IDX G9 Physics S+

Study Guide Issue 1

By Sissi and Desheng, Edited by Jillian

Chapter 2 Describing Motion: Kinematics In One Dimension

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2.1 Reference Frames and Displacement

- Mechanics
    - **Kinematics (the study of motion) and Dynamics (the study of force)**
- Motion
    - **An object is in motion if it changes position relative to a frame of reference**
    - Motion is relative (different view of point leads to a different result)
- Frame of reference (reference point)

- **A place or object used for comparison to determine of something is in motion**
- Always assumed to be stationary

- Picturing Motion
  - Motion Diagram
    - **A series of images showing the positions of a moving object at equal time intervals**
    - to visualize displacement and velocity
  - Particle Model
    - **A simplified version of a motion diagram in which the object in motion is replaced by a series of particles**
- Vector and Scalar
  - Vectors: **Quantities which has a direction and a magnitude**
    - Examples: Force, position, acceleration, displace etc...
    - Can be represented by an arrow; the length is its magnitude and the direction is the direction of the vector
  - Scalars: **Quantities which have magnitude but no direction**
    - Examples: Mass, volume, speed, distance etc...
- Distance
  - **How far objects are, or the accumulation of path**
  - Is a scalar
- Displacement
  - **The distance moved in a particular direction, or the object's overall change in position**
  - Is a vector
  - $\Delta d = d_f - d_i$ **(position$_f$ - position$_i$)**

❗**Distance is the actual length of the whole Journey, while Displacement is the difference between the final distance (d_f) and the initial distance (d_i)**

2.2 Average Velocity: Speed and Velocity

- Speed
    - **The distance the object travels per unit of time, or the rate at which an object moves**
    - **Speed** = $\frac{\textbf{distance}}{\textbf{time}}$ $v=\frac{d}{t}$
        - Is a scalar
        - Units: m/s; km/h
    - Average speed
        - When an object's speed is constant, then the object has constant speed motion
        - **average speed** = $\frac{\textbf{total distance}}{\textbf{total time}}$
- Velocity
    - **The speed in a given direction**
    - Can be shown using an arrow
    - For motion in a straight line, you can use a "+" or "-" sign to indicate direction
    - The direction given by velocity is crucial
    - **average velocity** =$\frac{\textbf{total displacement}}{\textbf{time}}$

2.3 Instantaneous Velocity

- Instantaneous Velocity (speed)
    - The velocity (speed) at any instant of time
        - $v=\lim\times\frac{\Delta x}{\Delta t}$
    - Magnitude of instantaneous velocity equals to instantaneous speed

2.4 Acceleration

- Acceleration
  - The rate at which an object's velocity changes is called the acceleration of the object
  - Average acceleration
    - $\vec{\mathbf{a}} = \frac{\Delta\vec{\mathbf{v}}}{\Delta \mathbf{t}} = \frac{\vec{\mathbf{v}}_\mathbf{f} - \vec{\mathbf{v}}_\mathbf{i}}{\mathbf{t}_\mathbf{f} - \mathbf{t}_\mathbf{i}}$ **unit: m/s^2**
  - Instantaneous Acceleration
    - The change in velocity at an instant of time
    - $\vec{\mathbf{a}} = \mathbf{lim}\frac{\Delta\vec{\mathbf{v}}}{\Delta \mathbf{t}}$
    - $\vec{\mathbf{a}} = \frac{\mathbf{F}_{\mathbf{net}}}{\mathbf{m}}$ **;** Direction of acceleration is the same as the direction of F_{net}
- Positive and Negative Acceleration
  - Acceleration Vector points
    - Positive direction: positive acceleration
    - Negative direction: negative acceleration
    - v_i and $\vec{a}$ same direction: speed up
    - v_i and $\vec{a}$ opposite direction: slowing down
    - The sign of acceleration doesn't indicate whether the object is speeding up or slowing down (initial velocity is needed)

2.5 Motion at Constant Speed

- Formula
  - Uniformly accelerated motion: Motion with constant acceleration
    - $\vec{a}$= constant, straight line
    - Instantaneous $\vec{a}$ = average a

    Important Formulas:
  - $\vec{\mathbf{a}} = \frac{\Delta\vec{\mathbf{v}}}{\Delta \mathbf{t}} = \frac{\vec{\mathbf{v}}_\mathbf{f} - \vec{\mathbf{v}}_\mathbf{i}}{\mathbf{t}_\mathbf{f} - \mathbf{t}_\mathbf{i}} \rightarrow \vec{\mathbf{a}} = \frac{\Delta\vec{\mathbf{v}}}{\Delta \mathbf{t}} = \frac{\vec{\mathbf{v}}_\mathbf{f} - \vec{\mathbf{v}}_\mathbf{i}}{\mathbf{t}}$

- $\Delta \mathbf{d} = (\mathbf{d_f}-\mathbf{d_i}) = \overrightarrow{\mathbf{v} \times \mathbf{t}} = \frac{(\vec{v}_f+\vec{v}_i)}{2}\mathbf{t}$
- $\Delta \mathbf{d} = (\mathbf{d_f}-\mathbf{d_i}) = \vec{v}_i \mathbf{t} + \frac{1}{2}\mathbf{a}\mathbf{t}^2$
- $\Delta \mathbf{d} = (\mathbf{d_f}-\mathbf{d_i}) = \frac{(\vec{v}_f 2 - \vec{v}_i 2)}{2\vec{a}}$

2.6 Solving Problems

- This section will explore hard multi-step problems with the formulas given in Chapter 2.5

2.7 Falling Objects

- Free Fall
  - **The motion of a falling object when air resistance is negligible and the action can be considered due to gravity alone**
  - Aristotle said that a heavier object falls faster than a lighter object
  - Galileo's thought experiment showed the improbability of Aristotle's view
    - Steeper inclines gives faster accelerations
    - Incline reaches absolutely vertical, means maximum acceleration (g)
    - all objects fall at g, neglecting air resistance; $g=9.8m/s^2$
- Acceleration Due to Gravity
  - No matter what the falling object is made of, how much it weighted, what height it dropped from, whether it was dropped down or thrown upward:
    - **$g=9.8m/s^2$**
    - "+g" defines downward to be the positive direction
    - "-g" defines upward to be the positive direction
  - Object is dropped: $\vec{v}_i=0m/s$, $\vec{a}=9.8m/s^2$ (down is +)
  - Object is dropped: $\vec{v}_i\neq0m/s$, $\vec{a}=9.8m/s^2$ (down is +)

- Objects Thrown Upward
    - $\vec{v}_i \neq 0m/s$
    - (if upward is "+") $\vec{v}_i > 0m/s$ $\vec{a} = -9.8m/s^2$
    - (if downward is "+") $\vec{v}_i < 0m/s$ $\vec{a} = 9.8m/s^2$
    - initial Δd is 0; highest position v=0, and Δd is largest in + direction
    - Same Δd (height), same speed
    - Returns to original position, $v = -v_i$, Δd = 0
        - time of rising t_{rise}= time of falling t_{fall}

2.8 Graphical Analysis of Linear Motion

- Position-Time Graph
    - No motion (at rest)
        - Horizontal straight line/ straight line parallel to x-axis
    - Uniform motion
        - Slanted straight line
        - y-intercept: initial position; X-axis: time
    - Intersection of graph lines
        - Two objects meet
    - Average Velocity
        - The slope: rising "+", descending "-"
        - Steeper: speed larger, |v| larger
    - Instantaneous Velocity
        - When constant velocity: instantaneous velocity=average velocity
    - Equation for average velocity
        - $\mathbf{d_f = \vec{v}_t + d_i}$

    ❗**Slope of d-t graph = Velocity**

- Accelerated Motion
    - Graph line is a curve:

        - average velocity: slope of connection of the two dots on the line.
        - instantaneous velocity=slope of the tangent to the curve
        - Curve shape, v and +/- acceleration
- Velocity-Time Graph
    - Uniform motion (a = 0)
    - Horizontal line in v-t: v=constant, a=0
    - Information:
        - Velocity of an object at any moment
        - Velocity is "-" or "+"
        - The area between the v-t graph and time is equal to the object's displacement
        - above time-axis: $\Delta d>0$; below t-axis: $\Delta d<0$

        ❗**Slope of v-t graph = Acceleration**
- Acceleration-Time Graph
    - At rest/uniform motion a=0
        - Horizontal line on t-axis
    - Uniformly accelerated motion
        - Horizontal line parallel to t-axis

❗**Instantaneous acceleration = Slope of the tangent to the curve at a particular moment**