

Introduction & Kinematics I

Introduction

§ Quickie Concepts

○ Units

§ SI is standard system of units used to measure physical quantities.

§ Base units that we use:

- meter (m) is standard unit of length
- kilogram (kg) is standard unit of mass
- second (s) is standard unit of time

	Prefix	Unit	What Unit Measures
ng			
μC			
mM			
kJ			
MPa			

Exercise #1:

Which of the following formulas could give the speed v (m/s) with which sound travels through a medium whose bulk modulus is B ($\text{kg}\cdot\text{m}^{-1}\text{s}^{-2}$) and whose mass density is ρ (kg/m^3)?

- A. $v = \sqrt{Br}$
- B. $v = \sqrt{B/r}$
- C. $v = \sqrt{Br^2}$
- D. $v = \sqrt{B/r^2}$

○ Vectors & Scalars

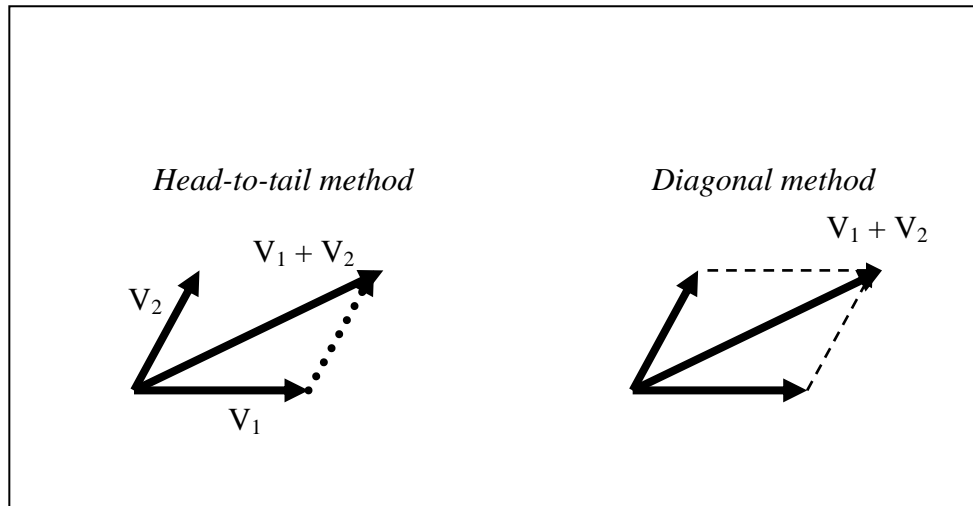
§ Scalars only have magnitude.

§ Vectors have both magnitude and direction.

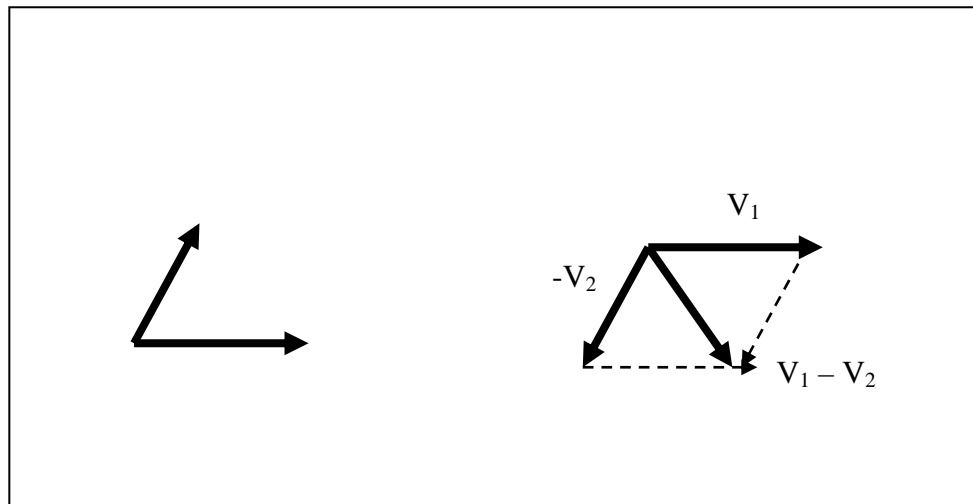
Physical Quantity	Vector or Scalar?
Time	
Mass	
Weight	
Temperature	

Physical Quantity	Vector or Scalar?
Velocity	
Speed	
Distance	
Displacement	
Acceleration	

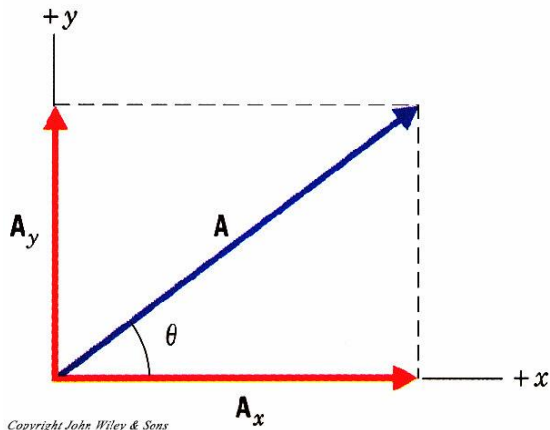
§ How do we add vectors? We can use diagonal or head-to-tail method.



§ How do we subtract vectors? Flip (180°) the vector being subtracted and add the two vectors. This is like adding the negative of a vector.



§ We often prefer to break down vectors into components. Usually, these components conveniently lie along the horizontal direction (x-axis) and vertical direction (y-axis).



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○	$A_x = \vec{A} \cos q$
○	$A_y = \vec{A} \sin q$

§ It is advisable to memorize the sines and cosines of common angles.

q	$\sin q$	$\cos q$
0	0	1
30	$\frac{1}{2} = 0.50$	$\frac{\sqrt{3}}{2} = 0.87$
45	$\frac{\sqrt{2}}{2} = 0.71$	$\frac{\sqrt{2}}{2} = 0.71$
60	$\frac{\sqrt{3}}{2} = 0.87$	$\frac{1}{2} = 0.50$
90	1	0

Kinematics

§ Kinematics is the study of motion. Importantly, we DON'T care about MASS.

§ Displacement

- Displacement is a vector. Position is merely a location in space.
- Displacement = Δ Position = position_{final} – position_{initial}
- Displacement is not the same as distance traveled.

§ Velocity

- Velocity is a vector.
- Velocity says how fast an object's position changes.
- Average Velocity = $\frac{\text{Displacement}}{\text{Time}} = \frac{\Delta x}{\Delta t}$
- Velocity is different from speed. Speed is not a vector but a scalar.

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$$

§ Acceleration

- Acceleration is a vector.
- Acceleration says how fast an object's velocity changes.
- Average Acceleration = $\frac{\Delta \text{Velocity}}{\text{Time}} = \frac{\Delta v}{\Delta t}$
- Can an object accelerate if its speed does not change?
 - § Think of the moon orbiting the Earth.
- Do objects always accelerate in the direction of its velocity?
 - § Think of what happens when we step on the breaks of a car.
- If an object's velocity is zero, is its acceleration zero?
 - § Think of a baseball thrown straight upward into the air.

§ When we try to solve kinematics problems, we must always know the state of acceleration in the system.

○ Zero Acceleration Case

§ $v = \frac{\Delta x}{\Delta t}$

§ Is it possible to ever encounter zero acceleration in a world always influenced by gravitational acceleration?

○ Constant Acceleration Case (also called Uniform Acceleration)

§ We often encounter constant acceleration because of gravity's constant pull.

§ There are 3 big equations to memorize:

Equation	Missing?
1. $v_f = v_o + at$	Δx
2. $\Delta x = x_f - x_o = v_o t + \frac{1}{2} at^2$	v_f
3. $v_f^2 = v_o^2 + 2a\Delta x$ (most important—why?)	t

Exercise #2:

If an object released from rest takes 3 seconds to fall to the Earth, from what height was it dropped?

- A. 15 m
- B. 45 m
- C. 90 m
- D. 180 m

Exercise #3:

A particle with an initial velocity of 4 m/s moves along the x-axis under constant acceleration. Three seconds later, its velocity is 14 m/s. How far did it travel during those three seconds?

- A. 21 m
- B. 24 m
- C. 27 m
- D. 30 m

Exercise #4:

An object decelerated uniformly from an initial velocity of v_o m/s to a final velocity of $(1/2)v_o$ m/s. If the distance traveled was $1/8$ m, what was its acceleration?

- A. $-6v_o^2$
- B. $-4v_o^2$
- C. $-3v_o^2$
- D. $-2v_o^2$

§ Projectile motion is really just the parabolic motion of a projectile under the influence of gravity. It can be separated into horizontal motion (zero acceleration case) and free-fall motion (constant acceleration case). In order to properly describe projectile, we need to remind ourselves of a few things:

- The velocity vector can be broken into a horizontal and vertical component.

§ $v_{o,x} = v_o \cos q$

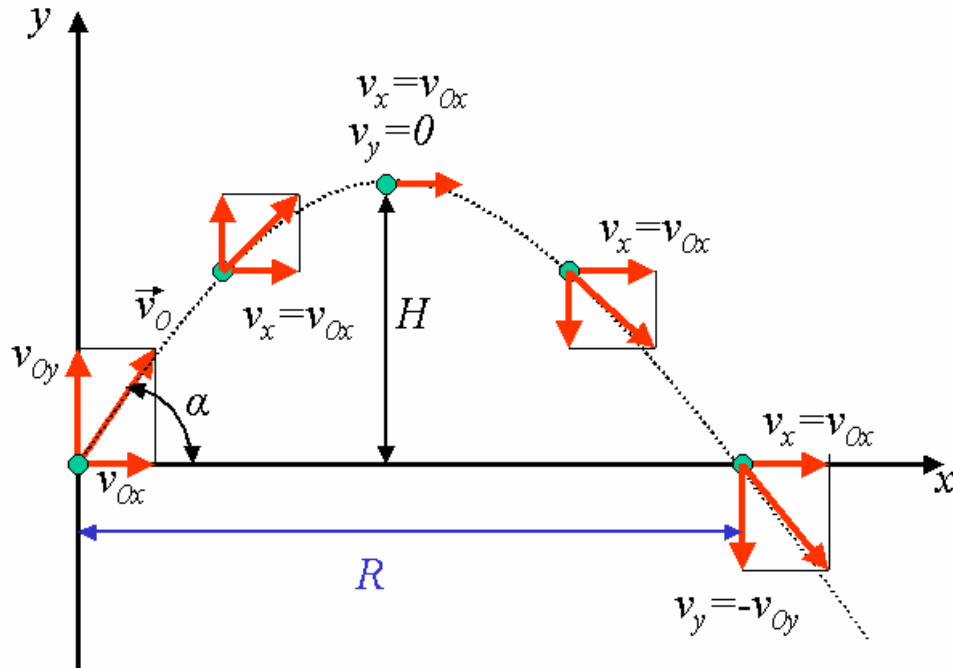
§ $v_{o,y} = v_o \sin q$

- Horizontal motion is described by the zero acceleration case, where:

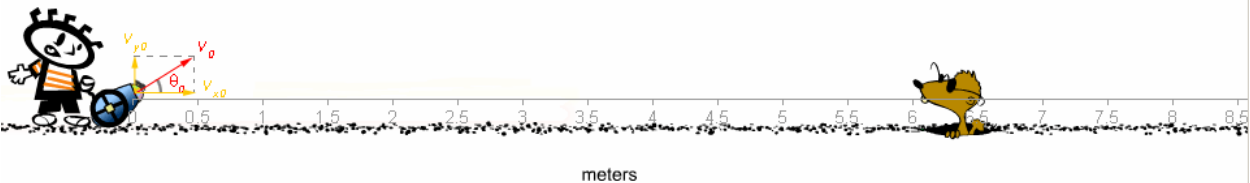
§ $\Delta x = v_{o,x}t$

- Free fall motion is described by the constant acceleration case, where we must resort to the big 3 equations (where $a = -g = -9.8 \text{ m/s}^2$):

<i>Equation</i>	<i>Missing?</i>
1. $v_{f,y} = v_{o,y} + gt$	Δy
2. $\Delta y = y_f - y_o = v_{o,y}t - \frac{1}{2}gt^2$	$v_{f,y}$
3. $v_{f,y}^2 = v_{o,y}^2 - 2g\Delta y$	t



- § What can we conclude about projectile motion?
- Does velocity change in the horizontal direction?
 - Does velocity change in the vertical direction?
 - In what way is projectile motion symmetric?
 - § With respect to time?
 - § With respect to vertical velocity?
 - What is the velocity of the projectile at its highest point?
 - What is the velocity of the projectile when it falls back down to the ground?

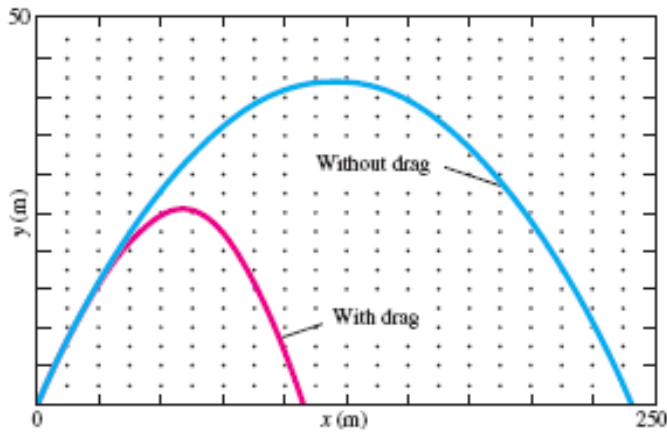


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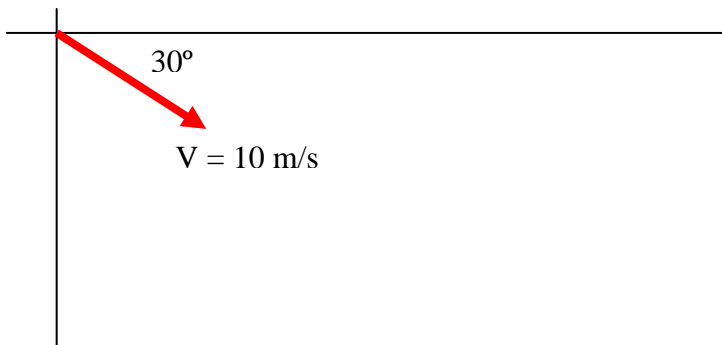
Example: A cannonball is fired with an initial velocity of 12 m/s at angle of 30° with respect to the ground.

- How long does the cannonball stay airborne? (Ans. 1.2 s)
- How far does the cannonball travel? (Ans. 13 m)
- What is the maximum height that the cannonball reaches? (Ans. 1.8 m)

§ We've been assuming that there is no such thing as air resistance. What would projectile motion look like if air resistance was considered?



§ Also realize that projectile motion appears in different forms:



Exercise #5:

An object is projected upward at a 30° angle with the horizontal with an initial speed of 20 m/s. How long will it take to reach the top of its trajectory?

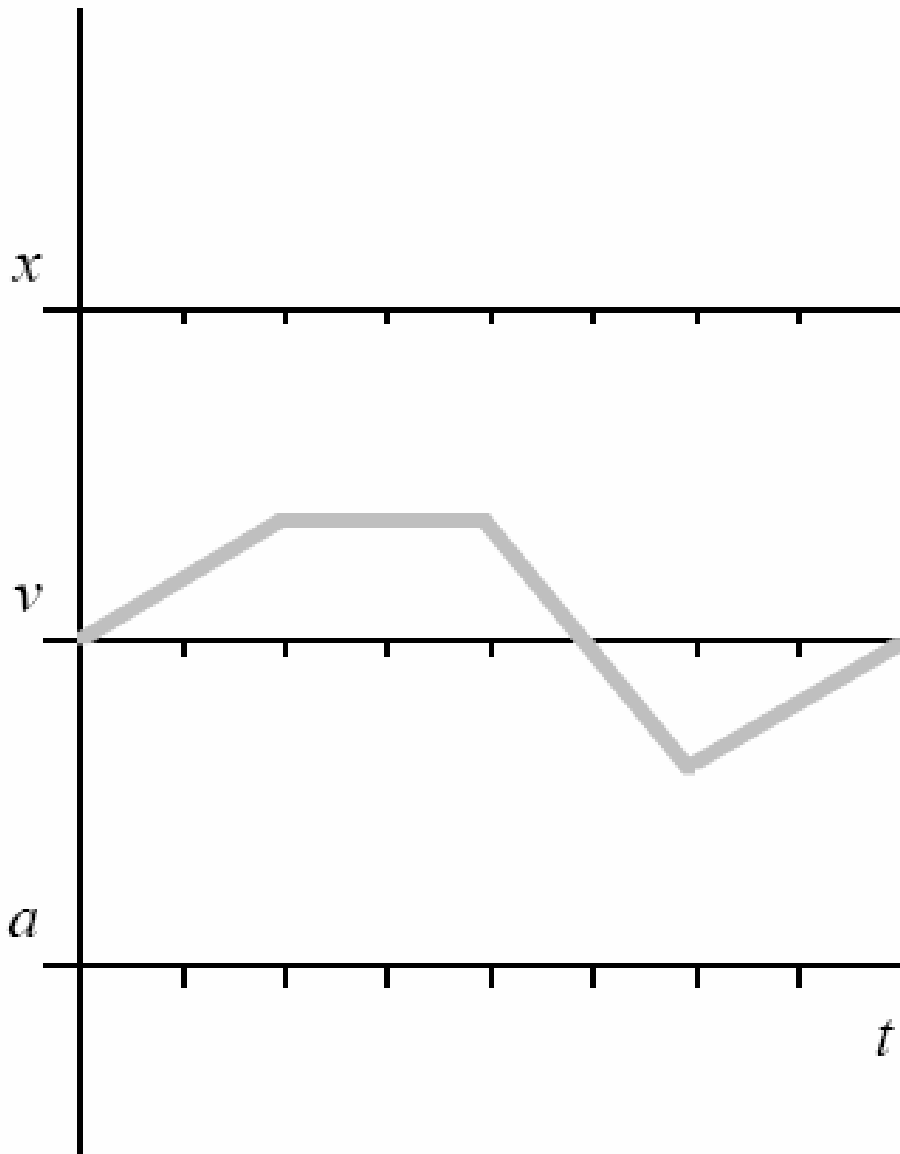
- A. 0.5 s
- B. 1.0 s
- C. 1.5 s
- D. 2.0 s

Exercise #6:

An object is projected upward at a 60° angle with the horizontal with an initial speed of 30 m/s. How far will it travel horizontally in its first three seconds of flight?

- A. 45.0 m
- B. 63.0 m
- C. 77.9 m
- D. 90.0 m

§ It is important to understand the “mechanics” and relationships between kinematic graphs in order to extract essential information such as displacement, velocity and acceleration.



Graph	Slope	Area Under Curve
Displacement vs. Time		
Velocity vs. Time		
Acceleration vs. Time		