Physics 2A
Mechanics

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Introduction,
Motion in a Line,
Vector Description of Motion
Motion in More than 1-D

Lectures 1, 2, 3, 4

Introduction

Why study physics?

Physics is the most fundamental of the sciences, and the foundation of all physical sciences, engineering and technology.

Basics physics concepts needed for everything from microchips to GPS to DVD to plasma TV to Medical Tools to Spacecraft

Physics teaches analytical abilities to the highest degree

These skills are portable to all other fields of analysis

You are trained to solve all kinds of problems

The real reason you're probably here:

Your major requires it! For good reason.

Physics 2A in a Nutshell

Mechanics is the first quarter of a four quarter introductory calculus based basic physics sequence.

Physics 2A - Mechanics
Physics 2B - Electricity and Magnetism
Physics 2C - Fluids, Waves, Thermo, Optics
Physics 2D - Relativity & Quantum Physics

Classical mechanics is the study of non-relativistic motion of macroscopic objects such as balls, planets, etc.

Spatial scales always larger than subatomic, smaller than galactic
Velocities always much less than the speed of light

Newton's laws and Conservation laws form the basis of classical mechanics.

The Physics 2A Curriculum

First we will learn the basic concepts of motion in one or more dimensions in terms of bodies and forces

We will use these concepts to study motion of multiple examples

Next we will introduce the ideas of momentum and energy. The concept of energy will allow us a new perspective on motion and extend our ability to analyze it

Remainder of the course will be on applications of classical mechanics:

– Rotational motion
– Oscillatory motion
– Newton’s theory of gravity

The Website is Key

Note particularly the Announcements page. This will be the method by which we will communicate all important information.

It is your responsibility to check it often. We will not send out mass-emails (problematic).

Check it at least a day before each quiz.

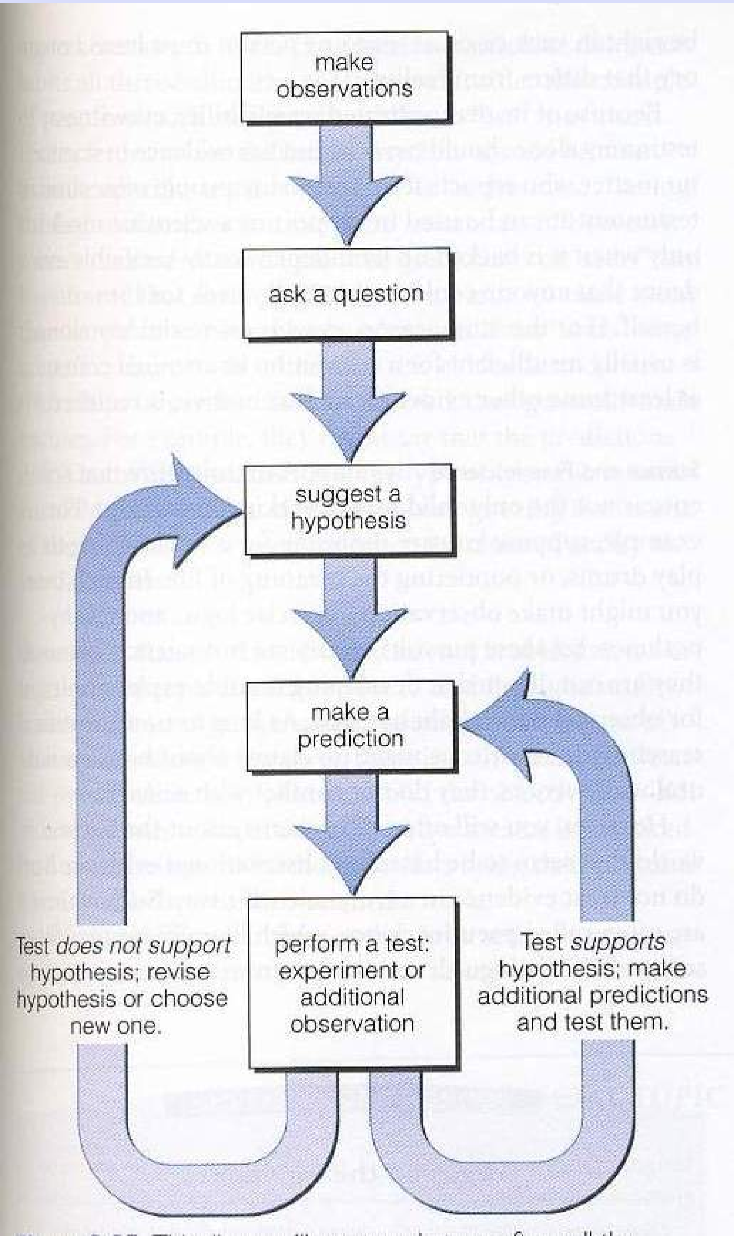
All lecture slides, home work and quiz solutions, and quiz grades will also be posted there.

Quizzes

Before or at the first quiz you will be assigned a code number. This number will be your code number for the entire quarter and will be used on each quiz in place of your name. Write it down and memorize it!

- **9 weekly Quizzes starting Friday, October 5**
- **The best 7/9 quiz scores will be used to determine your grade**
- **There will be NO makeup Quiz for ANY reason**
- **Quizzes will be multiple choice and last 40-45 minutes**
- **You must bring a scantron card and a #2 pencil**
- **You must write your code number, course number, and quarter on the scantron card**
- **You may bring a calculator, scratch paper, and a 5x7 “cheat card” (no laptop) to each quiz. Otherwise the quizzes are “closed book”.**
- **Bring your ID card as proctors will be checking identity**
- **Recorded grades will be posted by code number on the course web site**
- **Any appeal to the grading of quizzes should be made in writing to the teaching assistant, within one week of the posting of the grades for that quiz. You must provide a written explanation as to why you are appealing that grade (be specific).**

Scientific Method

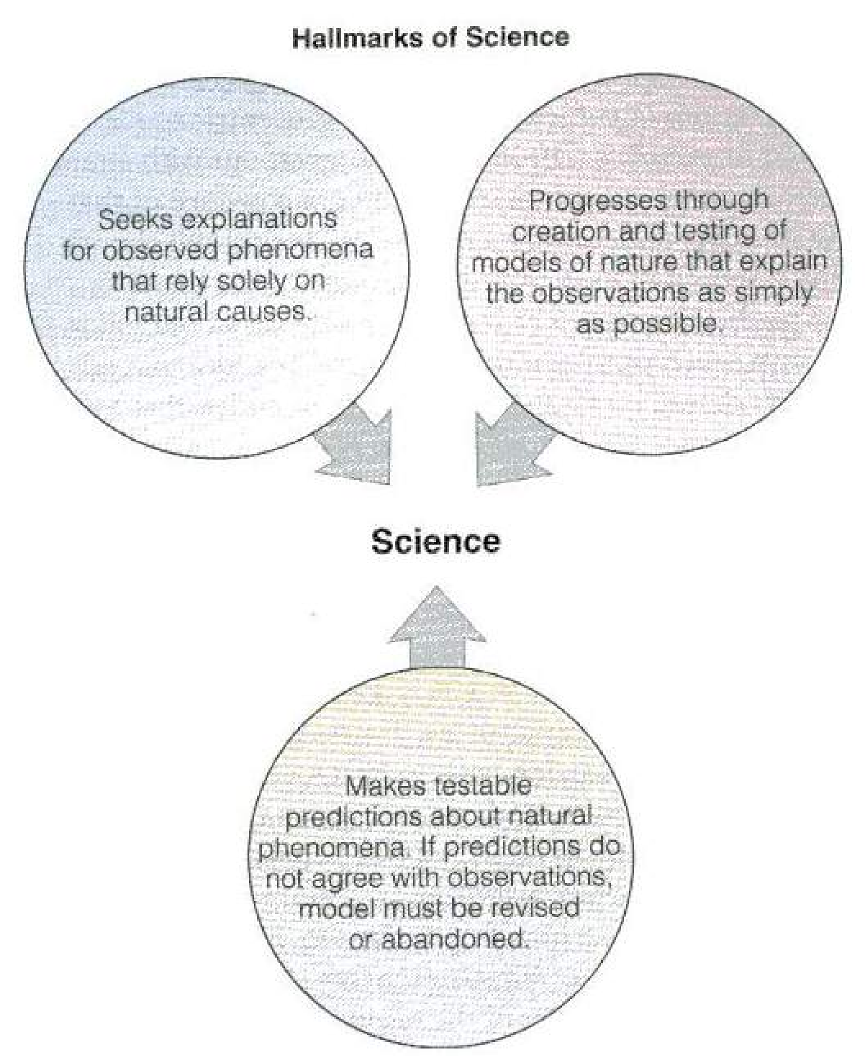


A scientific hypothesis must make **TESTABLE** predictions

This implies that not only can you verify the hypothesis but you must also be able to prove it **WRONG!**

This allows for progress which is not based on public opinion. Galileo’s astronomical observations led to his hypothesis that the Earth was rotating the Sun (which was the center of the solar system). Twenty million Italians disagreed, and they were all wrong.

Hallmarks of Science



- Modern Science seeks explanations for observations that rely solely on natural causes
- Testing of models that explain the observations as simply as possible
- Testable predictions of models force scientists to revise or abandon the model if the predictions do not agree with observations (a single time!)

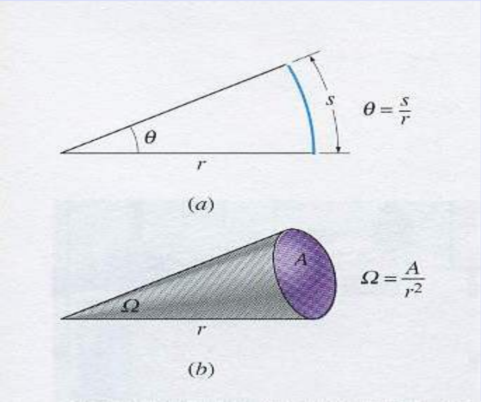
Occam's Razor – Scientists should prefer the simpler of two models that agree equally well with observations.

Is the hypothesis "There is intelligent life somewhere else in the galaxy" a scientific hypothesis?

International System of Units, SI

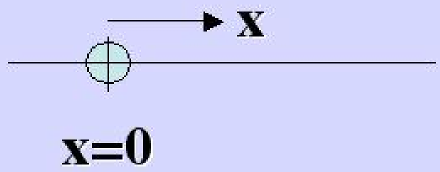
In mechanics we will primarily use the first three of the SI units – meter (m), kilogram (kg), and second (s).

- Meter – the length of the path traveled by light in vacuum during a time interval of 1/299,792,458 of a second. This means that the speed of light is now defined to be c = 299,792,458 m/s.
- Second – the duration of 9,192,631,770 periods of the radiation corresponding to the transition between two hyperfine levels of the ground state of cesium-133 atom.
- Kilogram – the mass of the international prototype of the kilogram. Scientists are now working on accurately measuring the atomic spacing of atoms in a silicon crystal, essentially counting the atoms in a given volume to form a new definition of a kilogram.



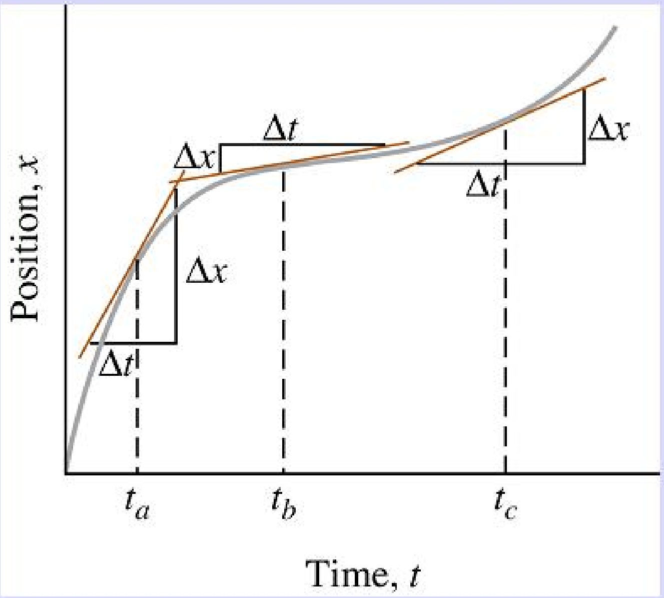
When we study rotation and rotating bodies we will use the SI unit of an angle, the radian defined as
$\theta = s$ (arc length) / r (radius)

Motion on a Line



x=0 chosen as origin

Position of body is given by x as a function of t



Average Velocity between a and b is defined as

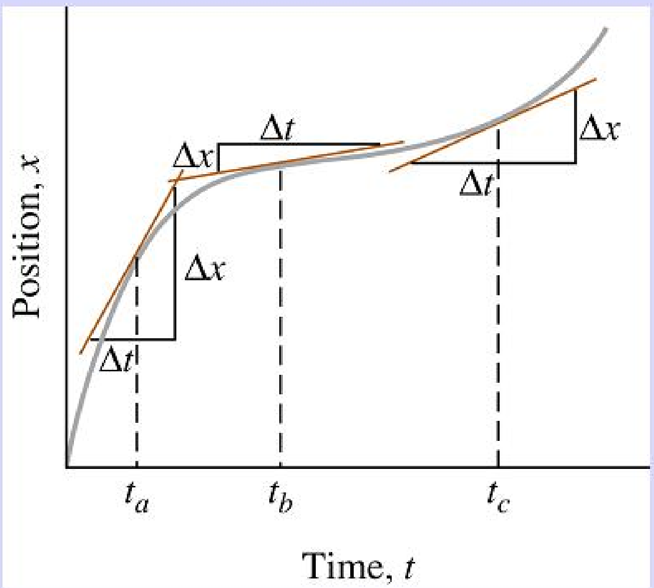
$$V_{ave} = \frac{x_b - x_a}{t_b - t_a} = \frac{\Delta x}{\Delta t}$$

Slope of the line between a and b

Instantaneous Velocity

As the difference in time between points a and b get smaller and smaller

$$\mathrm{V}(\mathbf{t}_{\mathbf{a}}) = \lim_{t_b \to t_a} \frac{x_b - x_a}{t_b - t_a} = \frac{dx}{dt}$$



Tangent Slope to position curve at point a

Thus if

$$x(t) = 3t^2 + 2$$

Then

$$V(t) = 6t$$

By differentiation

Position as the Integral of Velocity

Consider a velocity as a function of time

$$\mathbf{V}(\mathbf{t}) = \frac{dx}{dt}$$

Then the position

$$x(t) = \int V(t')dt' + C_t$$

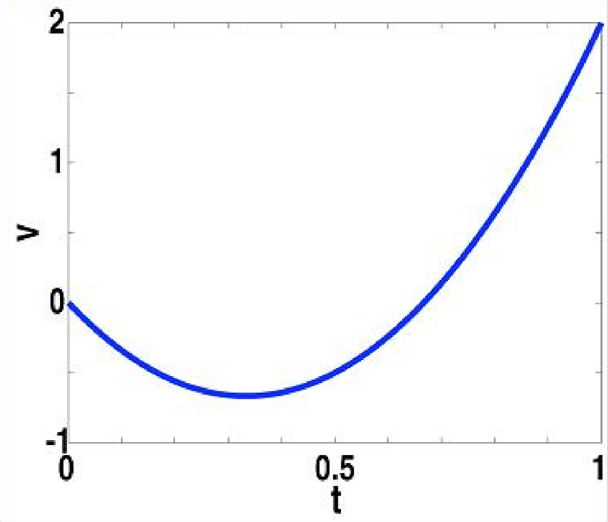
Where C_t is the position at time t=0

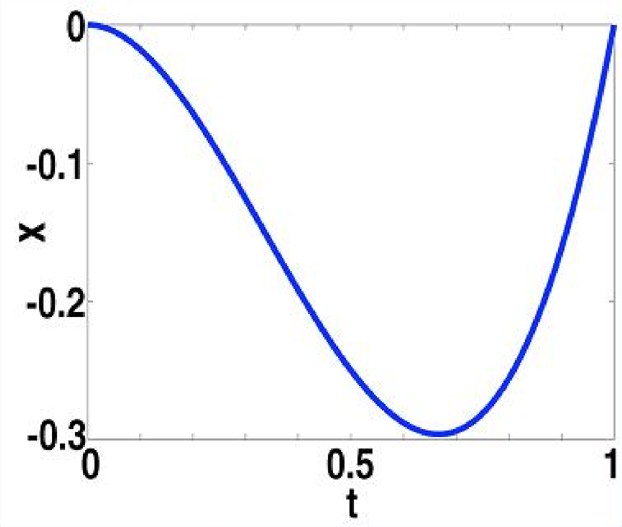
Example: Position as the Integral of Velocity

If the velocity as a function of time $\mathrm{V}(\mathbf{t}) = \dfrac{dx}{dt} = 6t^2 - 4t$

Then the position $x(t) = 2t^3 - 2t^2$

Where x(0)=V(0)=0





Acceleration

If the velocity changes in time then the body is accelerated

The average acceleration is defined

$$\mathbf{a}_{\text{ave}} = \frac{V_b - V_a}{t_b - t_a} = \frac{\Delta V}{\Delta t}$$

The Instantaneous Acceleration is defined

$$\mathbf{a}(\mathbf{t_a}) = \lim_{t_b \to t_a} \frac{V_b - V_a}{t_b - t_a} = \frac{dV}{dt}$$

For a constant acceleration (a=constant)

$$V_f = V_i + at$$

$$x_f = x_i + V_{ave}t = x_i + \frac{V_i + V_f}{2}t = x_i + \frac{V_i + V_i + at}{2}t$$

$$x_f = x_i + V_i t + \frac{1}{2}at^2 \qquad \textbf{(1)}$$

Acceleration Using Calculus

The distance traveled is

$$x_f - x_i = \int_0^t V(t')dt'$$

For a constant acceleration

$$x_f - x_i = \int_0^t (V_i + at)dt'$$

$$x_f - x_i = V_i t + \frac{1}{2}at^2 \qquad \textbf{(1)}$$

We can use the equation for the change in velocity to remove explicit time from the problem $V_f - V_i = at$

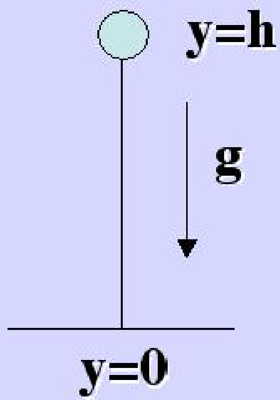
$$x_f - x_i = V_i\left(\frac{V_f - V_i}{a}\right) + \frac{1}{2}a\left(\frac{V_f - V_i}{a}\right)^2$$

$$x_f - x_i = \frac{V_f^{\,2} - V_i^{\,2}}{2a} \qquad \textbf{(2)}$$

Relates velocities to position without explicit time

Example: Gravity Accelerates Approximately Constantly

Earth's gravitational field accelerates all free bodies at approximately 9.8m/s² downwards



How long does it take for the body to reach the ground from a height h?

$$y_f = y_i + V_i t + \frac{1}{2} a t^2$$

$$0 = h + 0 + \frac{1}{2}(-g) t^2$$

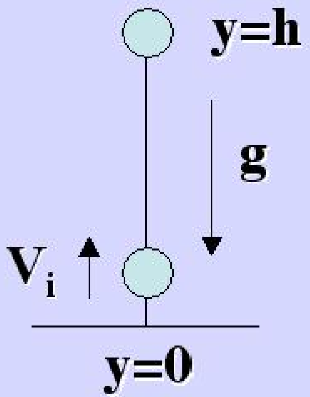
$$t = \sqrt{\frac{2h}{g}}$$

Thus a body of any mass falling from 2m would land in 0.64s

Example: The Velocity Needed to Throw a Stone to Height h

A stone is thrown directly upward, reaches a height h, and falls.

V=0 momentarily



Using equation (2) (without explicit time)

$$V_f^2 - V_i^2 = 2a(y_f - y_i)$$

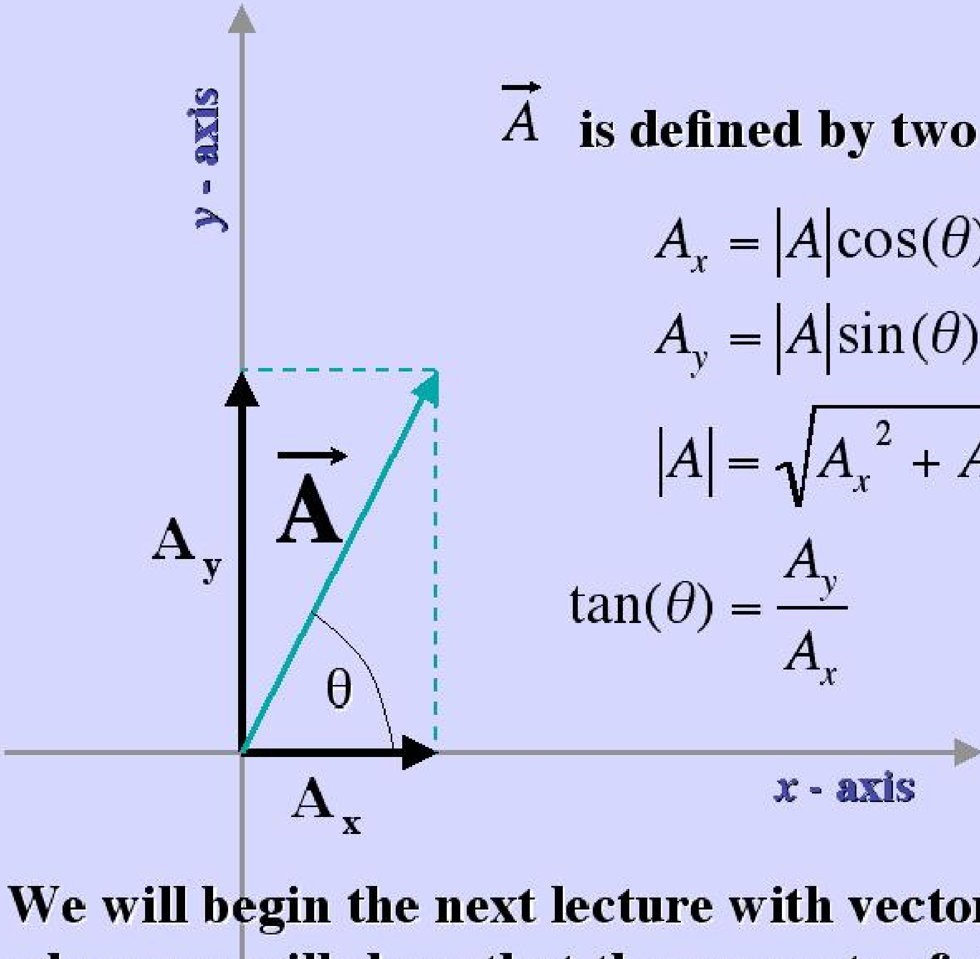
$$0 - V_i^2 = 2(-g)(h - 0)$$

$$V_i = \sqrt{2gh}$$

Example: For h=10m V_i=14m/s

The time to reach 10m: $V_f - V_i = (-g)t$ $\qquad t = \frac{V_i}{g} = 1.43s$

Vectors in 2 Dimensions



$\vec{A}$ **is defined by two components A_x, A_y**

$$A_x = |A|\cos(\theta)$$

$$A_y = |A|\sin(\theta)$$

$$|A| = \sqrt{A_x^{\ 2} + A_y^{\ 2}}$$

$$\tan(\theta) = \frac{A_y}{A_x}$$

We will begin the next lecture with vectors in two dimensions, where we will show that the concepts of single dimensional motion discussed above apply to each dimension individually.