Dimensions and Dimensional Analysis
Fundamentals of kinematics
One Dimensional Motion
Displacement
Speed and Velocity
Acceleration
Motion under constant acceleration

Today’s homework is homework #2, due 9pm, Monday, Sept. 8!!
Announcements

• Homework
  – 58 out of 68 registered so far.
  – Still have trouble w/ UT e-ID?
    • Check out https://hw.utexas.edu/bur/commonProblems.html
  – 25% of the total. So it is very important for you to set this up ASAP!!!

• 49 out of 68 subscribed to the class e-mail list
  – 3 point extra credit if done by midnight today, Wednesday, Sept. 3
  – Will send out a test message tomorrow, Thursday, for confirmation
  – Please reply only to me NOT to all!!

• Physics Department colloquium schedule at
  – Today’s topic is Nanostructure Fabrication

• The first term exam is to be on Wednesday, Sept. 17
  – Will cover CH1 – what we finish on Monday, Sept. 15 + Appendices A and B
  – Mixture of multiple choices and essay problems
  – Jason will conduct a review in the class Monday, Sept. 15
Nanostructures Fabricated by Glancing Angle Deposition and Their Novel Applications

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Wednesday, September 3, 2008 at 4:00 pm in Room 101 SH

Abstract

Glancing Angle Deposition (GLAD) is a simple nanofabrication technique that combines oblique angle deposition (OAD) with substrate manipulations and source controls in a physical vapor deposition system. The geometry shadowing effect is the dominant growth mechanism resulting in the formation of various nanostructure arrays by programming the substrate rotation in polar and/or azimuthal direction. With recent advance in a multilayer deposition procedure, one can design complex and multifunctional heterogeneous nanostructures. In addition, with a co-deposition system of two or more sources, novel nano-composites or doped nanostructure arrays can be produced, which results in nanostructures with different morphology. In this talk, I will highlight our recent progress in multi-component nanorod array fabrication. We find that the multi-component nanorods can be used as a high sensitive virus and bacteria sensor base on fluorescence enhancement. Using a unique multilayer deposition configuration, catalytically driven nanomotors have also been fabricated and demonstrated, which can directly convert chemical energy into mechanical energy. This device holds a great promising to mimic biological motors.

Refreshments will be served in the Physics Lounge at 3:30 pm
Dimension and Dimensional Analysis

- An extremely useful concept in solving physical problems
- Good to write physical laws in mathematical expressions
- No matter what units are used the base quantities are the same
  - *Length* (distance) is length whether meter or inch is used to express the size: Usually denoted as \([L]\)
  - The same is true for *Mass* ([M]) and *Time* ([T])
  - One can say “Dimension of Length, Mass or Time”
  - Dimensions are treated as algebraic quantities: Can perform two algebraic operations; multiplication or division
Dimension and Dimensional Analysis

- One can use dimensions only to check the validity of one’s expression: Dimensional analysis
  - Eg: Speed \( \dot{v} = \frac{[L]}{[T]} = [L][T^{-1}] \)
  - Distance \( L \) traveled by a car running at the speed \( V \) in time \( T \)
    \( L = V \times T = \frac{[L/T]}{[T]} = [L] \)
  - More general expression of dimensional analysis is using exponents: eg. \( \dot{v} = [L^nT^m] = [L][T^{-1}] \)
    where \( n = 1 \) and \( m = -1 \)
Examples

• Show that the expression \([v] = [at]\) is dimensionally correct
  
  \begin{itemize}
  \item Speed: \([v] = \text{[L]}/[T]\)
  \item Acceleration: \([a] = \text{[L]}/[T]^2\)
  \item Thus, \([at] = (\text{L}/\text{T}^2)xT = \text{LT}^{(-2+1)} = \text{LT}^{-1} = \text{[L]}/[T] = [v]\)
  \end{itemize}

• Suppose the acceleration \(a\) of a circularly moving particle with speed \(v\) and radius \(r\) is proportional to \(r^n\) and \(v^m\). What are \(n\) and \(m\)?

\[
L^1T^{-2} = \left(\frac{L}{T}\right)^n = L^{n+m}T^{-m}
\]

\[-m = -2 \implies m = 2\]

\[n + m = n + 2 \equiv 1 \implies n = -1\]

\[
a = kr^{-1}v^2 = \frac{v^2}{r}
\]
Some Fundamentals

- Kinematics: Description of Motion without understanding the cause of the motion
- Dynamics: Description of motion accompanied with understanding the cause of the motion
- Vector and Scalar quantities:
  - Scalar: Physical quantities that require magnitude but no direction
    - Speed, length, mass, height, volume, area, magnitude of a vector quantity, etc
  - Vector: Physical quantities that require both magnitude and direction
    - Velocity, Acceleration, Force, Momentum
    - It does not make sense to say “I ran with velocity of 10 miles/hour.”
- Objects can be treated as point-like if their sizes are smaller than the scale in the problem
  - Earth can be treated as a point like object (or a particle) in celestial problems
    - Simplification of the problem (The first step in setting up to solve a problem...)
  - Any other examples?
Some More Fundamentals

- **Motions:** Can be described as long as the position is known at any given time (or position is expressed as a function of time)
  - Translation: Linear motion along a line
  - Rotation: Circular or elliptical motion
  - Vibration: Oscillation

- **Dimensions**
  - 0 dimension: A point
  - 1 dimension: Linear drag of a point, resulting in a line ➔
    Motion in one-dimension is a motion on a line
  - 2 dimension: Linear drag of a line resulting in a surface
  - 3 dimension: Perpendicular Linear drag of a surface, resulting in a stereo object
Displacement, Velocity and Speed

One dimensional displacement is defined as:

$$\Delta x \equiv x_f - x_i$$

Displacement is the difference between initial and final positions of motion and is a vector quantity. How is this different than distance?

Average velocity is defined as:

$$v_x \equiv \frac{x_f - x_i}{t_f - t_i} = \frac{\Delta x}{\Delta t}$$

Displacement per unit time in the period throughout the motion

Average speed is defined as:

$$v \equiv \frac{\text{Total Distance Traveled}}{\text{Total Time Spent}}$$

Can someone tell me what the difference between speed and velocity is?
Difference between Speed and Velocity

- Let’s take a simple one dimensional translation that has many steps:

Let’s call this line as X-axis

\[ \begin{align*}
+10m & \quad +15m & \quad +5m \\
-5m & \quad -10m & \quad -15m
\end{align*} \]

Total Displacement: \( \Delta x \equiv x_f - x_i = x_i - x_i = 0(m) \)

Average Velocity: \( v_x \equiv \frac{x_f - x_i}{t_f - t_i} = \frac{\Delta x}{\Delta t} = \frac{0}{20} = 0(m/s) \)

Total Distance Traveled: \( D = 10 + 15 + 5 + 15 + 10 + 5 = 60(m) \)

Average Speed: \( v \equiv \frac{\text{Total Distance Traveled}}{\text{Total Time Interval}} = \frac{60}{20} = 3(m/s) \)
Example 2.1

The position of a runner as a function of time is plotted as moving along the x axis of a coordinate system. During a 3.00-s time interval, the runner’s position changes from $x_1=50.0\text{ m}$ to $x_2=30.5\text{ m}$, as shown in the figure. What was the runner’s average velocity? What was the average speed?

- **Displacement:**
  \[ \Delta x \equiv x_f - x_i = x_2 - x_1 = 30.5 - 50.0 = -19.5\text{ (m)} \]

- **Average Velocity:**
  \[ v_x \equiv \frac{x_f - x_i}{t_f - t_i} = \frac{x_2 - x_1}{t_2 - t_1} = \frac{\Delta x}{\Delta t} = \frac{-19.5}{3.00} = -6.50\text{ (m/s)} \]

- **Average Speed:**
  \[ v \equiv \frac{\text{Total Distance Traveled}}{\text{Total Time Interval}} = \frac{50.0 - 30.5}{3.00} = +19.5 = +6.50\text{ (m/s)} \]