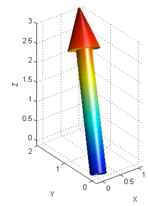
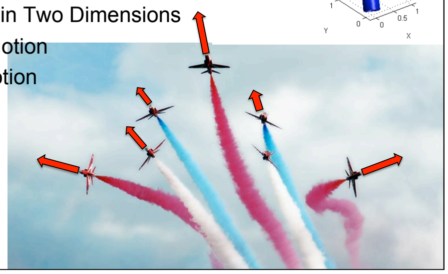
PHY131H1F Summer – Class 3



Today:
- Scalars and vectors
- Coordinate systems, Components
- Vector Algebra
- Kinematics in Two Dimensions
- Projectile Motion
- Relative Motion



Pre-class Reading Quiz. (Chapter 3) What is a vector?

A. A quantity having both magnitude and direction
B. The rate of change of velocity
C. A number defined by an angle and a magnitude
D. The difference between initial and final displacement
E. None of the above

Pre-class Reading Quiz. (Chapter 4)

You are running toward the right at 5 m/s toward an elevator that is moving up at 2 m/s. Relative to you, the direction and magnitude of the elevator's velocity are

A. down and to the right, less than 2 m/s.
B. up and to the left, less than 2 m/s.
C. up and to the left, more than 2 m/s.
D. up and to the right, less than 2 m/s.
E. up and to the right, more than 2 m/s.

Propagation of Errors

Sum rule: $z = x + y$, $z = x - y$ $\quad \Delta z = \sqrt{\Delta x^2 + \Delta y^2}$

Product rule: $z = x * y$, $z = x / y$ $\quad \frac{\Delta z}{z} = \sqrt{\left(\frac{\Delta x}{x}\right)^2 + \left(\frac{\Delta y}{y}\right)^2}$

Multiplying by exact constant: $z = A x$ $\quad \Delta z = |A \Delta x|$

Power rule: $z = x^n$ $\quad \Delta z = | n x^{n-1} \Delta x |$

Recall demonstration from last class:

- Harlow dropped a ball from a height of $y_i = 3.0 \pm 0.01$ m. Time of fall was $t = 0.78 \pm 0.05$ s.
- We also found that g is related to y_i and t by the equation: $g = 2y_i/t^2$. But how do you find the error?
- I used three steps:

1. Find error in $z = t^2$ using $\Delta t = 0.05$ s, and the exponent rule: $\Delta z = | nt^{n-1}\Delta t| = 2t\Delta t$.
2. Find error in $w = y_i/z$ using Δy_i, Δz and the product rule: $\Delta w = w \,\mathrm{sqrt}[(\Delta y_i/y_i)^2 + (\Delta z/z)^2]$
3. Find error in $g = 2w$ using Δw and the multiply by exact constant rule: $\Delta g = 2\Delta w$.

- Result: $g = 9.9 \pm 1.3$ m/s^2

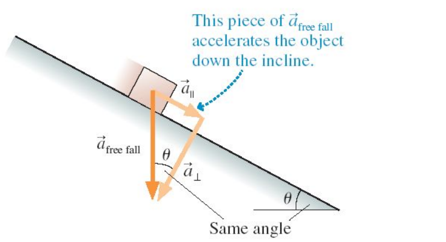
Recall demonstration from last class:

- Assuming Gaussian statistics:
  - Measured value should be within 1 sigma of the true value 68% of the time.
  - Measured value should be within 2 sigma of the true value 95% of the time.

Last day I asked at the end of class:

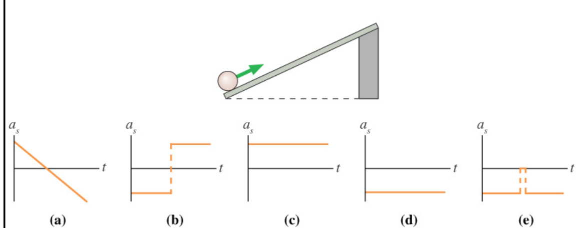
- Can you add a scalar to a vector?
- ANSWER: No. A 2-D vector is represented by a pair of numbers (ie x- and y- components, or magnitude and direction), and you can't add a scalar number to this.
- Can you multiply a vector by a scalar?
- ANSWER: YES! When you multiply a vector by a scalar, you can either:
  - Multiply both the x and y components by this scalar, or
  - Multiply the magnitude by the scalar, and keep the direction unchanged (but you flip direction 180° for a negative scalar)

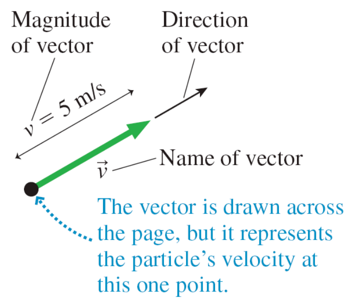
Motion on an Inclined Plane

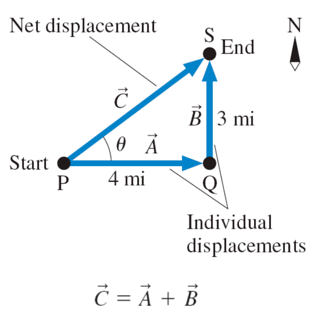


$$a_s = \pm g \sin\theta \qquad (2.25)$$

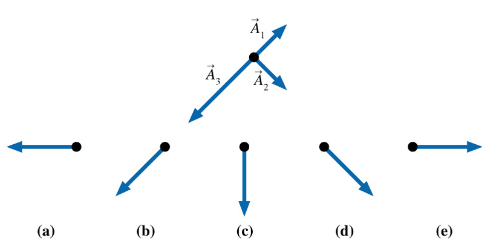
The ball rolls up the ramp, then back down.
Which is the correct acceleration graph?
[Define positive s as up and to the right.]







Which figure shows $\vec{A}_1 + \vec{A}_2 + \vec{A}_3$?



Which figure shows $2\vec{A} - \vec{B}$?

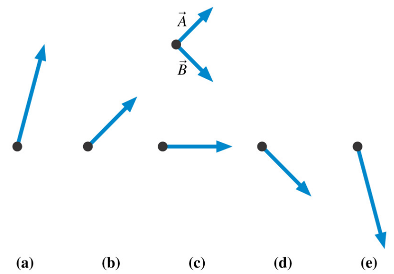


FIGURE 3.16 Moving between the geometric representation and the component representation.

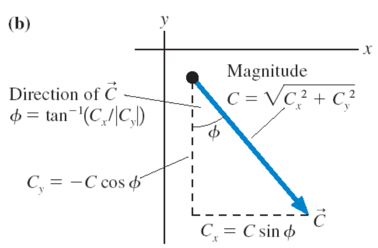


FIGURE 3.21 The unit vectors $\hat{\imath}$ and $\hat{\jmath}$.

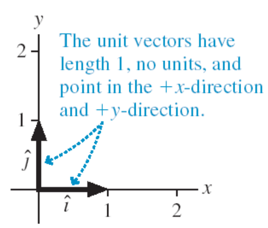
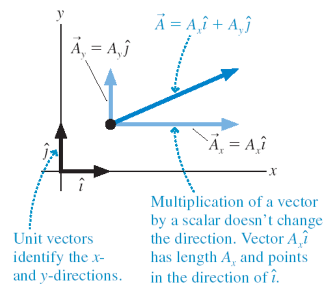
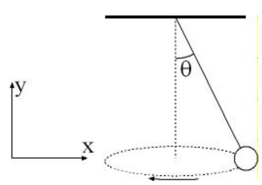


FIGURE 3.22 The decomposition of vector $\vec{A}$ is $A_x\hat{\imath} + A_y\hat{\jmath}$.



Example from a previous PHY131 Mid-Term Test

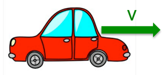
A ball is suspended on a string, and moves in a horizontal circle as shown in the figure. The string makes a constant angle θ = 10.0 degrees with the vertical. The tension in the string is 8.46 N, and the force of gravity on the ball is 8.33 N, in the negative-y direction. What is the net (total) force on the ball?



Acceleration in 1-D (along a line)

- Velocity is the time-derivative of position.
- Acceleration is the time-derivative of velocity.
- S.I. unit of acceleration is m/s ***per second***, also called m/s^2.
- Acceleration is like the "speed of the speed"
- Acceleration is "how fast fast changes!"
- It is possible to be momentarily stopped (v=0) with a non-zero acceleration!

Horizontal Acceleration Example



- A car starts from rest, then drives to the right. It speeds up to a maximum speed of 30 m/s. It coasts at this speed for a while, then the driver hits the brakes, and the car slows down to a stop.
- While it is speeding up, the acceleration vector of the car is

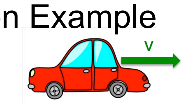
A. to the right.
B. to the left.
C. zero.

Horizontal Acceleration Example

- While the car is coasting, the acceleration vector of the car is

A. to the right.
B. to the left.
C. zero.

Horizontal Acceleration Example

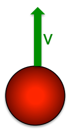


- While the car is slowing down, the acceleration vector of the car is

A. to the right.
B. to the left.
C. zero.

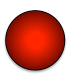
Vertical Acceleration Example (freefall)

- A ball starts with an upward velocity, reaches a maximum height, then falls back down again.
- While the ball is going up (after it has left my hand), the acceleration vector of the ball is



A. up.
B. down.
C. zero.

Vertical Acceleration Example (freefall)

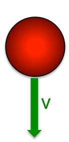


- When the ball is momentarily stopped at the top of its path, the acceleration vector of the ball is

A. up.
B. down.
C. zero.

Vertical Acceleration Example (freefall)

- While the ball is going down (but before I catch it), the acceleration vector of the ball is



A. up.
B. down.
C. zero.

Acceleration in 2-D

The *average acceleration* of a moving object is defined as the vector

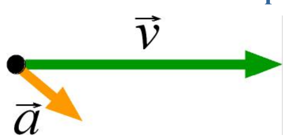
$$\vec{a}_{\text{avg}} = \frac{\Delta\vec{v}}{\Delta t}$$

As an object moves, its velocity vector can change in **two** possible ways:

1. The **magnitude** of the velocity can change, indicating a change in speed, or
2. The **direction** of the velocity can change, indicating that the object has changed direction.

…or both!

This acceleration will cause the particle to



A. slow down and curve downward.
B. slow down and curve upward.
C. speed up and curve downward.
D. speed up and curve upward.
E. move to the left and down.

Projectile Motion

FIGURE 4.15 The parabolic trajectory of a bouncing ball.

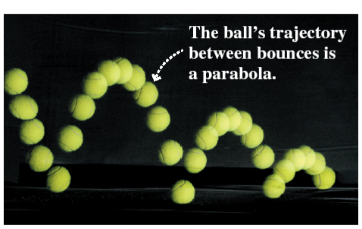
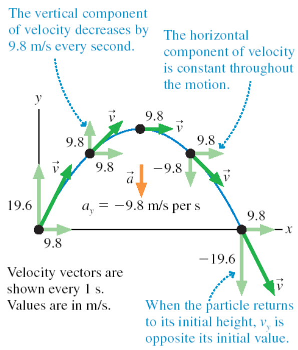


FIGURE 4.17 The velocity and acceleration vectors of a projectile moving along a parabolic trajectory.



Projectile Motion

Projectile motion is made up of two independent motions: uniform motion at constant velocity in the horizontal direction and free-fall motion in the vertical direction. The kinematic equations that describe these two motions are

$$x_f = x_i + v_{ix}\,\Delta t \qquad y_f = y_i + v_{iy}\,\Delta t - \tfrac{1}{2}g(\Delta t)^2$$

$$v_{fx} = v_{ix} = \text{constant} \qquad v_{fy} = v_{iy} - g\,\Delta t$$

Acceleration Due to Gravity, g in m/s²

Country	City	G-Constant
Argentina	Buenos Aires	9.7979
Australia	Sydney	9.7979
Austria	Vienna	9.8099
Belgium	Brussels	9.8114
Belize	Manamah	9.7904
Bolivia	La Paz	9.7844
Brazil	Brasilia	9.7889
Canada	Montreal	9.8069
	Ottawa	9.8069
	Toronto	9.8054
	Vancouver	9.8099
Czeck Republic	Prague	9.8114
Chile	Santiago	9.7979
China	Hong Kong	9.8099
Colombia	Bogota	9.7799
Costa Rica	San Jose	9.7829
Cypress	Nicosia	9.7979
Denmark	Copenhagen	9.8159
Ecuador	Quito	9.7724
Finland	Helsinki	9.8189
Germany	Dusseldorf	9.8129
Great Britain	London	9.8144
Greece	Athens	9.8009
Guatemala	Guatemala City	9.7844
Hungary	Budapest	9.8069
Indonesia	Djakarta	9.7814
Iraq	Baghdad	9.7964

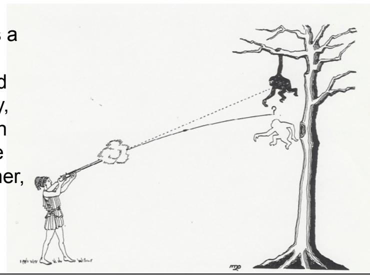
Country	City	G-Constant
Mexico	Mexico City	9.7799
Morocco	Rabat	9.7964
Netherlands	Amsterdam	9.8129
New Zealand	Wellington	9.8039
Norway	Oslo	9.8189
Panama	Panama City	9.7814
Peru	Lima	9.7829
Philippines	Manila	9.7844
Poland	Swider	9.8159
Portugal	Lisbon	9.8009
Rumania	Bucharest	9.8054
Saudi Arabia	Riyad	9.7904
Sweden	Stockholm	9.8189
Singapore	Singapore	9.7814
South Africa	Johannesburg	9.7919
Spain	Madrid	9.8024
Switzerland	Bern	9.8084
Taiwan	Taipei	9.7904
Tunisia	Tunis	9.7799
Turkey	Ankara	9.8024
Uruguay	Montevideo	9.7964
USA	Anchorage	9.8189
	Atlanta	9.7964
	Boston	9.8039
	Chicago	9.8024
	Dallas	9.7949
	Detroit	9.8039
	Los Angeles	9.7979
	New York	9.8024
	Philadelphia	9.8024
	San Francisco	9.7994
[illegible]	Caracas	9.7829

- Average: 9.799 m/s^2
- Standard Deviation: 0.012 m/s^2
- This class: let's use g = 9.80 m/s^2

Monkey and Hunter Demonstration

The classic problem: "A monkey hanging from the branch of a tree is spotted by a hunter. The monkey sees that the barrel of the gun is pointed directly at him. At the exact instant the gun is fired, the monkey lets go of the branch. Will the bullet (A) go above the monkey, (B) go below the monkey, or (C) hit the monkey?

Our demonstration uses a tennis ball launcher. The launcher is aimed directly at the monkey, which is held up by an electromagnet. As the ball leaves the launcher, it breaks a beam that releases the magnet.



- You drop a glass barometer from the top of McLennan Physical Labs. A short time later, before the barometer hits the ground, you drop a bottle of scotch. As they fall, the distance between the barometer and bottle

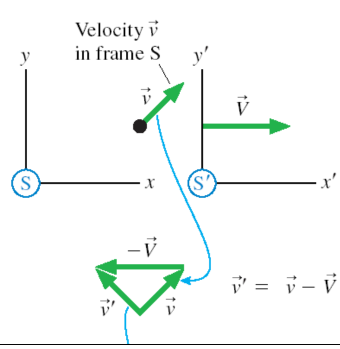
A. decreases

B. increases

C. stays the same.

Niels Bohr

Relative Motion



Relative Motion

If we know an object's velocity measured in one reference frame, *S*, we can transform it into the velocity that would be measured by an experimenter in a different reference frame, *S*′, using the Galilean transformation of velocity.

$$\vec{v} = \vec{v}\,' + \vec{V} \quad \text{or} \quad \vec{v}\,' = \vec{v} - \vec{V}$$

Or, in terms of components,

$$\begin{aligned} v_x &= v'_x + V_x \\ v_y &= v'_y + V_y \end{aligned} \quad \text{or} \quad \begin{aligned} v'_x &= v_x - V_x \\ v'_y &= v_y - V_y \end{aligned}$$

Relative Motion

- **Example 1:** A passenger walks toward the front of the train at 5 m/s. The train is moving at 36 m/s. What is the speed of the passenger relative to the ground?
- **Example 2:** Car A is traveling at 25.0 m/s E toward Bloor and Keele. Car B is traveling at 15.8 m/s N toward Bloor and Keele. Just before they collide, what is the velocity of car A relative to car B?

You are on an Eastbound subway train going at 20 m/s. You notice the Westbound train on the other track. Relative to the ground, that Westbound train has a speed of 20 m/s. What is the velocity of the Westbound train as measured by you?

A. 40 m/s, West
B. 20 m/s, West
C. zero
D. 20 m/s, East
E. 40 m/s, East

A plane traveling East at 100 m/s flies near a helicopter that is going North at 20 m/s. From the helicopter's perspective, the plane's direction and speed are

A. between North and East, more than 100 m/s.
B. between North and East, less than 100 m/s.
C. between South and East, more than 100 m/s.
D. between South and East, less than 100 m/s.
E. between South and East, 100 m/s.

Before Next Class:

- Read Chapters 4 and 5 of Knight.
- Complete MasteringPhysics.com Problem Set 2 due by May 25 at 11:59pm
- Something to think about: You are driving North Highway 427, on the smoothly curving part that will join to the Westbound 401. Your speedometer is constant at 115 km/hr. Your steering wheel is not rotating, but it is turned to the left to follow the curve of the highway. Are you accelerating? If so, in what direction?