## Advanced Placement Physics — Kinematics in One Dimension

***Kinematics*** Study of Motion

***Distance*** Total distance traveled from start to finish.

***Displacement*** Straight line distance between the start point and ending point of the problem.

***Speed*** A scalar quantity (no direction specified) that shows the rate that distance ***d*** is covered.

- ***Instantaneous*** The speed at an instant in time. Right now. Your speedometer reading when you glance it at.
- ***Average*** The total distance divided by the total time for the entire trip.
- ***Constant*** If the same speed is maintained over the entire trip

***Velocity*** A vector quantity consisting of magnitude and direction. Displacement ***x*** divided by time.

***Acceleration*** Change in velocity (change in displacement and/or direction)

### *Kinematic Equations*

You can only use the constant velocity equation when there is no acceleration. If acceleration is present (Question contains terms such as: starts from rest, final velocity of, accelerates, comes to rest, etc.), then you must use the three Kinematic equations in the highlighted boarder boxes below.

| ***Speed*** | ***Constant Velocity*** | **Average Velocity** | ***Acceleration*** |
|---|---|---|---|
| $\bar{v}_s = \dfrac{d}{t}$ | $v = \dfrac{x}{t}$ **or** $x = vt$ | $\bar{v} = \dfrac{x - x_o}{t}$ | $a = \dfrac{v - v_o}{t}$ |

| | |
|---|---|
| $\bar{v} = \dfrac{v_o + v}{2}$ | ***Another Way of Looking at Average Velocity*** One of the four Kinematic Equations. But it is mostly used in conjunction with the above equations to derive the next three equations. Occasionally it is useful in problems. |
| $v = v_o + at$ | ***Velocity*** Rearranged the acceleration equation from above. Useful for determining ***v***, when ***a*** and ***t*** are given. However, if any three variables are available and the fourth is needed rearrange this as necessary. |
| $x = x_o + v_o t + \frac{1}{2}at^2$ | ***Position*** Key equation to determine distance when ***a*** is involved. Used extensively in falling body problems. Its derivative is the velocity equation above. |
| $v^2 = v_o^2 - 2a(x - x_o)$ | ***When no time is given*** When ***v***, ***a***, and/or ***x*** are known, but no information is given about ***t***, then this can be used to solve for the unknown variable. |

$x_o$ initial position, $x$ final position, $v_o$ initial velocity, $v$ final velocity, $a$ acceleration, $t$ time

### *Problem Solving Strategy*

1. Draw a picture (Mental or on Paper)
2. List known and unknown variables.
   a) Caution; some may be extraneous, and are not necessary to solve the problem.
   b) Often either the starting or ending point is at rest, meaning a value of zero.
3. Do necessary conversions.
4. Choose an equation that can be solved with the known variables.
   a) This equation may or may not be the answer you are looking for.
   b) It may provide a new variable for use in another equation.
   c) This may lead to a succession of equations.

**+ or – ????:** " **+** " & "**–** " can be used to indicate direction, and/or acceleration (**+**) or deceleration (**–**).

**–9.8 *m/s*$^2$** Be careful here. Does this mean the object is decelerating (slowing) or does it mean that the object is moving along a negative (perhaps the ***y***) axis? It would depend on the problem. For an object moving on the ***x*** axis it would mean decelerating. For an object falling along the ***y*** axis, due to gravity, it means the object is accelerating, but in the downward direction (-+9.8). In forces it is easier to use 9.8 *m/s*$^2$ as a positive number.

## *Falling Bodies*

**Displacement**: $y_o = 0$ Initial position. We can choose the reference frame / coordinate axis.

$y = 0$ If the object ends the problem at the same elevation it started at.

$y = +$ If the object ends the problem at a higher elevation than it started.

$y = -$ If the object ends the problem at a lower elevation than it started.

**Velocity, initial**: $v_o = 0$ If it is dropped from rest.

$v_o = +$ If fired upward.

$v_o = -$ If fired downward.

**Velocity, final**: $v = 0$ At the moment it reaches maximum altitude, right before falling back to earth.

$v = +$ If it hits something on the way up and never reaches max altitude (Rare problem).

$v = -$ On the return trip.

$v = v_o$ If it lands at the same elevation that the problem began at.

**Acceleration**: $g = -9.8\, m/s^2$

## *Projectile Motion*

Motion in two dimensions happens simultaneously.

- In the ***x*** direction the velocity is constant, with no acceleration occurring in this dimension.
- In the ***y*** direction the acceleration of gravity slows upward motion and enhances downward motion.
- Both happen simultaneously, however they can be analyzed separately using vector components.

✱ ***The following review of variables can be overwhelming to memorize. It is much easier if you think it through or draw a pictorial representation.***

**Angles**: All angles are measured from East. Above the horizon is positive, below negative.

**Displacement**: $x_o = 0$

$y_o = 0$

$x = +$ The ***x*** is always positive.

$y = 0$ If the object ends the problem at the same elevation it started at.

$y = +$ If the object ends the problem at a higher elevation than it started.

$y = -$ If the object ends the problem at a lower elevation than it started.

**Velocity, initial**: $v_o$ Splits into components, $v_{ox} = v_o \cos\theta$, $v_{oy} = v_o \sin\theta$

$v_{ox} = +$ In every problem, we choose to fire it in the positive ***x*** direction.

$v_{oy} = 0$ If fired horizontally.

$v_{oy} = +$ If fired at a positive angle (above the horizon).

$v_{oy} = -$ If fired at a negative angle (below the horizon).

**Velocity, final**: $v_x = v_{ox}$ Since there is constant velocity in the ***x*** direction, initial and final are the same.

$v_{oy} = 0$ At the top of the trajectory

$v_{oy} = +$ If the object hits something on the way up. Not used in problems very often.

$v_{oy} = -$ On the return trip.

$v$ Resultant from adding vectors $v_x$ and $v_{x_o}$. Has an angle not a + or **–**.

**Acceleration**: $g = -9.8\, m/s^2$