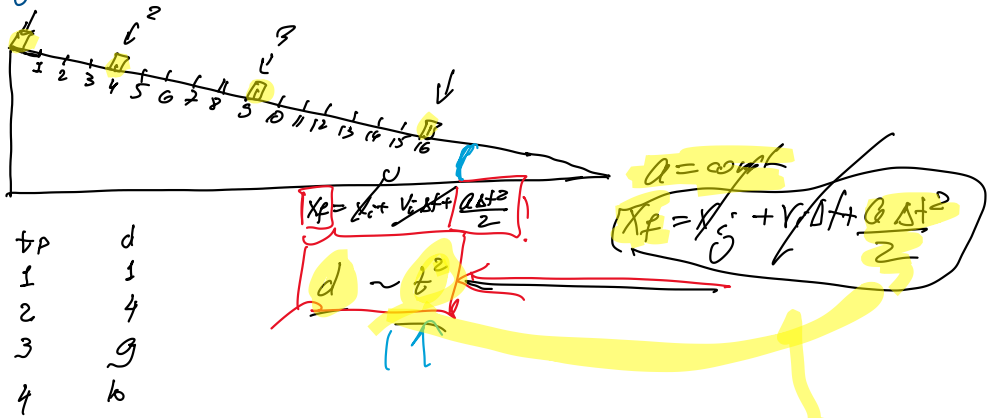
Lecture 2

Tuesday, May 9, 2023 10:47 AM

Galileo Galilei 1564 - 1642

Physics to Experimentation / Measurements



tp	d
1	1
2	4
3	9
4	16

Physics of Motion

- How things are moving - Kinematics - Galileo Galilei
- Why thing are moving - Dynamics - Isaac Newton

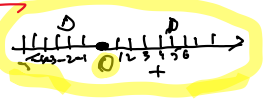
Abstraction

Motion of Object

- Linear
  - 2d-3d Motion
- Rotational
- Oscillations / Periodic Motion
- Wave Motion
- Point Object

Definitions:

0. Point object P.O.
1. Reference Frame / Reference Point



2. Initial Position of Point object x_i, m, ±
2.' Time when P.O. was at x_i; t_i, s, +

$x_i = 2\,m$

$x_f = -5\,m$

3. Final Position x_f, m, ±

$\Delta x = x_f - x_i = -5m - 2m = -7m$

3'. Time when p.o. reaches x_f t_f, s +

4. Displacement $\Delta x = x_f - x_i$, m ±

Distance $s = 7m$

4'. Time Interval $\Delta t = t_f - t_i$, s +

5. Average Velocity $V_{AV} = \frac{\Delta x}{\Delta t}$, $\frac{m}{s}$, ±

Speed $= \frac{s}{\Delta t}$, $\frac{m}{s}$, +

Instantaneous Velocity $V = V_{inst} = \left.\frac{\Delta x}{\Delta t}\right|_{\Delta t \to 0} = \frac{dx}{dt}$

6. Average Acceleration $a_{AV} = \frac{\Delta V}{\Delta t}$, $\frac{m}{s^2}$, ±

$\Delta V = V_f - V_i$

$a = a_{inst} = \left.\frac{\Delta V}{\Delta t}\right|_{\Delta t \to 0} = \frac{dV}{dt}$

Predictions ⇒ Equation of Motion ← method of

1) Baby version $a_{AV} = 0$ ⇒

$a_{AV} = \frac{\Delta V}{\Delta t} = \frac{V_f - V_i}{\Delta t} = 0 \Rightarrow V_f - V_i = 0 \Rightarrow V_f = V_i = V$

$V_{AV} = V = \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{\Delta t}$ | $V \cdot \Delta t = x_f - x_i \Rightarrow x_f = x_i + V \cdot \Delta t$

2) Junior Version $a_{AV} = const = a$

$a_{AV} \equiv a = \frac{\Delta V}{\Delta t} = \frac{V_f - V_i}{\Delta t}$ | $a \cdot \Delta t = V_f - V_i \Rightarrow V_f = V_i + a \cdot \Delta t$ (1)

$a = a$

$\Delta t = \frac{V_f - V_i}{a}$

$\frac{V_f - V_i}{a} = \frac{a \Delta t}{a}$

$V_{AV} = \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{\Delta t}$ | $V_{AV} \cdot \Delta t = x_f - x_i$ $\quad x_f = x_i + V_{AV} \cdot \Delta t$

$V_{AV} = \frac{V_i + V_f}{2}$

$x_f = x_i + \left(\frac{V_i + V_f}{2}\right) \cdot \Delta t$

$x_f = x_i + \left(\frac{V_i + V_i + a\Delta t}{2}\right) \cdot \Delta t$

$\left[\frac{2}{\quad}\right]^2 \quad 2V_iV + V_i^2$

$x_f = x_i + \frac{(2v_i + a\Delta t)}{2}\Delta t$

$x_f = x_i + v_i\Delta t + \frac{a\Delta t^2}{2}$ (2)

$a = 0$

$(v_f - v_i) = v_f - 2v_f v_i + v_i$

$x_f = x_i + v_i\left(\frac{v_f - v_i}{a}\right) + \frac{a(v_f - v_i)^2}{a2 2} = x_i + \frac{v_i v_f}{a} - \frac{v_i^2}{a} + \frac{a\left(v_f^2 - 2v_f v_i + v_i^2\right)}{2a^2} =$

$x_f = x_i + \frac{v_i v_f}{a} - \frac{v_i^2}{a} + \frac{v_f^2}{2a} - \frac{v_i v_f}{a} + \frac{v_i^2}{2a} = x_i + \frac{v_f^2}{2a} - \frac{v_i^2}{2a} = x_i + \frac{v_f^2 - v_i^2}{2a}$

$x_f - x_i = \frac{v_f^2 - v_i^2}{2a}$

Δx

$\Delta x = \frac{v_f^2 - v_i^2}{2a}$

$2a\Delta x = v_f^2 - v_i^2$

3) Advanced Version $a \neq$ const

$a = \frac{dv}{dt}$ $\quad v = \int_{t_i}^{t_f} a\,dt$

$v = \frac{dx}{dt} \Rightarrow x = \int_{t_i}^{t_f} v\,dt$

Running Time t

$\Delta t = t_f - t_i = t$

t $\uparrow$
0

$\Rightarrow$ $a = \text{const}$

$$x_f = x_i + v_i \Delta t + \frac{a \Delta t^2}{2}$$

$$v_f = v_i + a \Delta t$$

$x_f \longrightarrow x(t)$

$v_f = v(t)$

$$\boxed{\begin{aligned} x(t) &= x_i + v_i t + \frac{a t^2}{2} \\ v(t) &= v_i + a t \end{aligned}}$$

$\Rightarrow$ Vertical Motion:

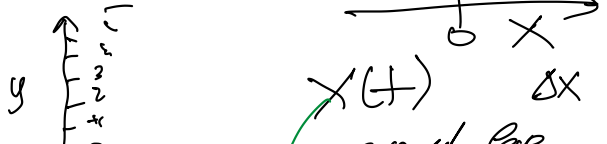
No Air Resistance

- Throwing an object upward with a initial speed of $20 \frac{m}{s}$

a) how long it takes to reach its highest point?

b) what is the height of the highest point?

c) Total time that object is in the air?



1) Reference Frame

2) a) t_{max}? b) h_{max}

c) t_{total}?

$\Delta y = y_f - y_i$

$y(t)$

3) What is known / what is given

$V_i = 20 \frac{m}{s}$

$y_i = 0$

$a = -g$; $g = 9.8 \frac{m}{s^2}$

$V(t) = V_i + at$

$y(t) = y_i + V_i t + \frac{at^2}{2}$

$V(t) = V_i - gt$

$y(t) = V_i t - \frac{gt^2}{2}$

$t_{max} =$

$V(t_{max}) = 0 = V_i - g t_{max}$

$g t_{max} = V_i$

$\Rightarrow t_{max} = \frac{V_i}{g}$

$t_{max} = 12s$

$t_{max} = \frac{V_i}{g}$

$h_{max} = y(t_{max}) = V_i \cdot \frac{V_i}{g} - \frac{g}{2} \frac{V_i^2}{g^2} = \frac{V_i^2}{g} - \frac{V_i^2}{2g} = \frac{V_i^2}{2g}$

$x - \frac{x}{2} = \frac{x}{2}$

$t_{total} = ?$

$y(t_{total}) = 0 = V_i t_{total} - \frac{g t_{total}^2}{2}$

$$t_{total}\left(V_i - \frac{g\,t_{total}}{2}\right) = 0$$

$x(x-6)=0$

$t_{total} = 0$

$x=0$

$x-6=0$

$x=6$

$$V_i - \frac{g\,t_{total}}{2} = 0 \Rightarrow 2V_i - g\,t_{total} = 0$$

$$t_{total} = \frac{2V_i}{g} = 2\cdot t_{max}$$