05: Vectors and Kinematics in Two Dimensions

Key Physics Terms

- **Vector:** A quantity that represents magnitude (size) and direction. It is usually represented with an arrow to indicate the appropriate direction. Vectors may or may not be drawn to scale.
- **Scalar:** A quantity that can be completely described by its magnitude, (size). It has no direction associated with its size.
- **Resultant:** the result of adding two or more vectors; vector sum.
- **Vector Component**: The perpendicular parts into which a vector can be separated and that act in different directions from the vector.
- **Vector Addition**: The process of combining vectors; added tip to tail.
- **Distance:** The quantity that describes the position of an object. **Distance is a scalar**.
- **Displacement:** The quantity that describes the change in location of an object and includes its direction of motion. **Displacement is a vector**.
- **Speed:** The distance an object travels per unit of time; the magnitude of velocity. **Speed is a scalar**.
- **Velocity**: Speed of an object including its direction of motion. **Velocity is a vector quantity**.
- **Constant velocity**: A velocity that does not change with time.
- **Acceleration:** The rate at which an object's velocity changes with time; this change may in speed, direction, or both. **Acceleration is a vector**.

Variables Used

- d = distance
- t = time
- v = velocity (usually average velocity or constant velocity)
- a = acceleration
- v_f = final velocity
- v_i = initial velocity
- Δ = change in

θ = angle

Key Formulas

- v = d/t
- a = $\Delta v/\Delta t=(v_f - v_i) / t$
- d = $v_i t + at^2 / 2$
- $v_f^2 = v_i^2 + 2ad$
- Pythagorean Theorem: $c^2 = a^2 + b^2$
- Sin θ = opp / hyp
- Cos θ = adj / hyp
- Tan θ = opp / adj
- For the vertical sign convention of up is positive: Acceleration due to gravity, g, = -9.8 m/s^2

Key Metric Units

- Displacement/distance: meters, m
- Time: s
- Velocity/speed: m/s
- Acceleration: m/s^2, m/s/s

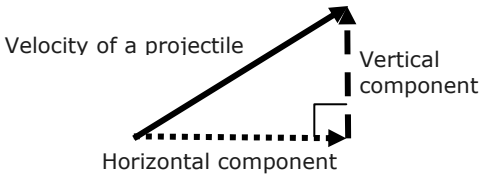
Key Conventions

- Assign a direction as positive.
- Keep this convention throughout the problem.
- Any quantities in the opposite direction must be negative.
- Often, up and right are positive, while down and left are negative.
- Even if someone else choses the opposite direction as positive, for their sign convention they will arrive at the correct answer, assuming everything else is done correctly.

Constant Velocity vs. Constant Acceleration

- Projectiles move with a constant acceleration due to gravity only in the **vertical** direction.
- Projectiles move with a constant velocity only in the **horizontal** direction.

Component Diagram



Kinematics in 2-D Problem Solving Tips

These tips will make it easier to solve any kinematics physics problems.

- Thoroughly read the entire problem.
- Draw a diagram if needed.
- Identify all given information.
- Identify the quantity to be found.
- Select appropriate formula(s) that incorporate what you know and what you want to find.
- Convert units if needed. Use units throughout your calculations.
- Do any mathematical calculations carefully. Check the number of significant figures in the problem.
- For all projectiles, the horizontal velocity is constant. Gravity only affects the vertical component of motion.

Typical 2-D Kinematics Problem

Example: A toy projectile is fired horizontally from a launcher at height of 1.0 m and a velocity of 15 m/s. How far away from the starting point will the projectile land?

Known:

d_v = -1m a = -9.8 m/s^2 v_h = 15 m/s v_{iv} =0 m/s

Unknowns:

d_h = ? t = ?

Define: First, find the time in the air: $d= v_i t + at^2/2$
This formula can be used since the air time for horizontally launched projectile equals the time for one that is simply dropped.
Since v_{iv}=0 m/s then $d = at^2/2$

Rearranging: $t = \sqrt{(2d/a)}$

Second, find the horizontal distance: $d_h=vt$
This formula can be used since the horizontal velocity is constant.

Output:

$t = \sqrt{(2d/a)}= \sqrt{(2(-1m)/(-9.8m/s^2))}= .45s$

d_h=(.45 s)(15 m/s)= 6.8 m

Substantiate:

Units are correct, sig fig correct, magnitude looks reasonable.

How to Use This Cheat Sheet: These are the keys related this topic. Try to read through it carefully twice then write it out on a blank sheet of paper. Review it again before the exams.