Physics 121: Vectors and Coordinate Systems

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Quiz

1. What is the magnitude of the gravitational acceleration near the surface of the earth?

A. 4.98 m/s^2

B. 9.80 m/s

C. 9.80 m/s^2

D. It depends on the velocity

2. Which of these is **NOT** a kinematic equation?

A. $s_f = s_i + v_i \Delta t + \frac{1}{2} a (\Delta t)^2$

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

C. $a_f = a_i + \int_{t_i}^{t_f} v_s dt$

D. $v_f^2 = v_i^2 + 2a\Delta s$

Reminders

- The next HW will be due on Saturday and will include all the material we cover in chapters 3 and 4.
- The exam is coming up on Tuesday 19 Sep. The exam will be taken in class. It will cover all material from chapters 1-4.

Vectors

Before we dive anymore into physics and motion in multiple dimensions let's do a thorough review of vectors!

Vectors

- In your words what is a vector?

Vectors

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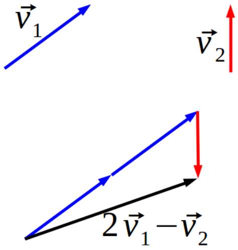
- You have learned how to add vectors as pictures so I won't bore you with that.



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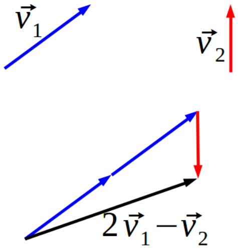
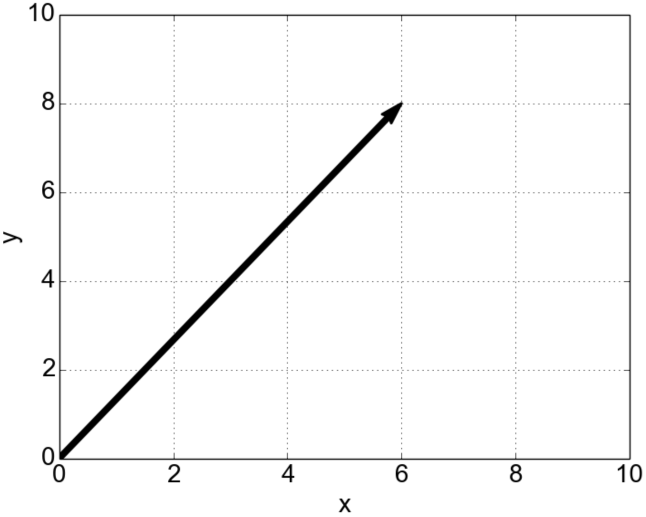


- However we haven't talked about their components in detail much.

Vectors

Write down how you would describe this vector

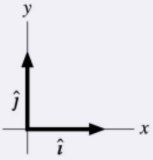


What are unit vectors?

Unit vectors define what we *mean* by the $+x$- and $+y$-directions in space.

- A unit vector has magnitude 1.
- A unit vector has no units.

Unit vectors simply point.



Vectors

- What is the difference between a scalar and a vector?

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- The magnitude (length) of a vector is a scalar (ex. $\vec{V} = X\hat{i} + Y\hat{j}$).

$$V = \left|\vec{V}\right| = \sqrt{X^2 + Y^2}$$

Think of the pythagorean theorem

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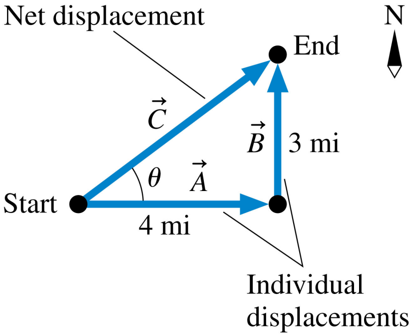
  Think of the pythagorean theorem
- If the vector was the velocity then notice that the magnitude would be the speed. Also, the magnitude cannot be negative (just like speed can't be negative, but velocity can).

Add the two displacement vectors, $\vec{A}$ and $\vec{B}$ to get the **resultant vector** (or total displacement) $\vec{C}$.



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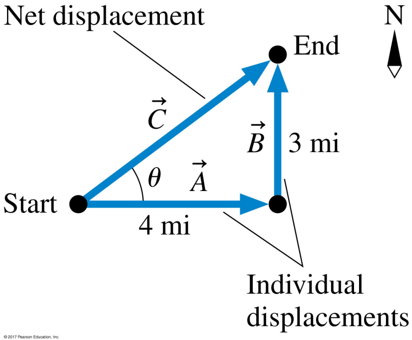
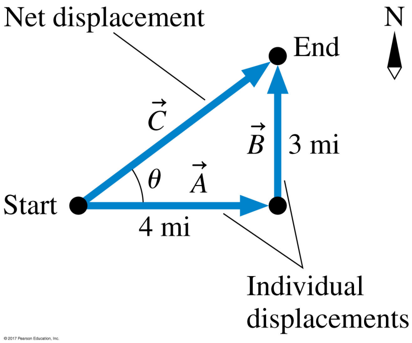


$$\vec{C} = 4 \text{ mi } \hat{i} + 3 \text{ mi } \hat{j}$$

This time use $\vec{A}$ and $\vec{B}$ to get $\vec{C}$ in terms of the magnitude C and the angle as measured from the x axis, θ.



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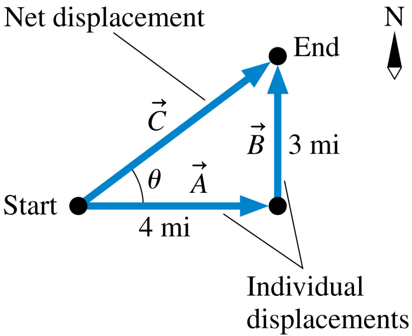
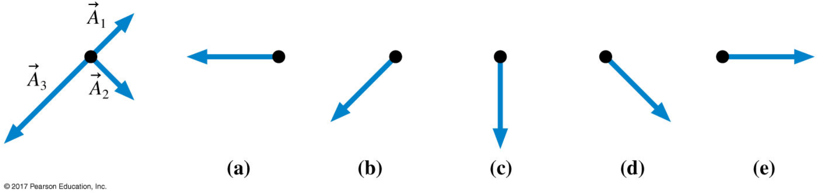


$$C = \sqrt{A^2 + B^2} = \sqrt{(4\text{ mi})^2 + (3\text{ mi})^2} = 5\text{ mi}$$

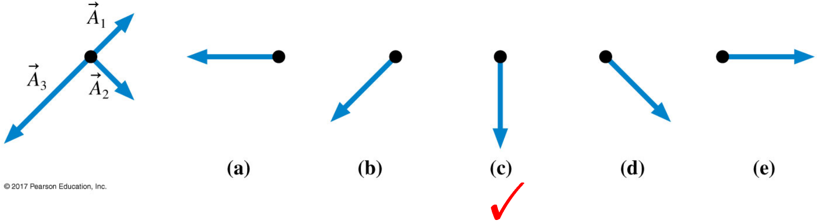
$$\theta = \tan^{-1}\left(\frac{B}{A}\right) = \tan^{-1}\left(\frac{3\text{ mi}}{4\text{ mi}}\right) = 37^\circ$$

What is $\vec{A}_1 + \vec{A}_2 + \vec{A}_3$?



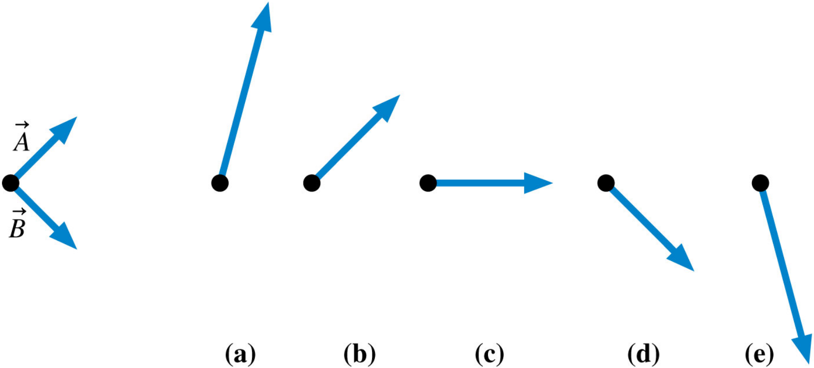
Quick Check

What is $\vec{A}_1 + \vec{A}_2 + \vec{A}_3$?



Quick Check

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



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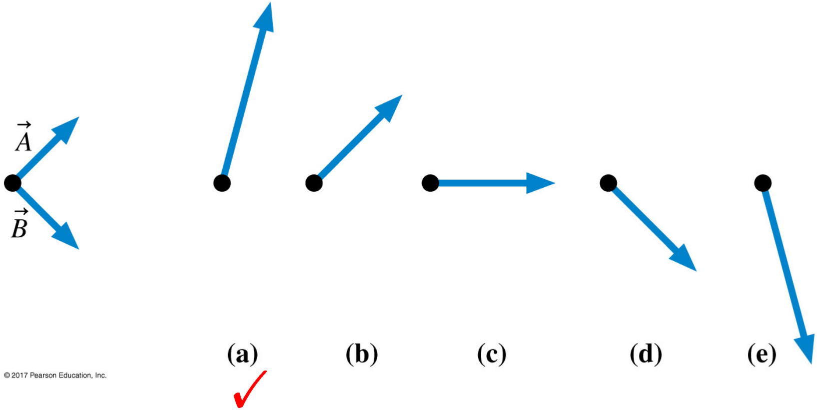
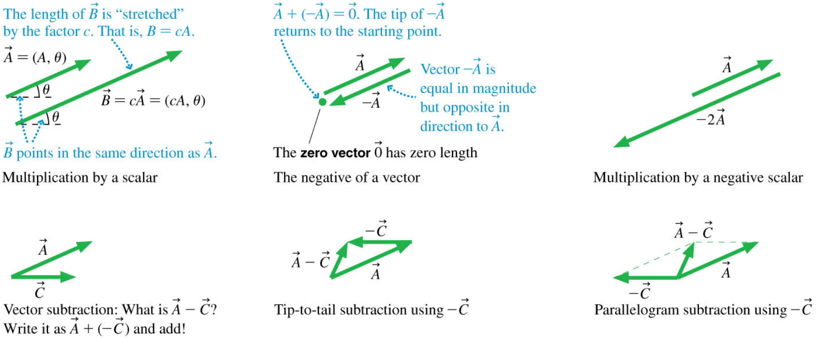


More vector math



Coordinate Systems

- We have talked about coordinate systems and origins (on the first day)
- Which of these things depends on the coordinate system and origin?
  1. Vector components
  2. Magnitude of vector
  3. Angle of vector
  4. Displacement vector (i.e. $\Delta\vec{r} = \vec{r}_1 - \vec{r}_0$)

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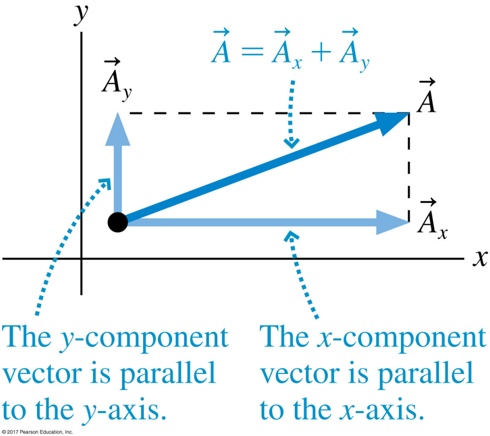
1 and 3

- Once we have picked a suitable coordinate system we can then take any vector and decompose it into it's **component vectors**. This is called **decomposition** of a vector into it's component vectors.

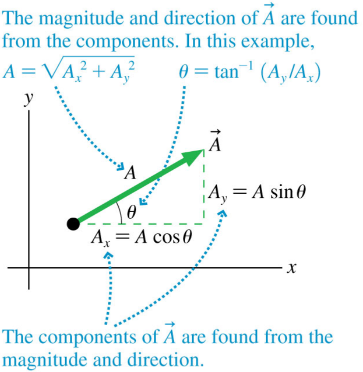


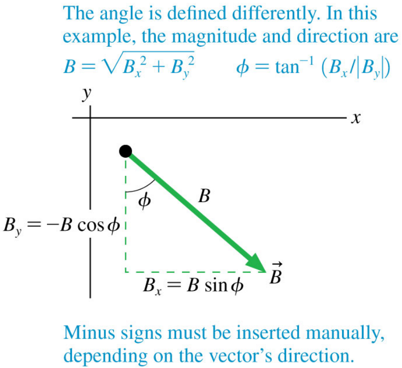
Warning

Just as a warning $\vec{A}_x$ is not the same as the component A_x.

$$\vec{A}_x = A_x \hat{i}.$$

As a second warning when going between component and geometric forms of vectors make sure you get signs right (sometimes you have to put them in by hand) and make sure you know where angles are being measured from.

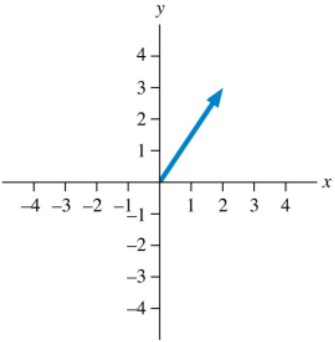




Quick Check

What are the x- and y-components of this vector?

A. 3, 2
B. 2, 3
C. –3, 2
D. 2, –3
E. –3, -2



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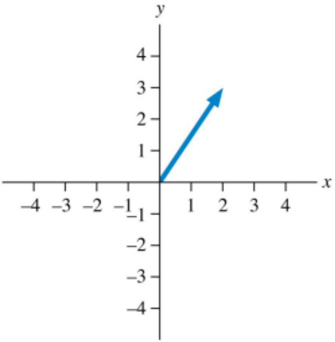
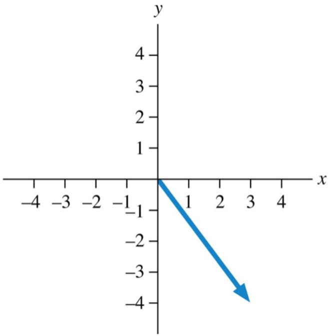


Quick Check

What are the x- and y-components of this vector?

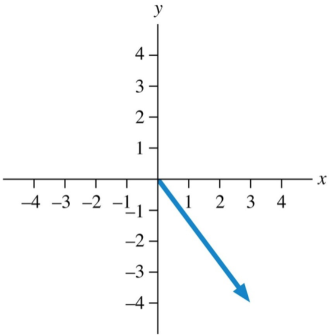
A. 3, 4
B. 4, 3
C. –3, 4
D. 4, –3
E. 3, –4



Quick Check

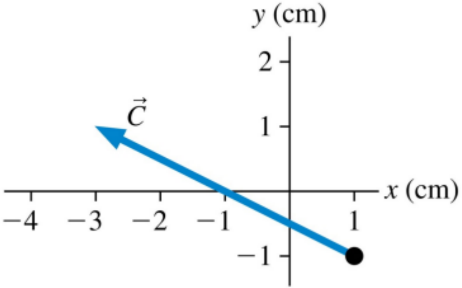
What are the x- and y-components of this vector?

A. 3, 4
B. 4, 3
C. –3, 4
D. 4, –3
✓E. 3, –4



What are the x- and y-components of vector $\vec{C}$?

A. 1, –3
B. –3, 1
C. 1, –1
D. –4, 2
E. 2, –4



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A. 1, –3
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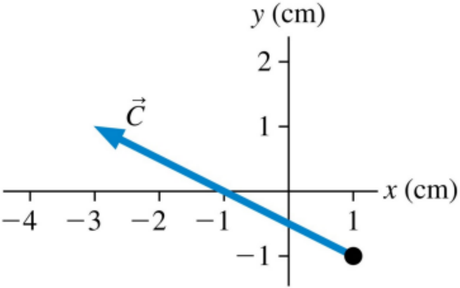
C. 1, –1
✓D. –4, 2
E. 2, –4



- How would you add three vectors $\vec{D} = \vec{A} + \vec{B} + \vec{C}$ where the vectors are given by $\vec{A} = A_x\hat{i} + A_y\hat{j}$ and similar for $\vec{B}$ and $\vec{C}$?

Vector Math

- How would you add three vectors $\vec{D} = \vec{A} + \vec{B} + \vec{C}$ where the vectors are given by $\vec{A} = A_x\hat{i} + A_y\hat{j}$ and similar for $\vec{B}$ and $\vec{C}$?
$\vec{D} = (A_x + B_x + C_x)\hat{i} + (A_y + B_y + C_y)\hat{j}$

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A bird flies 100 m due east from a tree, then 50 m northwest (45° north of west). What is the bird s net displacement?

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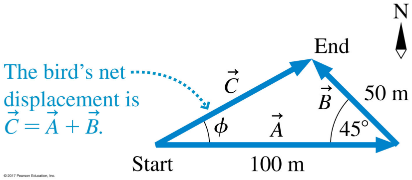

$$\vec{A} = 100\hat{i}$$
$$\vec{B} = -50\sin(45^\circ)\hat{i} + 50\sin(45^\circ)\hat{j} = -35.4\hat{i} + 35.4\hat{j}$$
$$\vec{C} = 64.6\hat{i} + 35.4\hat{j}$$

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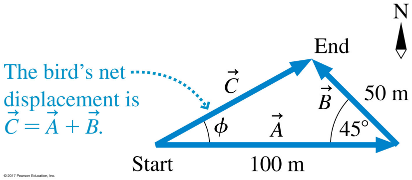


$$\vec{A} = 100\hat{i}$$

$$\vec{B} = -50\sin(45^\circ)\hat{i} + 50\sin(45^\circ)\hat{j} = -35.4\hat{i} + 35.4\hat{j}$$

$$\vec{C} = 64.6\hat{i} + 35.4\hat{j}$$

$$C = \sqrt{C_x^2 + C_y^2} = \sqrt{64.6^2 + 35.4^2} = 73.6m$$

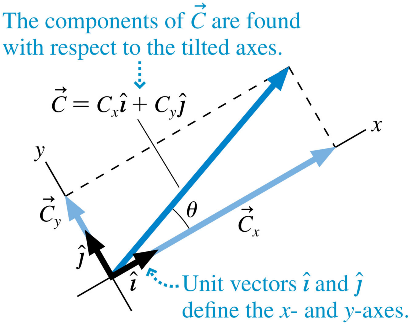
$$\theta = \tan^{-1}\left(\frac{C_y}{C_x}\right) \tan^{-1}\left(\frac{35.4}{64.6}\right) = 28.7^\circ$$

$$\vec{C} = (73.6 \text{ m}, 28.7^\circ)$$

Tilted Axes

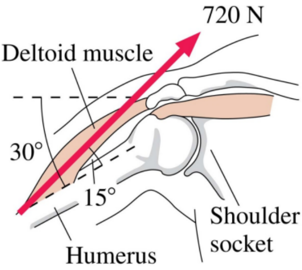
- Let's say I have an inclined plane. Can I set my axes such that $\hat{i}$ points along (parallel) to the plane and $\hat{j}$ points perpendicular to the plane?

- Let's say I have an inclined plane. Can I set my axes such that $\hat{i}$ points along (parallel) to the plane and $\hat{j}$ points perpendicular to the plane?
- Of course you can, we talked about how that could be useful last time! This can help you determine the component vectors that are "parallel" (make object move) and "perpendicular" (doesn't make the object move).



EXAMPLE 3.7 | **Muscle and bone**

The deltoid—the rounded muscle across the top of your upper arm—allows you to lift your arm away from your side. It does so by pulling on an attachment point on the humerus, the upper arm bone, at an angle of 15° with respect to the humerus. If you hold your arm at an angle 30° below horizontal, the deltoid must pull with a force of 720 N to support the weight of your arm, as shown in FIGURE 3.21a. (You'll learn in Chapter 5 that force is a vector quantity measured in units of *newtons*, abbreviated N.) What are the components of the muscle force parallel to and perpendicular to the bone?



EXAMPLE 3.7 | **Muscle and bone**

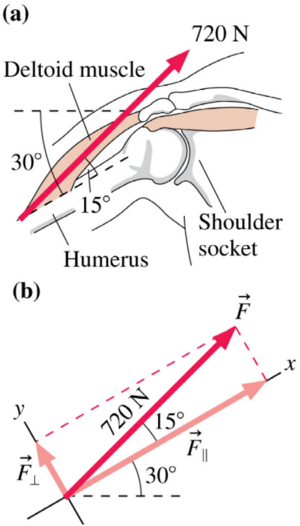
VISUALIZE **FIGURE 3.21b** shows a tilted coordinate system with the x-axis parallel to the humerus. The force $\vec{F}$ is shown 15° from the x-axis. The component of force parallel to the bone, which we can denote $F_{\parallel}$, is equivalent to the x-component: $F_{\parallel} = F_x$. Similarly, the component of force perpendicular to the bone is $F_{\perp} = F_y$.

SOLVE From the geometry of Figure 3.21b, we see that

$$F_{\parallel} = F\cos 15° = (720\text{ N})\cos 15° = 695\text{ N}$$

$$F_{\perp} = F\sin 15° = (720\text{ N})\sin 15° = 186\text{ N}$$

ASSESS The muscle pulls nearly parallel to the bone, so we expected $F_{\parallel} \approx 720$ N and $F_{\perp} \ll F_{\parallel}$. Thus our results seem reasonable.



Picture References

None yet