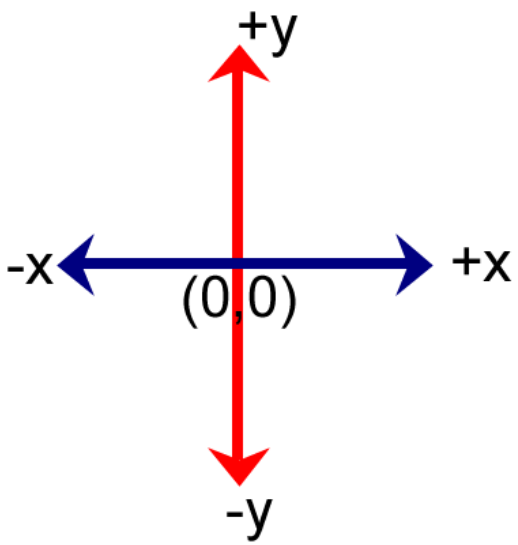
So N = 70 X 60 X 525600 = 2,207,520,000

Average heart beats about 2 billion times in your lifetime!!

Other Kinds of Estimates ("Fermi Questions")

- How much does a cloud weigh?
- How many *piano tuners* in Chicago?
- How many gallons of gasoline are used by cars each year in the United States?
- How many jelly beans fill a one-liter jar?
- Approximately what fraction of the area of the continental United States is covered by automobiles?

Need to Define A Reference Frame First

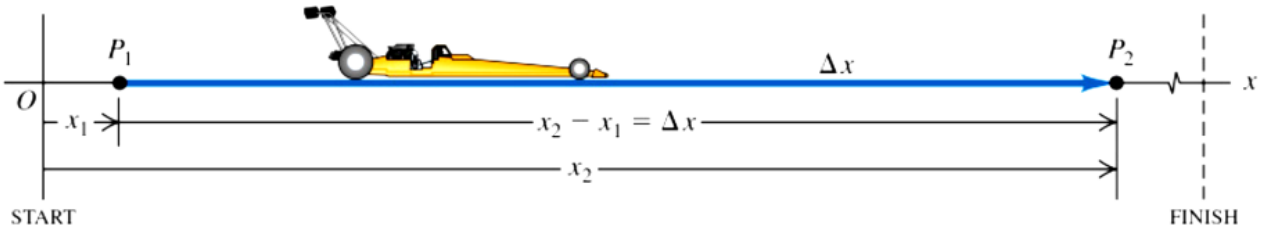


Defines for a displacement vector
which way is positive and which way is negative

Displacement Vector $\vec{x}$

Describe race car's motion by the that of a representative point on car→middle

Need a coordinate system to describe car's change in position
Choose x axis of coord. system to lie along car's straight line path



Displacement $\Delta x = x_2 - x_1$

Velocity: Average and Instantaneous

Define x-component of *average* velocity

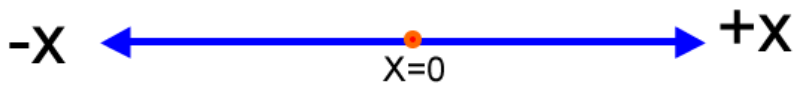
$$v_{av-x} = \frac{x_2 - x_1}{t_2 - t_1} = \frac{\Delta x}{\Delta t}$$

(unit= m/s)

Positive $v_{av\text{-}x}$ $\Rightarrow$ x coordinate increases with time t

Negative $v_{av\text{-}x}$ $\Rightarrow$ x coordinate decreases with time t

definition



Time always increases

The *x-t* Graph of An Object's Motion

Pictorial representation of object's motion in x as function of time t

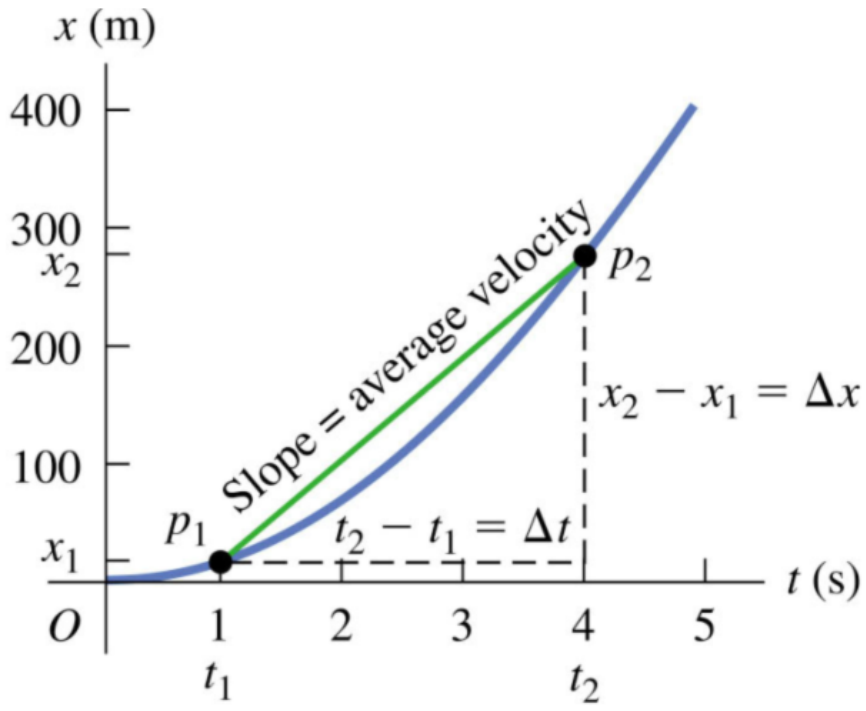
Not the path the object took along x axis !

$$v_{av-x} = \frac{\Delta x}{\Delta t}$$

$$=$$

slope of line $p_1 p_2$

v_{av-x} depends on Δx & Δt not on details of motion !



Some Velocities

A snail's pace	10^{-3} m/s
A brisk walk	2 m/s
Fastest human	11 m/s
Running cheetah	35 m/s
Fastest car	341 m/s

Random motion of air molecules	500 m/s
Fastest airplane	1000 m/s
Orbiting communications satellite	3000 m/s
Electron orbiting in a hydrogen atom	2×10^6 m/s
Light traveling in a vacuum	3×10^8 m/s

Instantaneous Velocity v_x

- Definition: Velocity of an object at any specific instant of time or location
  - Is the limit of average velocity as the time interval $\Delta t \to 0$

$$v_x = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$$

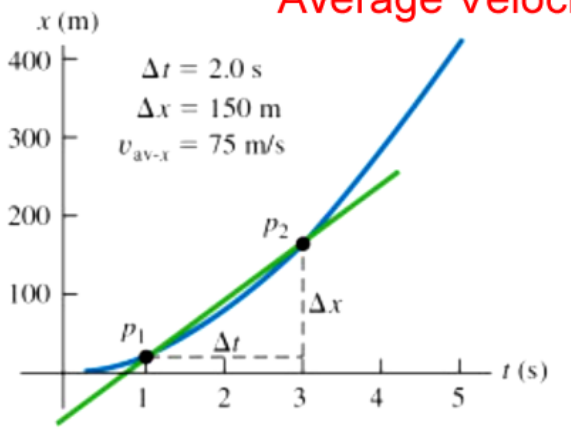
v_{av-x} & v_x are both vectors, can be + or - depending on the change in displacement

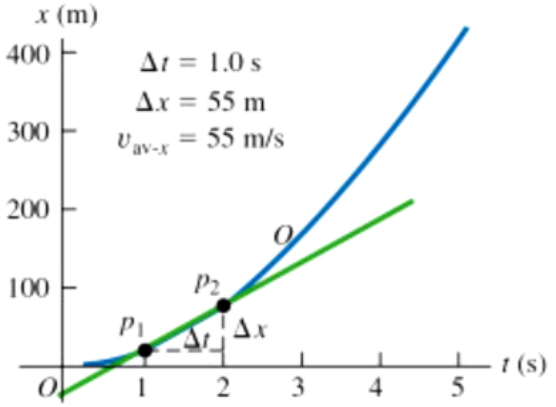
Refer to v_x as velocity

Speed, the magnitude of the velocity vector, is a scalar

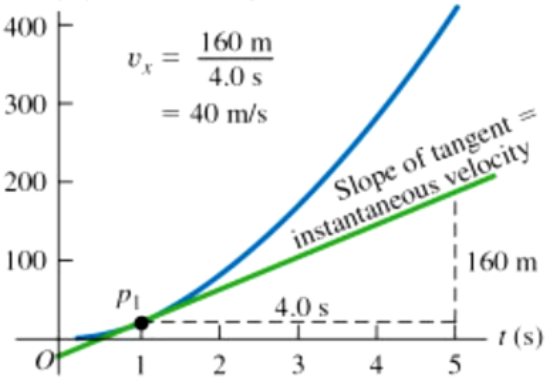
Instant. Velocity v_x on x-t Graph

Average Velocity

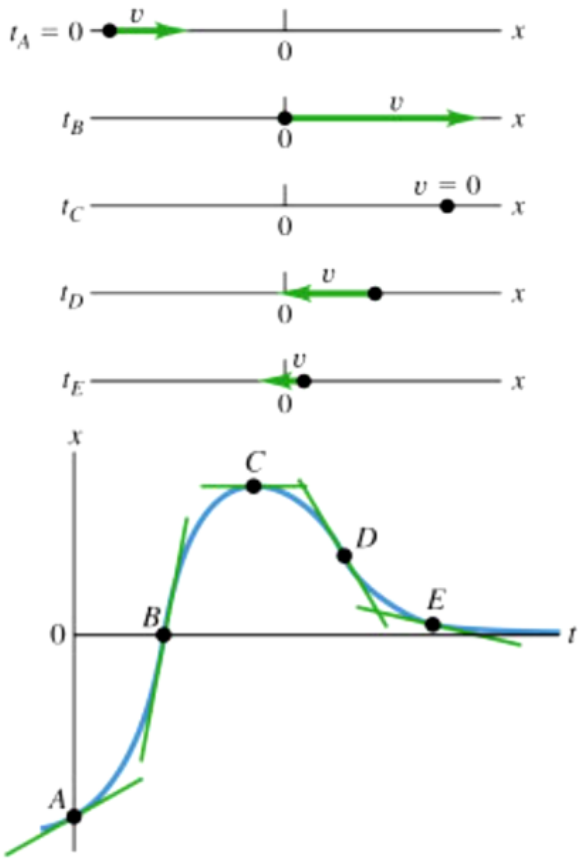




On an x-t graph, the Instantaneous velocity v_x is the slope of the tangent to the curve at that point



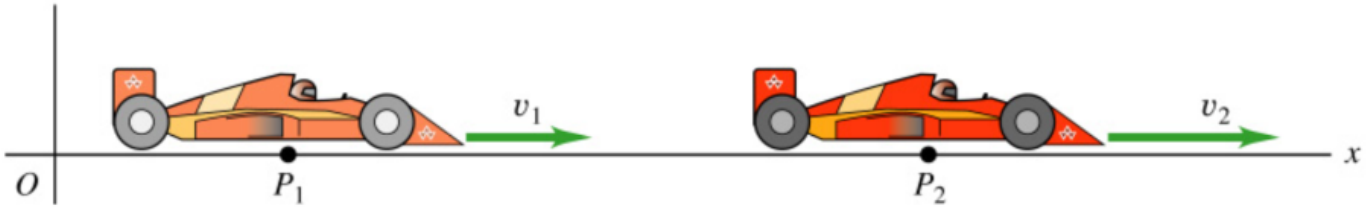
Interpreting An x-t Graph



Examine motion of object along x axis with when its velocity is changing vs time

	x-t graph	Motion of particle
A	positive slope, so $v_x > 0$	moving in $+x$-direction
B	larger positive slope, so $v_x > 0$	moving in $+x$-direction faster than at A
C	zero slope, so $v_x = 0$	instantaneously at rest
D	negative slope, so $v_x < 0$	moving in $-x$-direction
E	smaller negative slope, so $v_x < 0$	moving in $-x$-direction more slowly than at D

Average & Instant. Acceleration



$$\text{Average Acceleration } a_{av\text{-}x} = \frac{v_{2x} - v_{1x}}{t_2 - t_1} = \frac{\Delta v_x}{\Delta t}$$

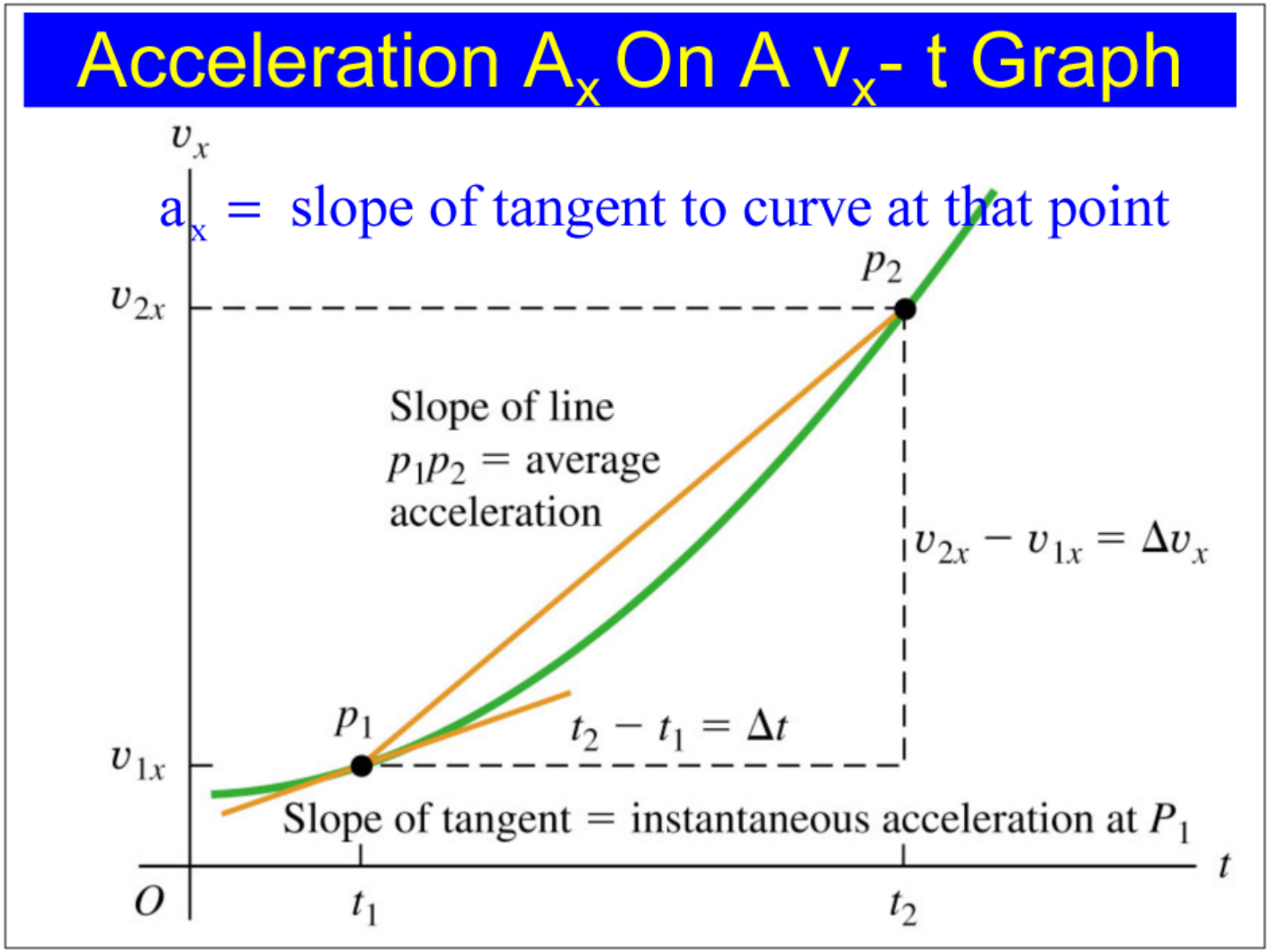
Instant acceleration = limit of average accelaration

when time $\Delta t \to 0$. $$a_x = \lim_{\Delta t \to 0} \frac{\Delta v_x}{\Delta t} = \frac{dv_x}{dt}$$

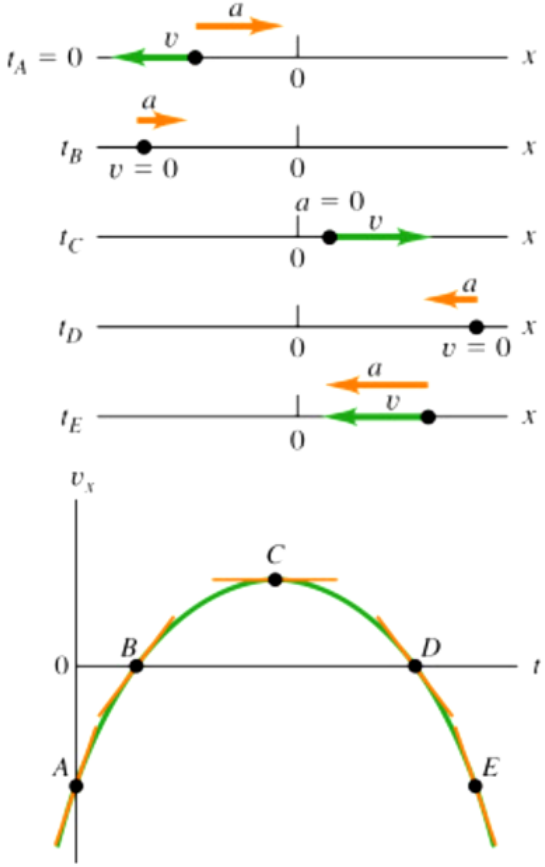
Acceleration has units of (m/s^2)

Now on, use acceleration to mean instant acceleration

Acceleration A_x On A v_x- t Graph



Examining a v_x – t Graph



	v_x-t graph	Motion of particle
A	$v_x < 0$; positive slope, so $a_x > 0$	moving in $-x$-direction, slowing down
B	$v_x = 0$; positive slope, so $a_x > 0$	instantaneously at rest, about to move in $+x$-direction
C	$v_x > 0$; zero slope, so $a_x = 0$	moving in $+x$-direction at maximum speed
D	$v_x = 0$; negative slope, so $a_x < 0$	instantaneously at rest, about to move in $-x$-direction
E	$v_x < 0$; negative slope, so $a_x < 0$	moving in $-x$-direction, speeding up

Acceleration & The x-t Graph

Remember Calculus ?

Can rewrite definition of (instant.) acceleration a_x

$$\boxed{a_x = \frac{dv_x}{dt} = \frac{d}{dt}\left(\frac{dx}{dt}\right) = \frac{d^2x}{dt^2}}$$

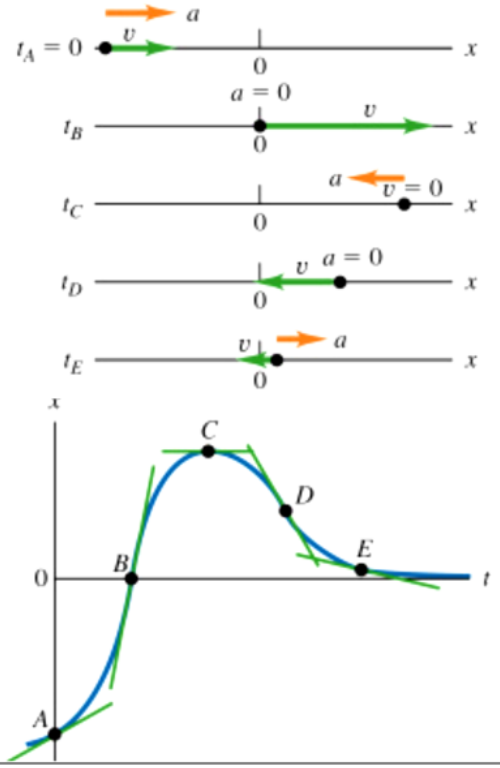
When

$\frac{d^2x}{dt^2} > 0$, $x-t$ curve is concave (curves $\uparrow$), v_x increasing

$\frac{d^2x}{dt^2} < 0$, $x-t$ curve is convex (curves $\downarrow$), v_x decreasing

$\frac{d^2x}{dt^2} = 0$, $x-t$ curve has no curvature (inflexion pt), $v_x = \text{const.}$

The x-t Graph For Same Motion



	x-t graph	Motion of particle
A	positive slope, upward curvature, so $v_x > 0, a_x > 0$	moving in $+x$-direction, speeding up
B	positive slope, zero curvature, so $v_x > 0, a_x = 0$	moving in $+x$-direction, speed not changing
C	zero slope, downward curvature, so $v_x = 0, a_x < 0$	instantaneously at rest, velocity changing from + to −
D	negative slope, zero curvature, so $v_x < 0, a_x = 0$	moving in $-x$-direction, speed not changing
E	negative slope, upward curvature, so $v_x < 0, a_x > 0$	moving in $-x$-direction, slowing down