Today: Sections 3.1 & 3.2

L7

Today: Sections 3.1 & 3.2

L7

Position & velocity vectors

Today: Sections 3.1 & 3.2

L7

↑ Acceleration vector

L7

Today: Sections 3.1 & 3.2

Monday: Holiday

L7

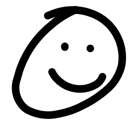
Today: Sections 3.1 & 3.2

Monday: Holiday ☺

ASU

L7

Today: Sections 3.1 & 3.2

Monday: Holiday 

Wednesday: Section 3.3 & 3.2

Today: Sections 3.1 & 3.2

L7

Monday: Holiday ☺

Wednesday: Section 3.3 & 3.2

projectile motion

L7

Today: Sections 3.1 & 3.2

Monday: Holiday ☺

Wednesday: Section 3.3 & 3.2

HW#2: Will accept as late as Monday

ASU

L7

Today: Sections 3.1 & 3.2

Monday: Holiday ☺

Wednesday: Section 3.3 & 3.2

HW#2: Will accept as late as Monday

But no more HW extensions are to be expected!

L7

Today: Sections 3.1 & 3.2

Monday: Holiday ☺

Wednesday: Section 3.3 & 3.2

HW#2: Will accept as late as Monday

HW#3: Due Friday Sept 11

3.1, 3.3b	§3.1
3.5b & c, 3.7b	§3.2
3.9a & b, 3.11, 3.13, 3.15, 3.19	§3.3

L7

Today: Sections 3.1 & 3.2

Monday: Holiday ☺

Wednesday: Section 3.3 & 3.2

HW#2: Will accept as late as Monday

HW#3: Due Friday Sept 11

3.1, 3.3b	§3.1
3.5b & c, 3.7b	§3.2
3.9a & b, 3.11, 3.13, 3.15, 3.19	§3.3

HW#4: Due Wednesday Sept 16

ASU

Today: Sections 3.1 & 3.2 [L7]

Monday: Holiday ☺

Wednesday: Section 3.3 & 3.2

HW#2: Will accept as late as Monday

HW#3: Due Friday Sept 11

3.1, 3.3b	§3.1
3.5b&c, 3.7b	§3.2
3.9a&b, 3.11, 3.13, 3.15, 3.19	§3.3

HW#4: Due Wednesday Sept 16

3.25, 3.27, 3.31	§3.4
3.35, 3.37, 3.41	§3.5

ASU

L7

Today: Sections 3.1 & 3.2

Monday: Holiday ☺

Wednesday: Section 3.3 & 3.2

HW#2: Will accept as late as Monday

HW#3: Due Friday Sept 11

3.1, 3.3b	§3.1
3.5b&c, 3.7b	§3.2
3.9a&b, 3.11, 3.13, 3.15, 3.19	§3.3

HW#4: Due Wednesday Sept 16 — Date of Exam #1

3.25, 3.27, 3.31	§3.4
3.35, 3.37, 3.41	§3.5

ASU

Position vector

Position vector

Let $\vec{r} \equiv$ position vector

Position Vector

Let $\vec{r} \equiv$ position vector &

$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$

Position Vector

Let $\vec{r} \equiv$ position vector $\hat{}$ &

$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$

↑

unit
Vector
in x-direction

Position Vector

Let $\vec{r} \equiv$ position vector &

$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$

↑ unit vector in y-direction

Position Vector

Let $\vec{r} \equiv$ position vector &

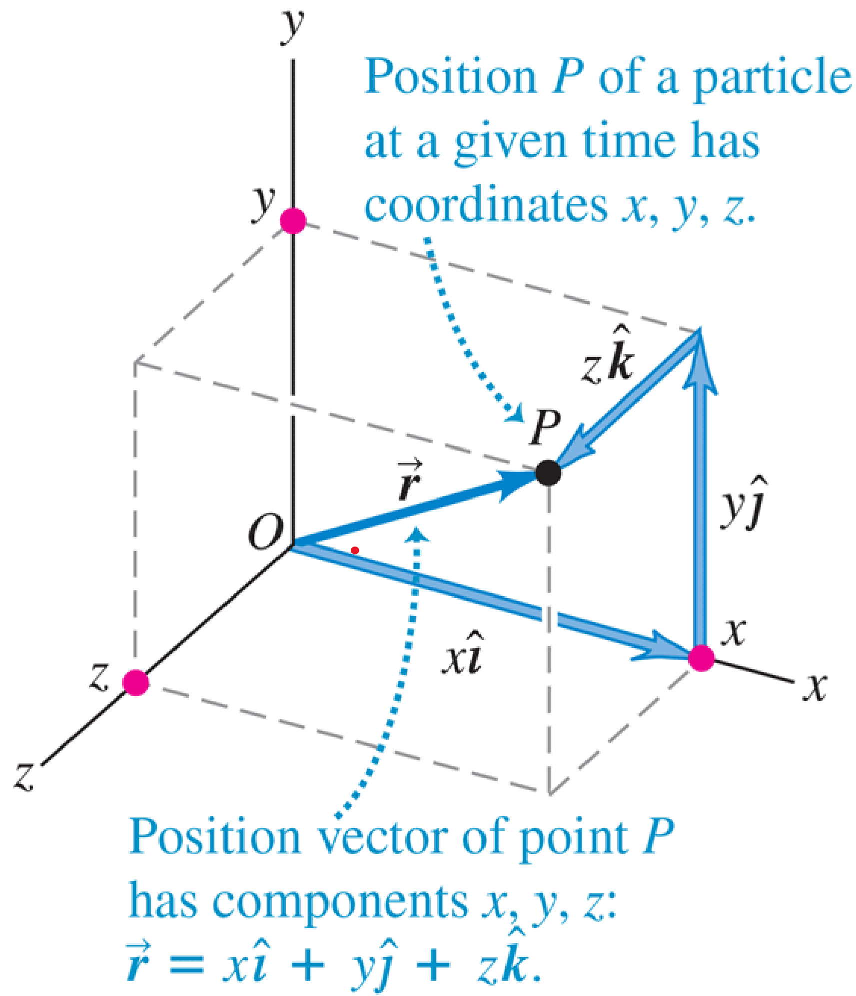
$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$

↑ unit vector in z-direction

Position Vector

Let $\vec{r} \equiv$ position vector &

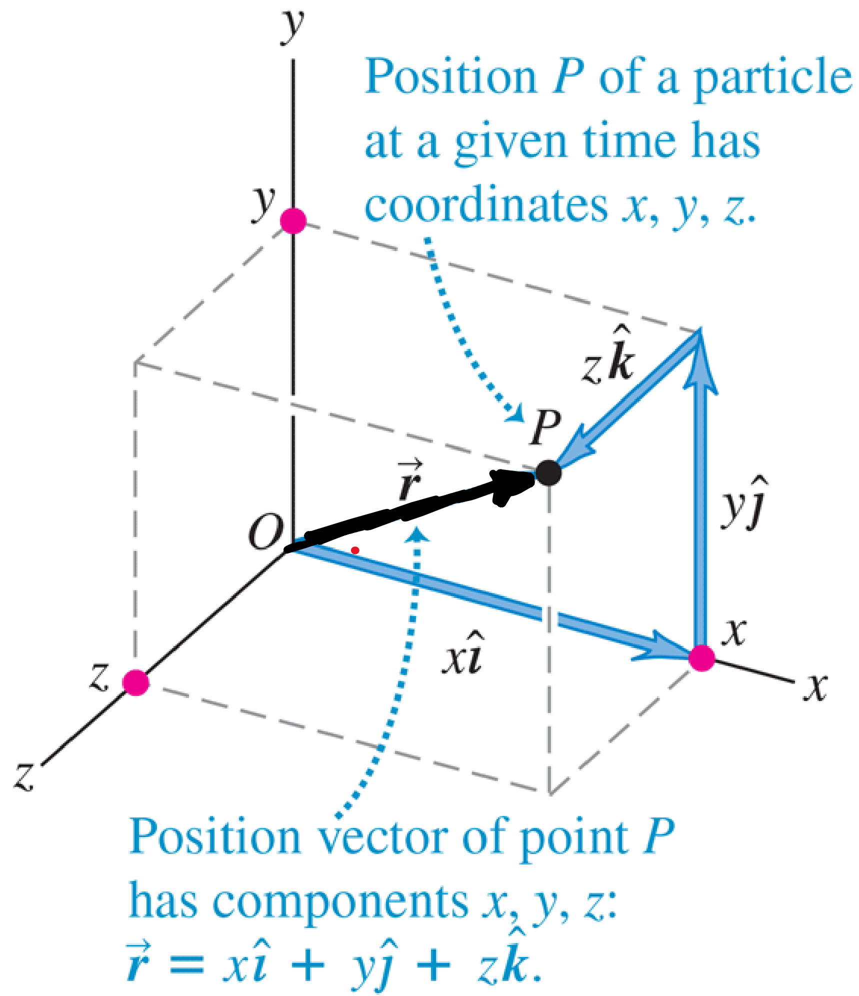
$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$



Position Vector

Let $\vec{r} \equiv$ position vector &

$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$

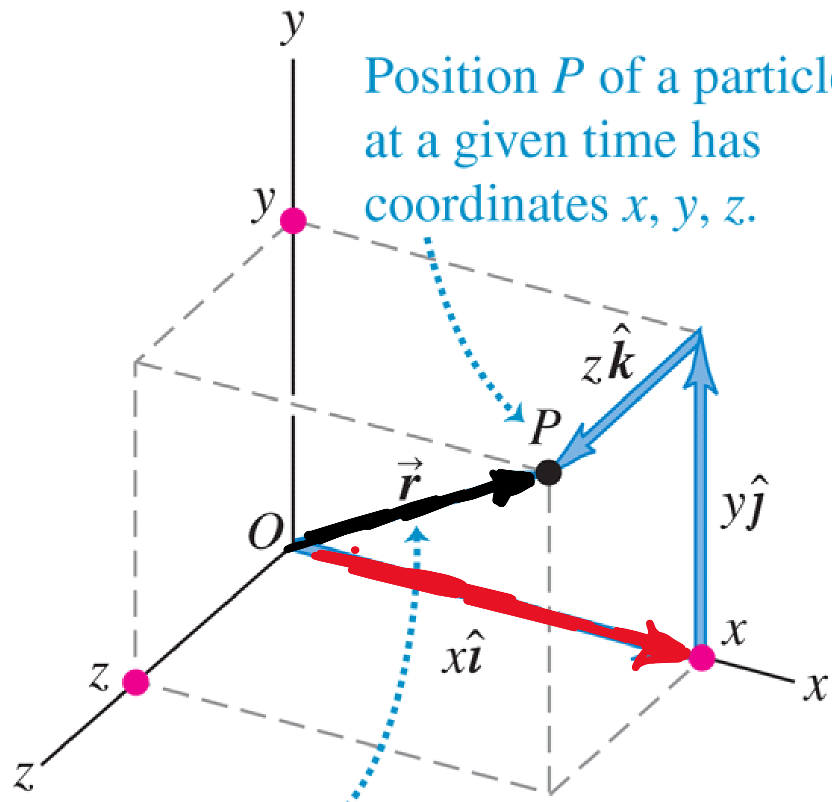


Position Vector

Let $\vec{r} \equiv$ position vector &

$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$

go out in x-direction



Position vector of point P has components x, y, z:
$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$.

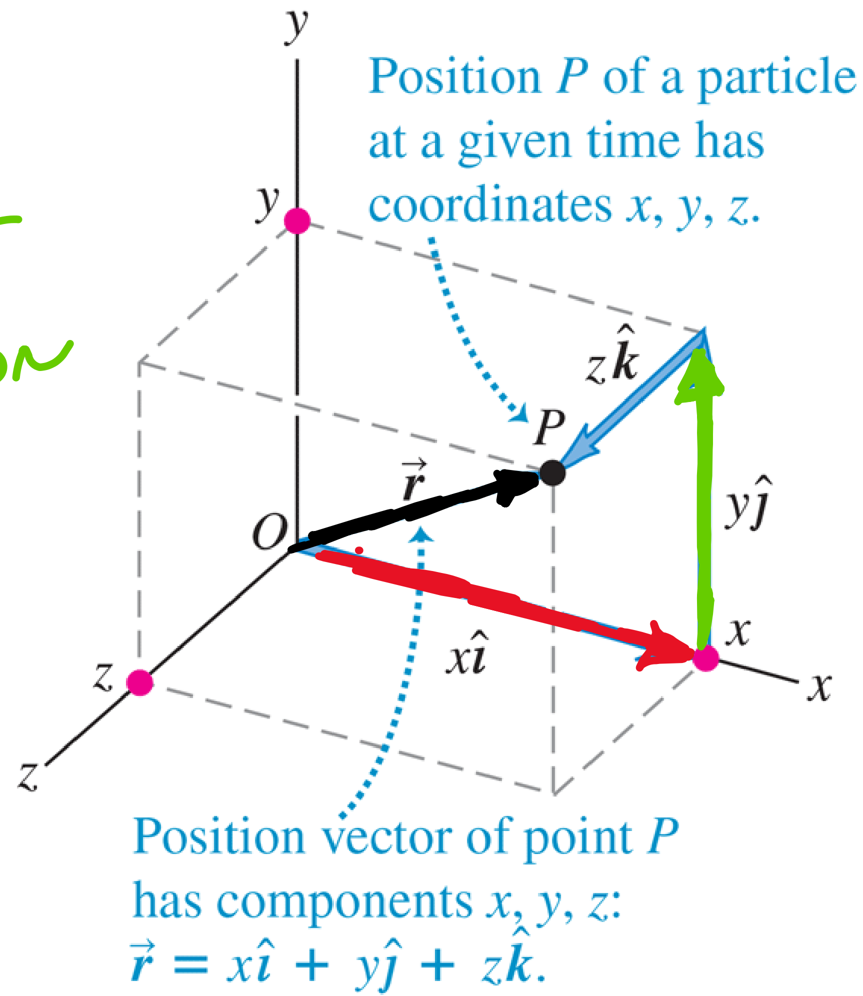
ASU

Position Vector

Let $\vec{r} \equiv$ position vector &

$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$

Then go out in y-direction



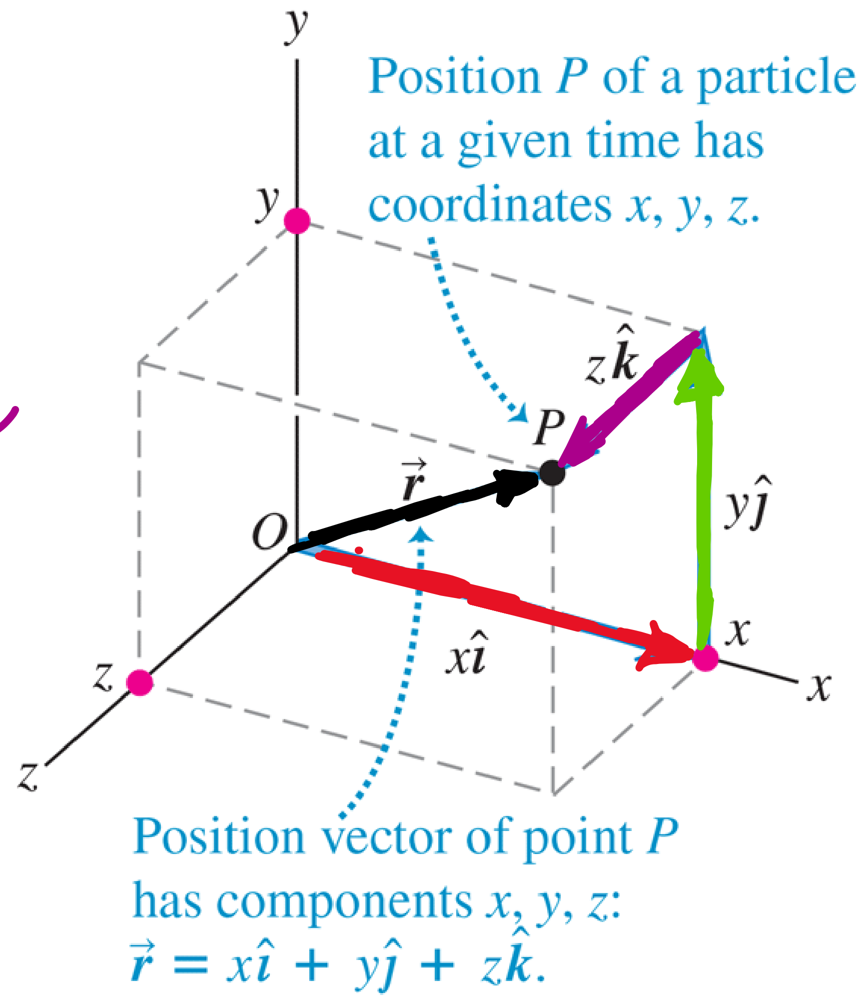
ASU

Position Vector

Let $\vec{r} \equiv$ position vector &

$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$

Now move in z-direction

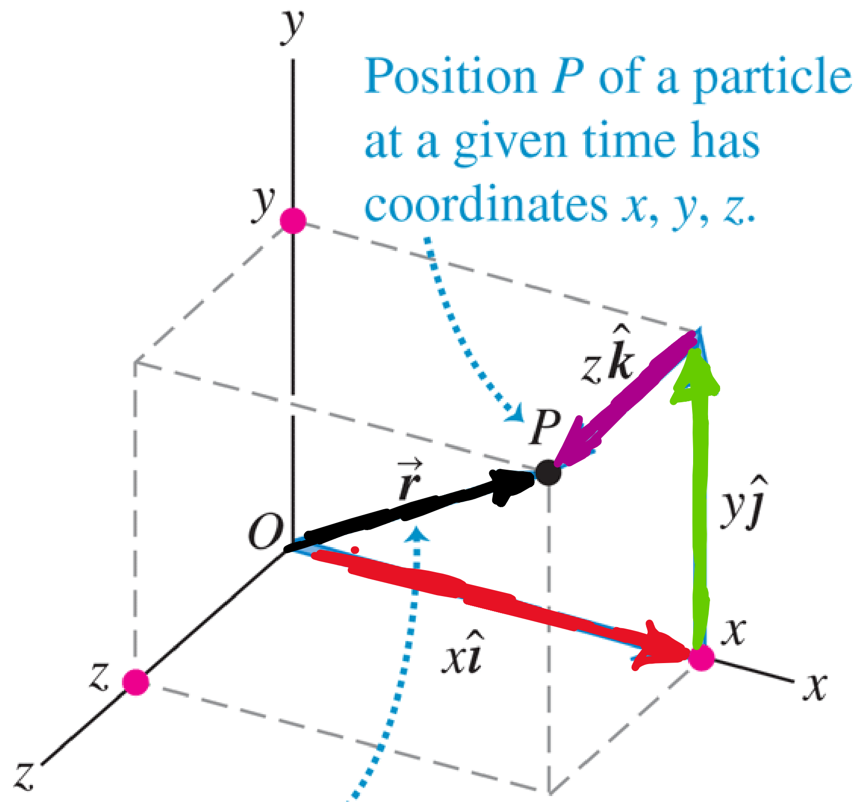


Position Vector

Let $\vec{r} \equiv$ position vector &

$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$

gets you to the same place as $\vec{r}$



Position vector of point P has components x, y, z:
$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$.

Position Vector

Let $\vec{r} \equiv$ position vector &

$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$

For purposes of drawing, I will often stick to 2-D

Position vector

Let $\vec{r} \equiv$ position vector &

$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$. Let

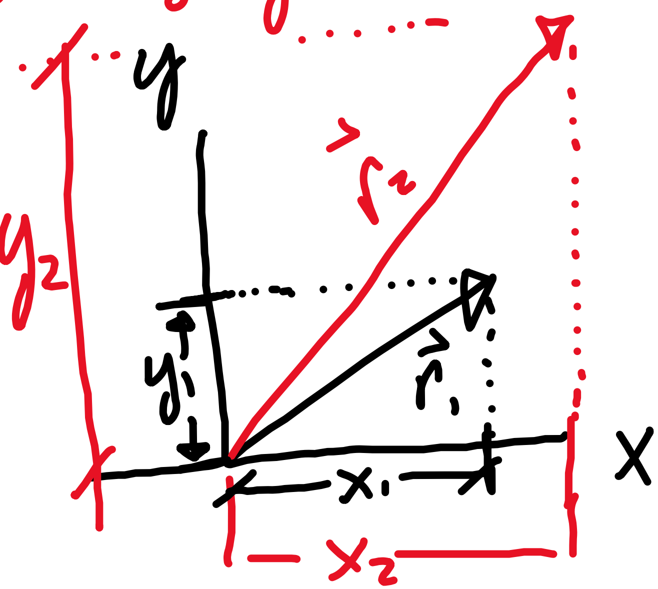
$\vec{r}_1 = x_1\hat{i} + y_1\hat{j}$

Position Vector

Let $\vec{r} \equiv$ position vector &

$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$. Let

$\vec{r}_1 = x_1\hat{i} + y_1\hat{j}$ & $\vec{r}_2 = x_2\hat{i} + y_2\hat{j}$



Position Vector

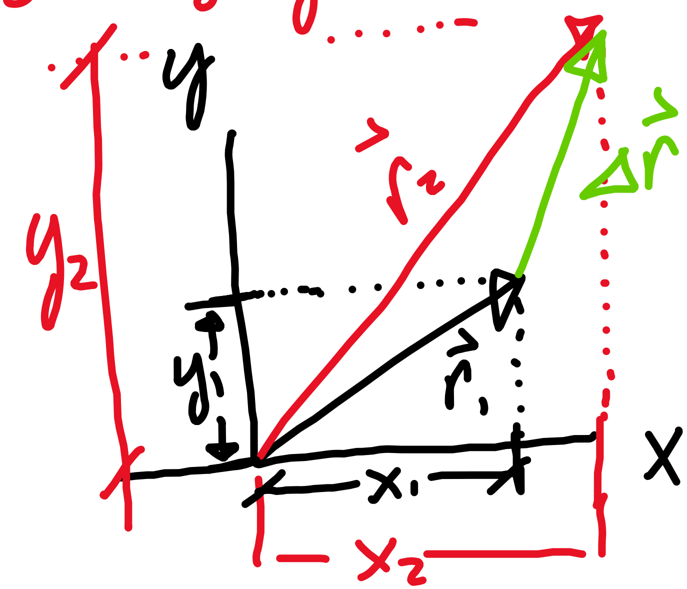
Let $\vec{r} \equiv$ position vector &

$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$. Let

$\vec{r}_1 = x_1\hat{i} + y_1\hat{j}$ & $\vec{r}_2 = x_2\hat{i} + y_2\hat{j}$

& $\Delta\vec{r} = \vec{r}_2 - \vec{r}_1$

$\Rightarrow \Delta\vec{r} = (x_2 - x_1)\hat{i} + (y_2 - y_1)\hat{j}$



Position Vector

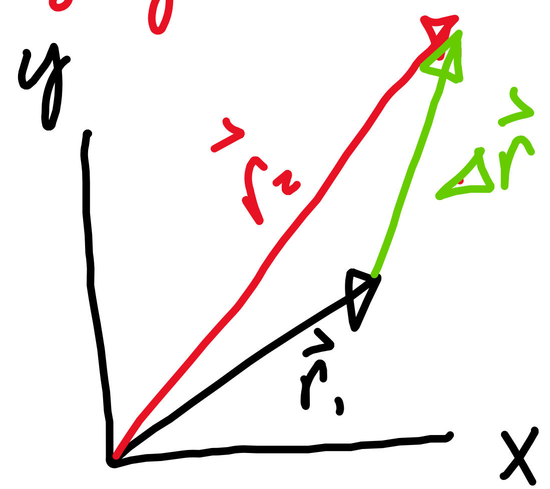
Let $\vec{r} \equiv$ position vector &

$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$. Let

$\vec{r}_1 = x_1\hat{i} + y_1\hat{j}$ & $\vec{r}_2 = x_2\hat{i} + y_2\hat{j}$

& $\Delta\vec{r} = \vec{r}_2 - \vec{r}_1$

$\Rightarrow \Delta\vec{r} = (x_2 - x_1)\hat{i} + (y_2 - y_1)\hat{j}$



Position Vector

Let $\vec{r} \equiv$ position vector &

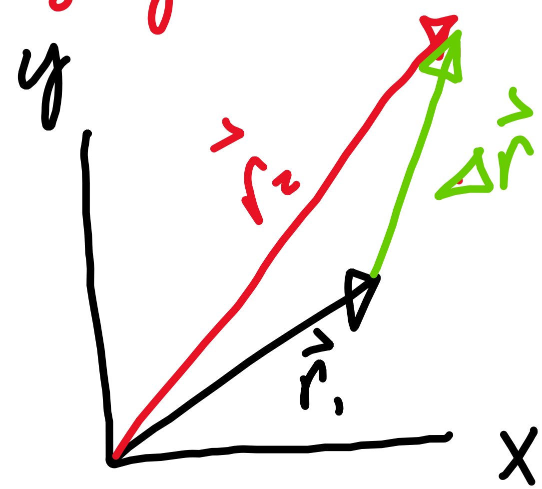
$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$. Let

$\vec{r}_1 = x_1\hat{i} + y_1\hat{j}$ & $\vec{r}_2 = x_2\hat{i} + y_2\hat{j}$

& $\Delta\vec{r} = \vec{r}_2 - \vec{r}_1$

$\Rightarrow \Delta\vec{r} = (x_2 - x_1)\hat{i} + (y_2 - y_1)\hat{j}$

rearrange to obtain



Position Vector

Let $\vec{r} \equiv$ position vector &

$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$. Let

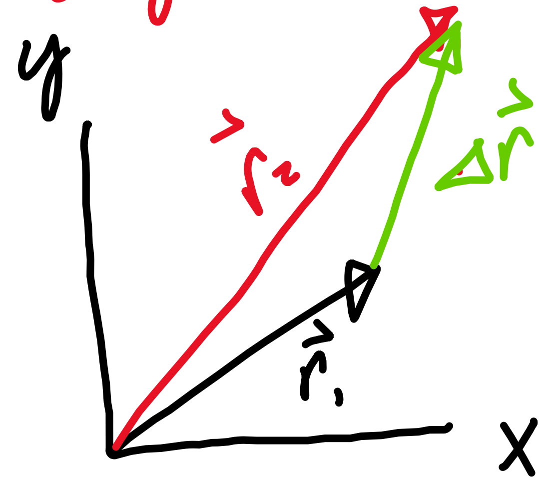
$\vec{r}_1 = x_1\hat{i} + y_1\hat{j}$ & $\vec{r}_2 = x_2\hat{i} + y_2\hat{j}$

& $\Delta\vec{r} = \vec{r}_2 - \vec{r}_1$

$\Rightarrow \Delta\vec{r} = (x_2 - x_1)\hat{i} + (y_2 - y_1)\hat{j}$

rearrange to obtain

$\vec{r}_1 + \Delta\vec{r} = \vec{r}_2$



Position Vector

Let $\vec{r} \equiv$ position vector $\hat{}$ &

$\vec{r} = x\hat{\imath} + y\hat{\jmath} + z\hat{k}$. Let

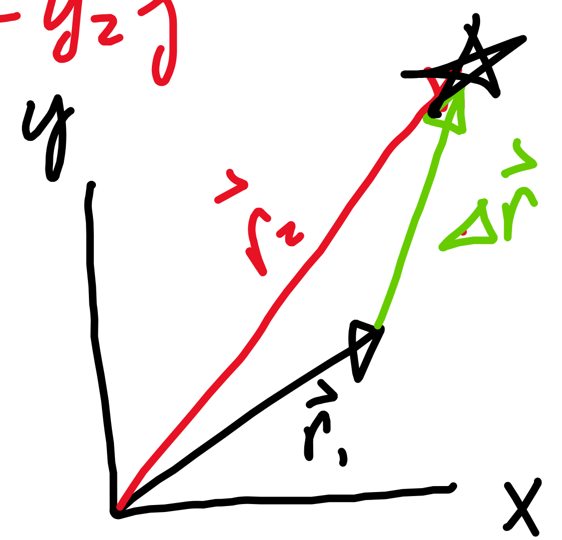
$\vec{r}_1 = x_1\hat{\imath} + y_1\hat{\jmath}$ & $\vec{r}_2 = x_2\hat{\imath} + y_2\hat{\jmath}$

& $\Delta\vec{r} = \vec{r}_2 - \vec{r}_1$

$\Rightarrow \Delta\vec{r} = (x_2 - x_1)\hat{\imath} + (y_2 - y_1)\hat{\jmath}$

rearrange to obtain

$\underbrace{\vec{r}_1 + \Delta\vec{r}}_{\text{path to point } \star} = \vec{r}_2$



Position Vector

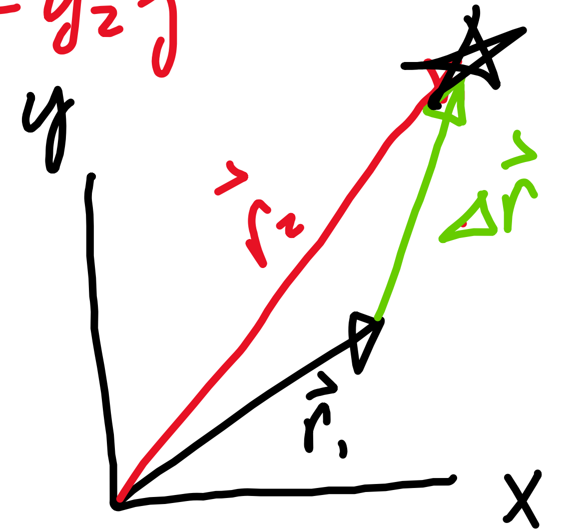
Let $\vec{r} \equiv$ position vector &

$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$. Let

$\vec{r}_1 = x_1\hat{i} + y_1\hat{j}$ & $\vec{r}_2 = x_2\hat{i} + y_2\hat{j}$

& $\Delta\vec{r} = \vec{r}_2 - \vec{r}_1$

$\Rightarrow \Delta\vec{r} = (x_2 - x_1)\hat{i} + (y_2 - y_1)\hat{j}$



rearrange to obtain

$$\vec{r}_1 + \Delta\vec{r} = \underbrace{\vec{r}_2}$$

Another path to ☆

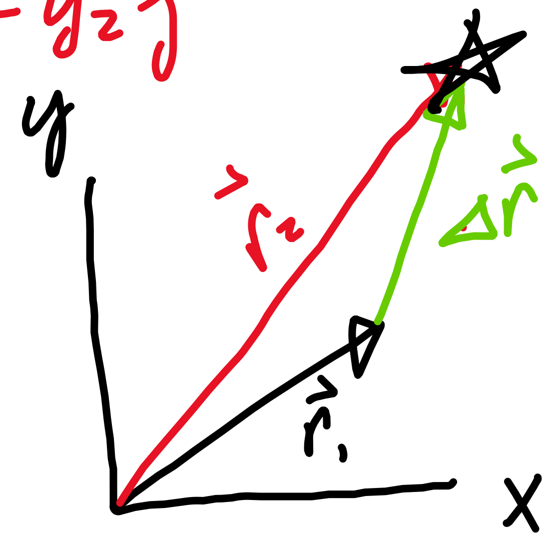
Position Vector

Let $\vec{r} \equiv$ position vector &

$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$. Let

$\vec{r}_1 = x_1\hat{i} + y_1\hat{j}$ & $\vec{r}_2 = x_2\hat{i} + y_2\hat{j}$

& $\Delta\vec{r} = \vec{r}_2 - \vec{r}_1$



Velocity vector

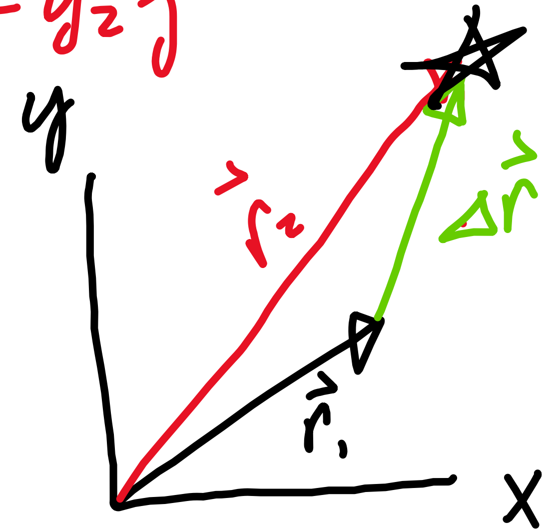
Position Vector

Let $\vec{r} \equiv$ position vector &

$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$. Let

$\vec{r}_1 = x_1\hat{i} + y_1\hat{j}$ & $\vec{r}_2 = x_2\hat{i} + y_2\hat{j}$

& $\Delta\vec{r} = \vec{r}_2 - \vec{r}_1$



Velocity vector

$$\vec{V}_{AVE} = \frac{\Delta\vec{r}}{\Delta t}$$

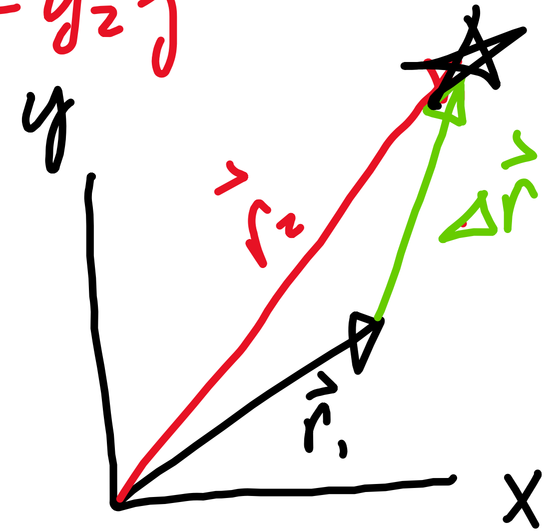
Position vector

Let $\vec{r} \equiv$ position vector &

$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$. Let

$\vec{r}_1 = x_1\hat{i} + y_1\hat{j}$ & $\vec{r}_2 = x_2\hat{i} + y_2\hat{j}$

& $\Delta\vec{r} = \vec{r}_2 - \vec{r}_1$



Velocity vector

$\vec{V}_{AVE} = \frac{\Delta\vec{r}}{\Delta t}$ ← scalar

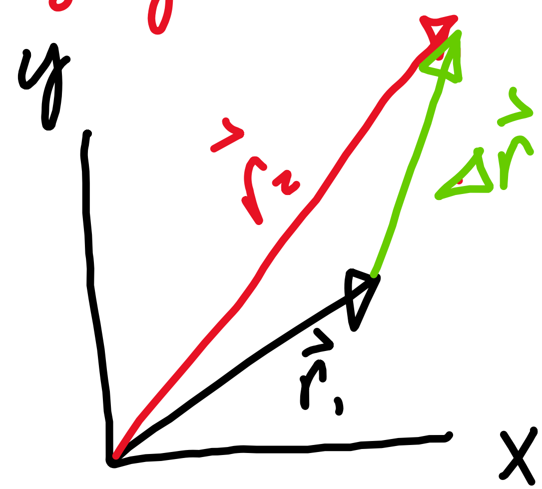
Position Vector

Let $\vec{r} \equiv$ position vector &

$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$. Let

$\vec{r}_1 = x_1\hat{i} + y_1\hat{j}$ & $\vec{r}_2 = x_2\hat{i} + y_2\hat{j}$

& $\Delta\vec{r} = \vec{r}_2 - \vec{r}_1$

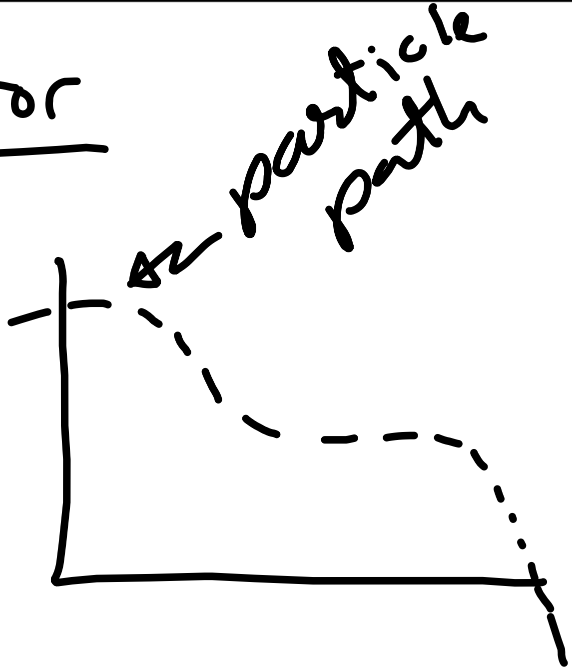


Velocity vector

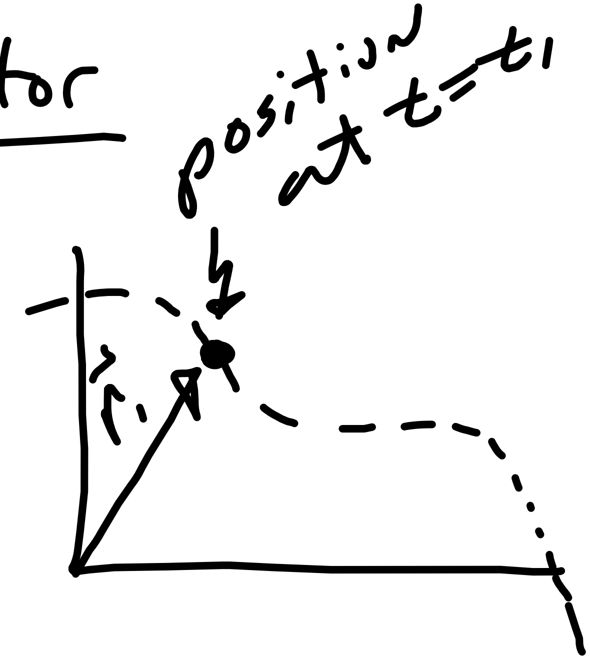
$$\vec{v}_{AVE} = \frac{\Delta\vec{r}}{\Delta t}$$

Note: $\vec{v}_{AVE}$ & $\Delta\vec{r}$ are in the same direction

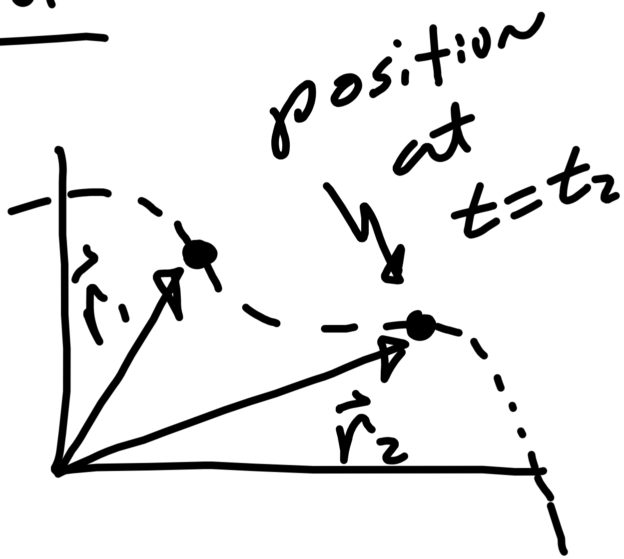
Velocity vector



Velocity vector



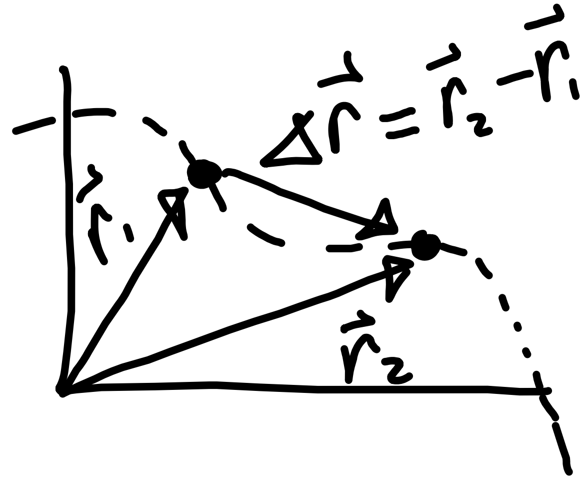
Velocity vector



Velocity vector

$\vec{v}_{AVE}$ is in same direction as $\Delta\vec{r}$ since

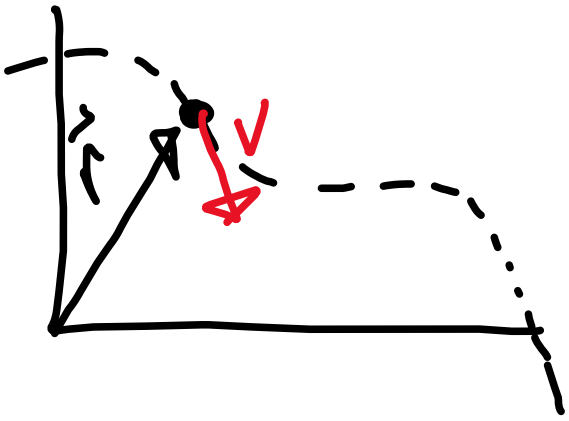
$$\vec{v}_{AVE} = \frac{\Delta\vec{r}}{\Delta t}$$



Velocity vector

Instantaneous velocity vector

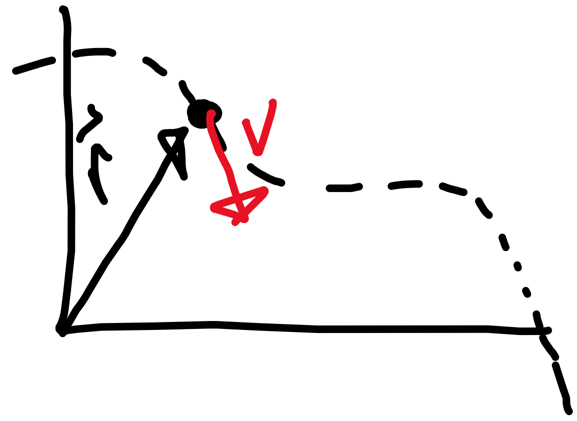
Is tangential to path



Velocity vector

Instantaneous velocity vector is defined by

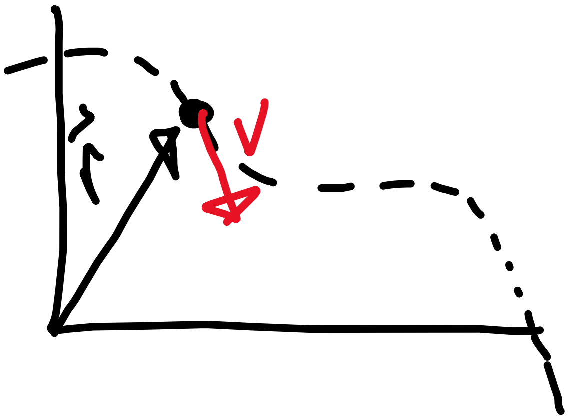
$$\vec{V} = \lim_{\Delta t \to 0} \frac{\Delta \vec{r}}{\Delta t} = \frac{d\vec{r}}{dt}$$



Velocity vector

Instantaneous velocity vector is defined by

$$\vec{V} = \lim_{\Delta t \to 0} \frac{\Delta \vec{r}}{\Delta t} = \frac{d\vec{r}}{dt}$$

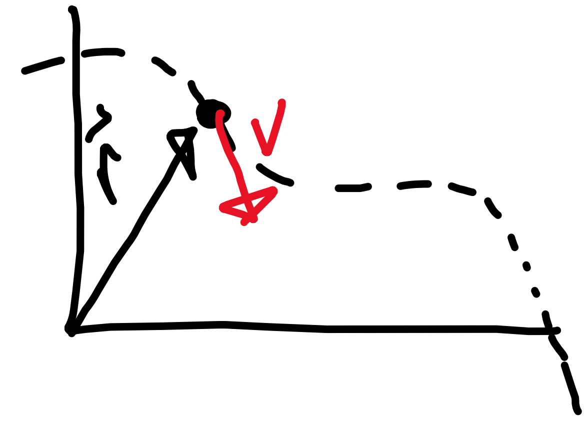


$$\Rightarrow \quad \vec{V} = \hat{i}\frac{dx}{dt} + \hat{j}\frac{dy}{dt} + \hat{k}\frac{dz}{dt}$$

Velocity vector

Instantaneous velocity vector is defined by

$$\vec{V} = \lim_{\Delta t \to 0} \frac{\Delta \vec{r}}{\Delta t} = \frac{d\vec{r}}{dt}$$



$$\Rightarrow \quad \vec{V} = \hat{i}\frac{dx}{dt} + \hat{j}\frac{dy}{dt} + \hat{k}\frac{dz}{dt}$$

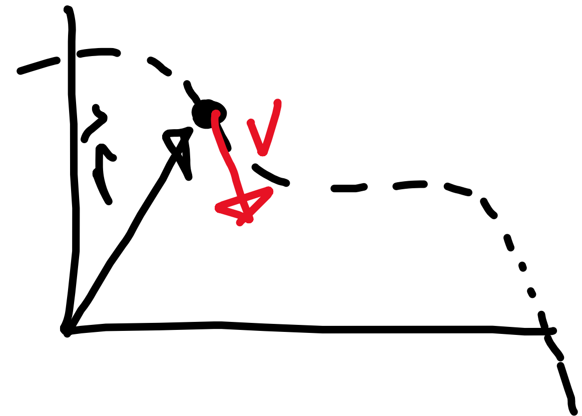
$$= \hat{i}V_x + \hat{j}V_y + \hat{k}V_z$$

ASU

Velocity vector

Instantaneous velocity vector is defined by

$$\vec{V} = \lim_{\Delta t \to 0} \frac{\Delta \vec{r}}{\Delta t} = \frac{d\vec{r}}{dt}$$



$$\Rightarrow \quad \vec{V} = \hat{i}\frac{dx}{dt} + \hat{j}\frac{dy}{dt} + \hat{k}\frac{dz}{dt}$$

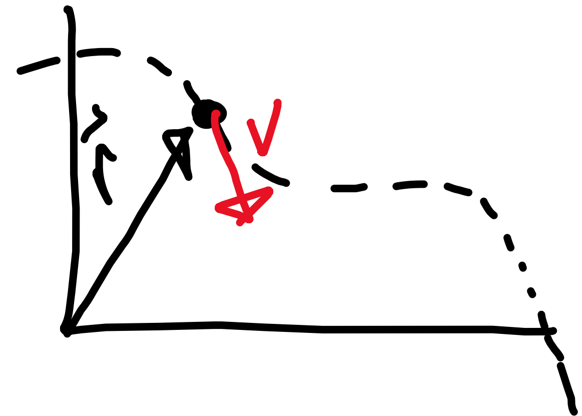
$$= \hat{i}\,V_x + \hat{j}\,V_y + \hat{k}\,V_z, \text{ where}$$

$$V_x = \frac{dx}{dt}$$

Velocity vector

Instantaneous velocity vector is defined by

$$\vec{V} = \lim_{\Delta t \to 0} \frac{\Delta \vec{r}}{\Delta t} = \frac{d\vec{r}}{dt}$$



$$\Rightarrow \quad \vec{V} = \hat{i}\frac{dx}{dt} + \hat{j}\frac{dy}{dt} + \hat{k}\frac{dz}{dt}$$

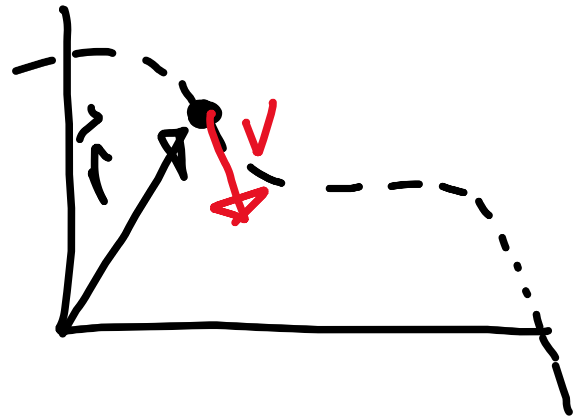
$$= \hat{i}V_x + \hat{j}V_y + \hat{k}V_z, \text{ where}$$

$$V_x = \frac{dx}{dt}, \quad V_y = \frac{dy}{dt}$$

Velocity vector

Instantaneous velocity vector is defined by

$$\vec{V} = \lim_{\Delta t \to 0} \frac{\Delta \vec{r}}{\Delta t} = \frac{d\vec{r}}{dt}$$



$$\Rightarrow \quad \vec{V} = \hat{i}\frac{dx}{dt} + \hat{j}\frac{dy}{dt} + \hat{k}\frac{dz}{dt}$$

$$= \hat{i}V_x + \hat{j}V_y + \hat{k}V_z \text{, where}$$

$$V_x = \frac{dx}{dt}, \quad V_y = \frac{dy}{dt} \;\&\; V_z = \frac{dz}{dt}$$

Velocity vector

Magnitude v

Velocity vector

Magnitude $v = |\vec{v}|$

Velocity vector

Magnitude $v = |\vec{v}| = \sqrt{\vec{v} \cdot \vec{v}}$

Velocity vector

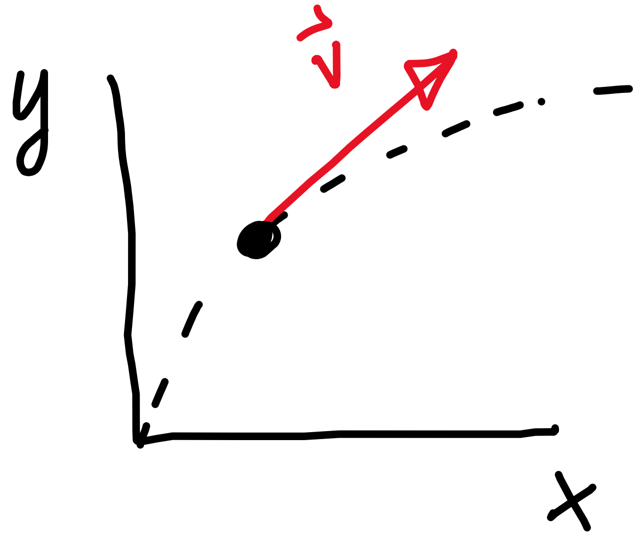
Magnitude $V = |\vec{V}| = \sqrt{\vec{V} \cdot \vec{V}} = \sqrt{V_x^2 + V_y^2 + V_z^2}$

Velocity vector

Magnitude $v = |\vec{v}| = \sqrt{\vec{v} \cdot \vec{v}} = \sqrt{v_x^2 + v_y^2 + v_z^2}$

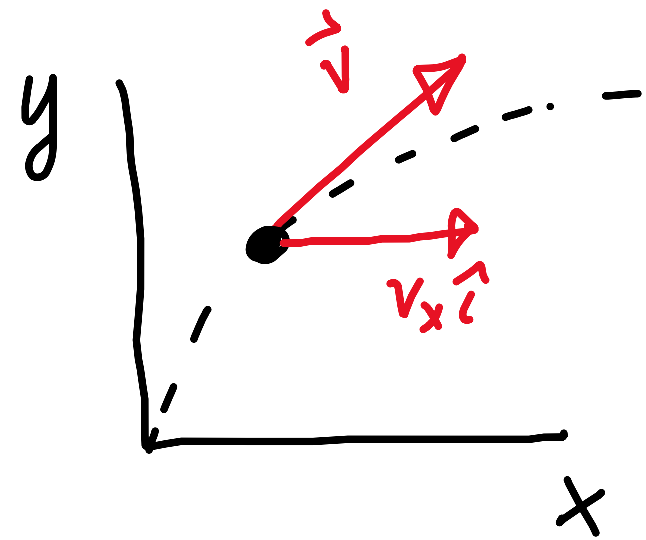
Velocity vector

Magnitude $v = |\vec{v}| = \sqrt{\vec{v} \cdot \vec{v}} = \sqrt{v_x^2 + v_y^2 + v_z^2}$



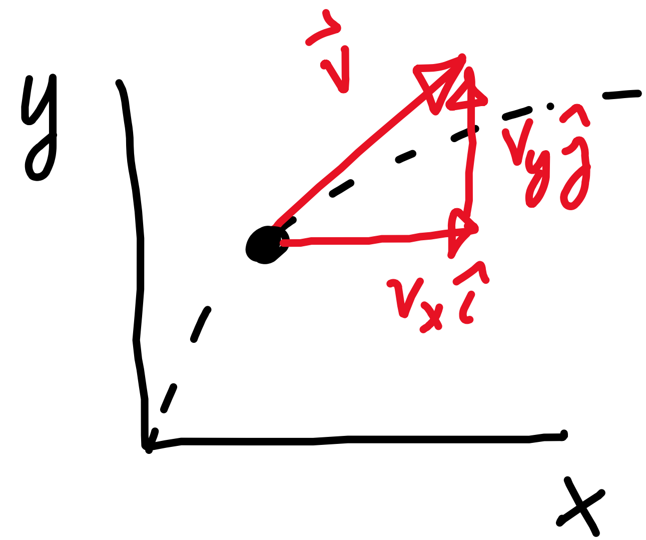
Velocity vector

Magnitude $v = |\vec{v}| = \sqrt{\vec{v}\cdot\vec{v}} = \sqrt{v_x^2 + v_y^2 + v_z^2}$



Velocity vector

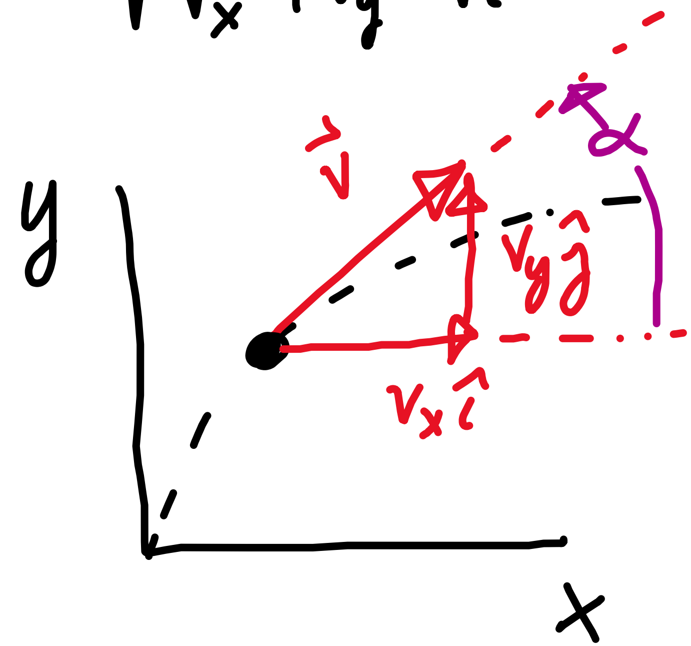
Magnitude $v = |\vec{v}| = \sqrt{\vec{v}\cdot\vec{v}} = \sqrt{v_x^2 + v_y^2 + v_z^2}$



Velocity vector

Magnitude $v = |\vec{v}| = \sqrt{\vec{v}\cdot\vec{v}} = \sqrt{v_x^2 + v_y^2 + v_z^2}$

$$\tan(\alpha) = \frac{v_y}{v_x}$$



A robotic vehicle, or rover, is exploring the surface of Mars. The stationary Mars lander is the origin of coordinates, and the surrounding Martian surface lies in the xy-plane. The rover, which we represent as a point, has x- and y-coordinates that vary with time:

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$\vec{V}_0 = \emptyset$, $\vec{r}_0 = \emptyset$, $x = 2m - \frac{1}{4}\frac{m}{s^2}t^2$ &

$y = (1 m/s)t + \left(\frac{1}{40}\right)\frac{m}{s^3}t^3$, find $\vec{V}(t)$:

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$$\vec{v} = \hat{i}\left[-\frac{m}{25^2}t\right] + \hat{j}\left[1\frac{m}{s} + \left(\frac{3}{40}\right)\frac{m}{s^3}t^2\right],$$

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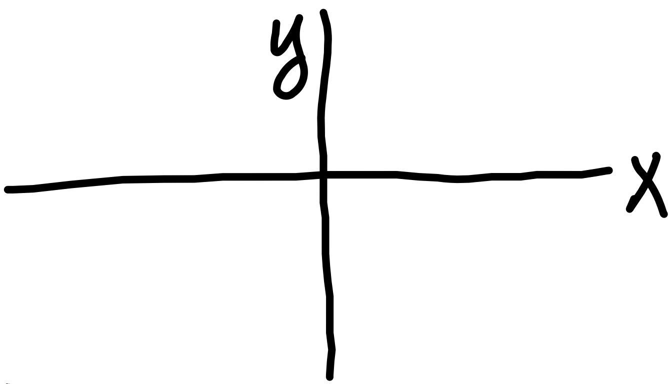

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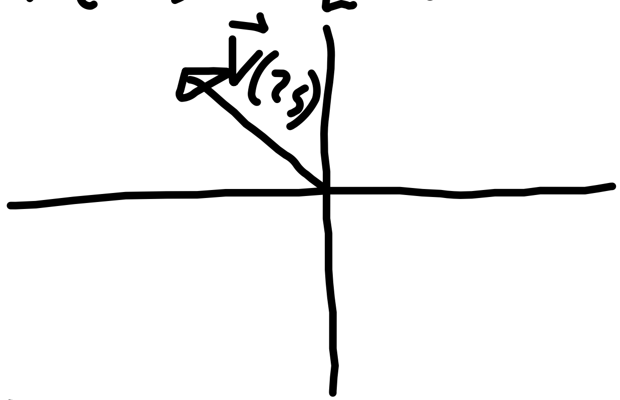

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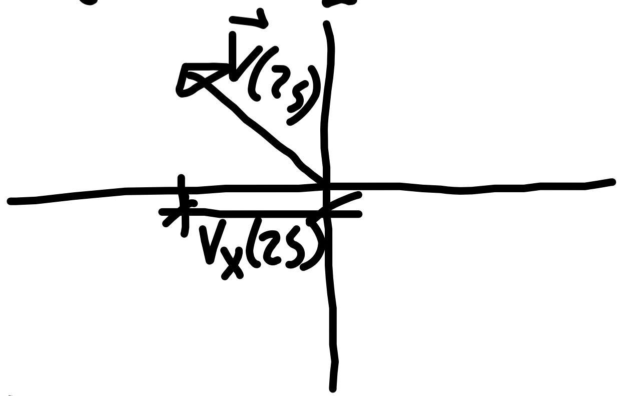

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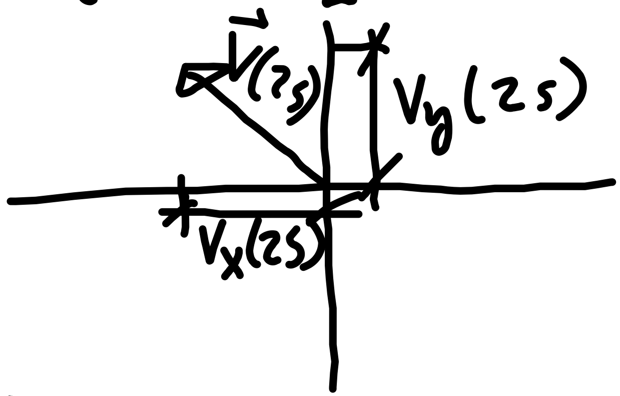

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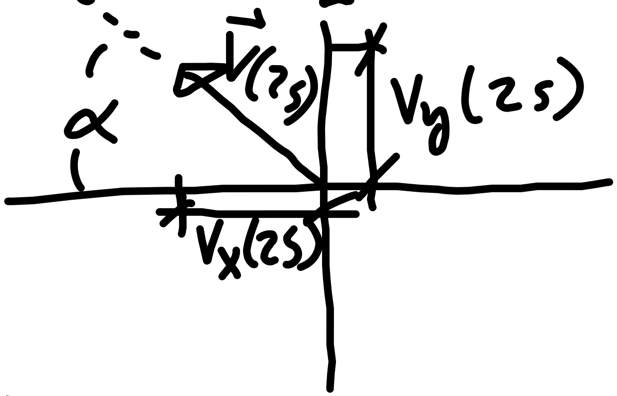
$$\vec{v}(2s) = \hat{i}\,[-1]\frac{m}{s} + \hat{j}\left[1 + \frac{3}{10}\right]\frac{m}{s} = \{-\hat{i} + 1.3\hat{j}\}\frac{m}{s}$$

So $V_x(2s) = -1\frac{m}{s}$ & $V_y(2s) = 1.3\frac{m}{s}$ $\Longrightarrow$

$$V(2s) = \left[V_x(2s)^2 + V_y(2s)^2\right]^{1/2} = \left[1 + 1.3^2\right]^{1/2}\frac{m}{s} = 1.6\frac{m}{s}$$



(a) Find the rover's coordinates and distance from the lander at $t = 2.0$ s. (b) Find the rover's displacement and average velocity vectors for the interval $t = 0.0$ s to $t = 2.0$ s. (c) Find a general expression for the rover's instantaneous velocity vector $\vec{v}$. Express $\vec{v}$ at $t = 2.0$ s in component form and in terms of magnitude and direction.

$$\vec{v} = \hat{i}\left[-\frac{m}{2s^2}t\right] + \hat{j}\left[1\frac{m}{s} + \left(\frac{3}{40}\right)\frac{m}{s^3}t^2\right],$$

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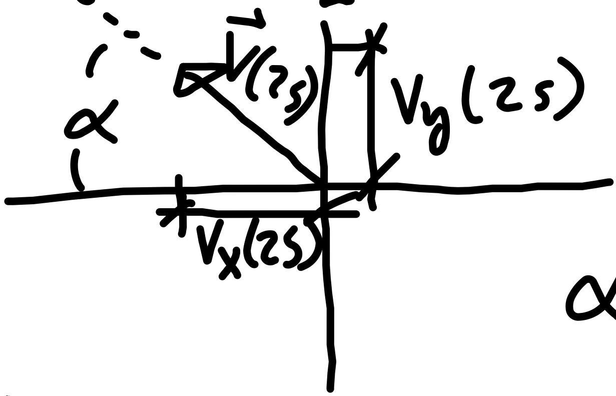
$$V(2s) = \left[V_x(2s)^2 + V_y(2s)^2\right]^{1/2} = \left[1 + 1.3^2\right]^{1/2}\frac{m}{s} = 1.6\frac{m}{s}$$

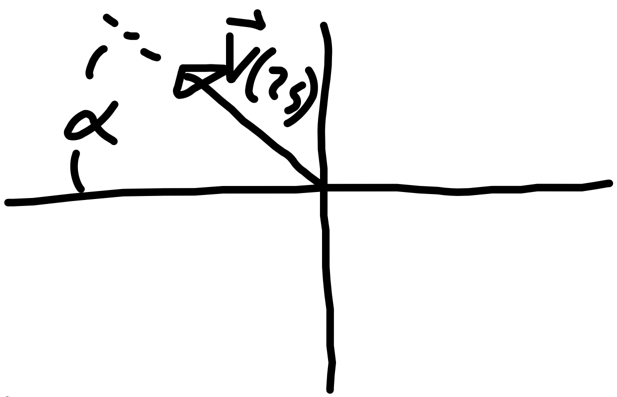


$$\tan(\alpha) = \frac{|V_y|}{|V_x|} \Rightarrow$$

$$\alpha(2s) = \tan^{-1}\left[\frac{1.3}{1}\right] = 52^\circ$$

(a) Find the rover's coordinates and distance from the lander at $t = 2.0$ s. (b) Find the rover's displacement and average velocity vectors for the interval $t = 0.0$ s to $t = 2.0$ s. (c) Find a general expression for the rover's instantaneous velocity vector $\vec{v}$. Express $\vec{v}$ at $t = 2.0$ s in component form and in terms of magnitude and direction.

$\alpha = 52^\circ$



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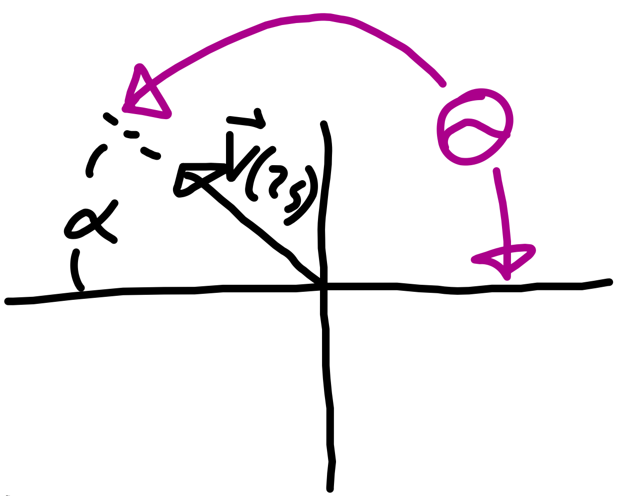

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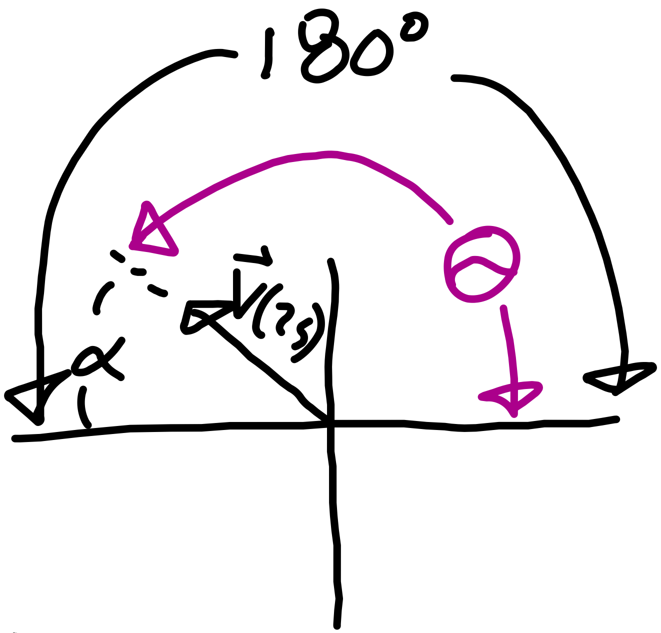
$\alpha = 52^\circ$ $\theta + \alpha = 180^\circ$



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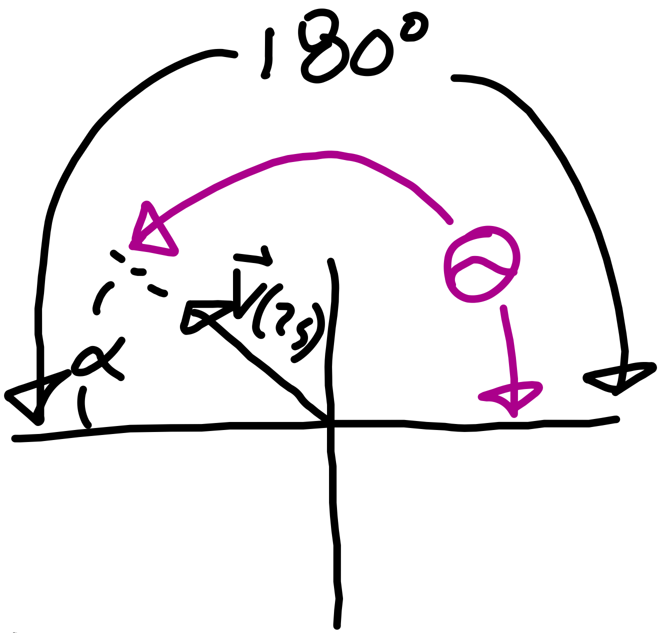
$\alpha = 52^\circ$ $\quad$ & $\quad \theta + \alpha = 180^\circ$

so $\quad \theta = 180^\circ - \alpha$



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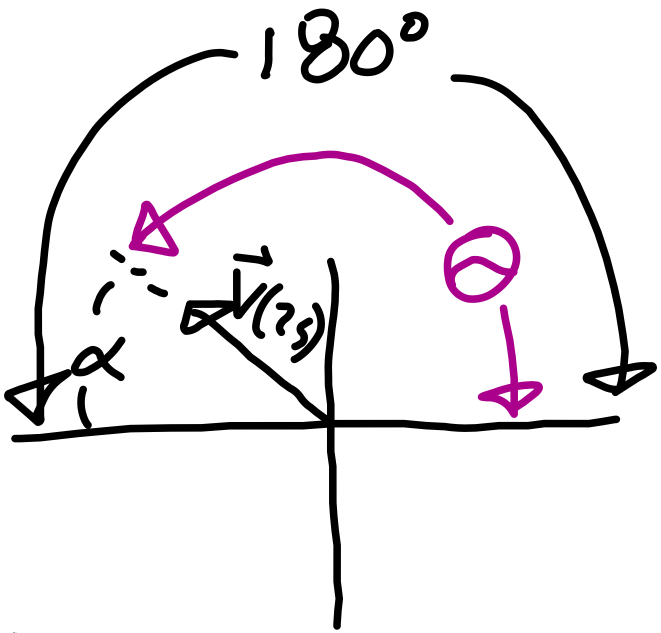
$\alpha = 52^\circ$

$\theta + \alpha = 180^\circ$

so $\theta = 180^\circ - \alpha$

$\Rightarrow \theta = 180^\circ - 52^\circ$



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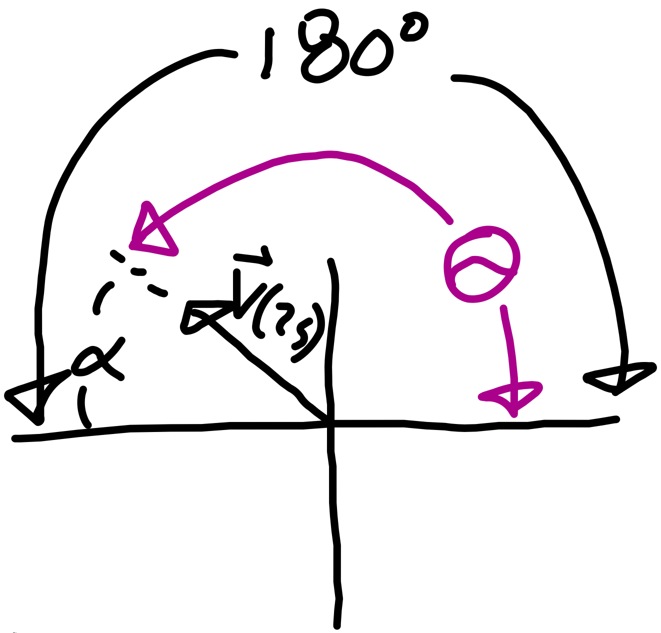
$\alpha = 52^\circ$

$\therefore \theta + \alpha = 180^\circ$

so $\theta = 180^\circ - \alpha$

$\Rightarrow \theta = 180^\circ - 52^\circ$

$\Rightarrow \boxed{\theta = 128^\circ}$



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Acceleration vector

Acceleration Vector

$$\vec{a}_{AVE} = \frac{\Delta \vec{V}}{\Delta t}$$

Acceleration Vector

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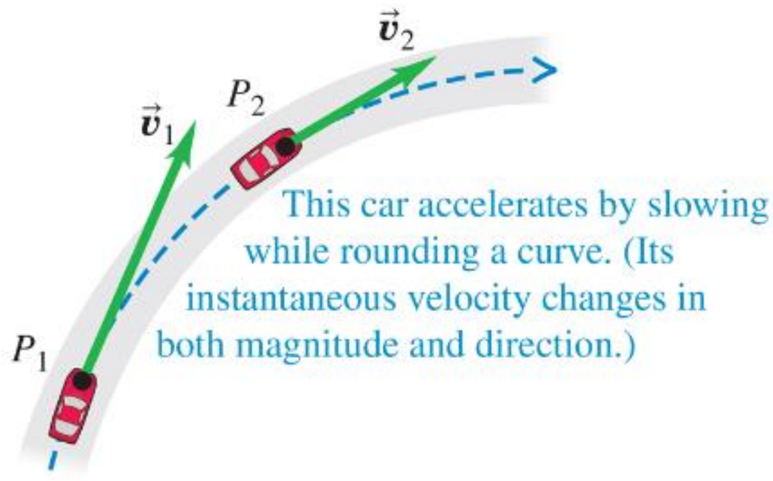
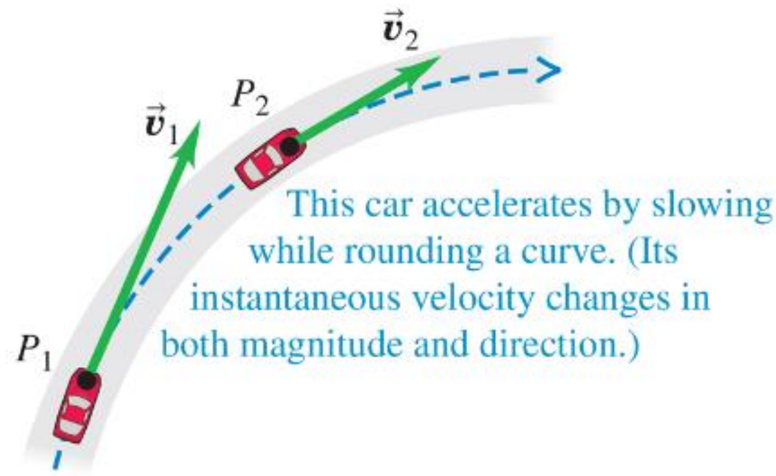
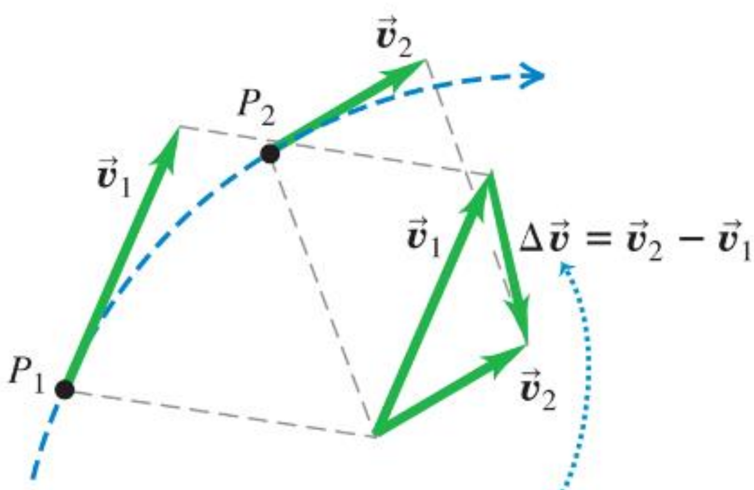


Acceleration Vector

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





To find the car's average acceleration between P_1 and P_2, we first find the change in velocity $\Delta\vec{v}$ by subtracting $\vec{v}_1$ from $\vec{v}_2$. (Notice that $\vec{v}_1 + \Delta\vec{v} = \vec{v}_2$.)

Acceleration Vector

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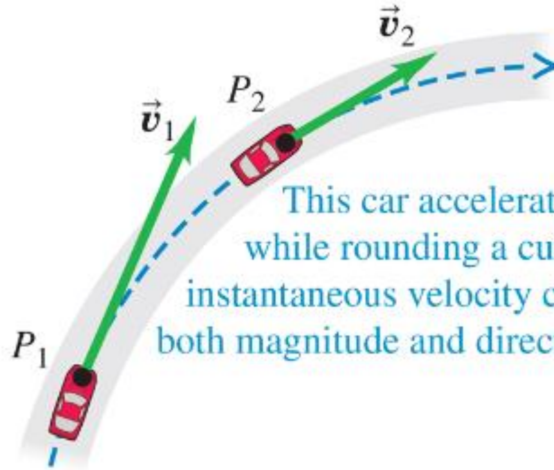
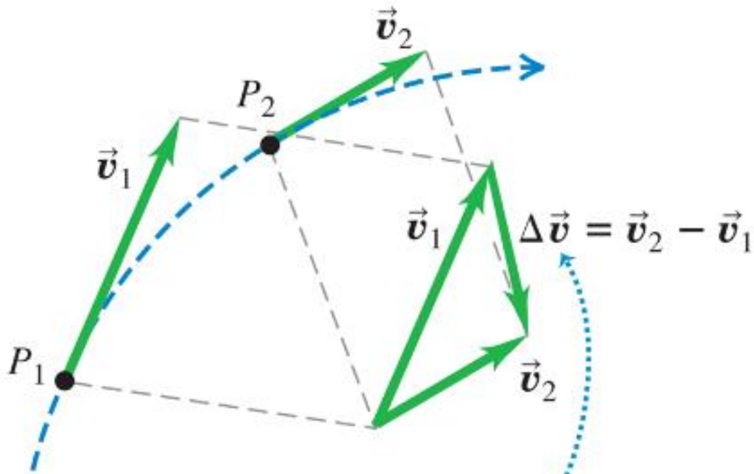


This car accelerates by slowing while rounding a curve. (Its instantaneous velocity changes in both magnitude and direction.)



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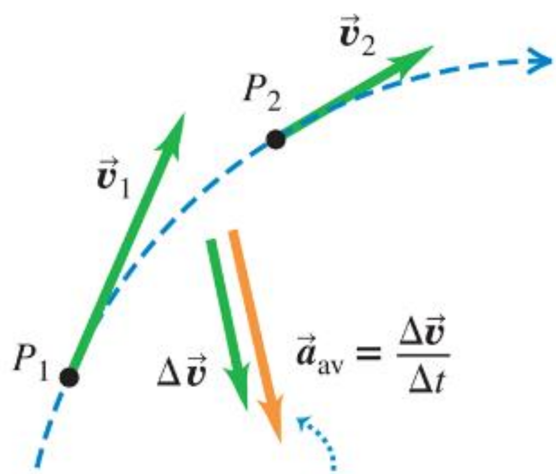

The average acceleration has the same direction as the change in velocity, $\Delta\vec{v}$.

Acceleration Vector

Instantaneous acceleration $\vec{a} = \lim_{\Delta t \to 0} \frac{\Delta \vec{v}}{\Delta t} = \frac{d\vec{v}}{dt}$

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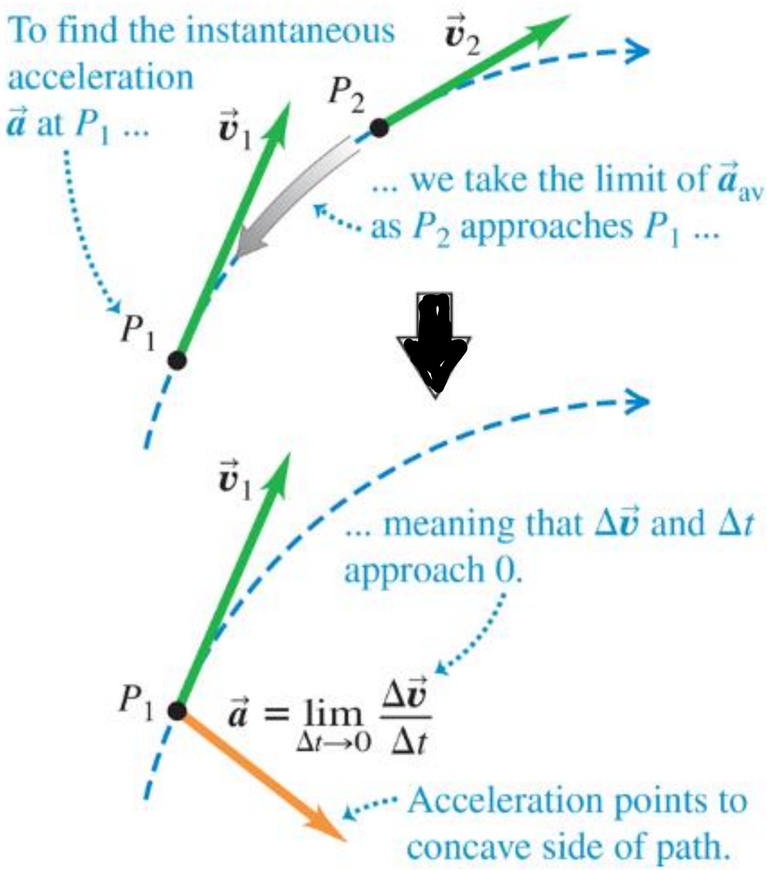
(a) Acceleration: curved trajectory



Acceleration Vector

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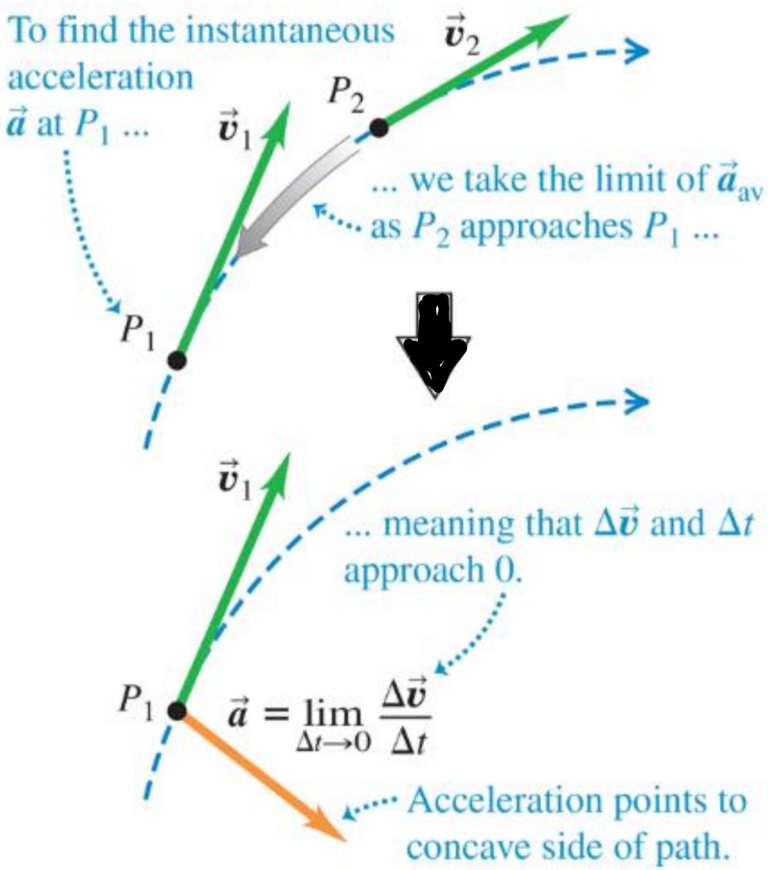
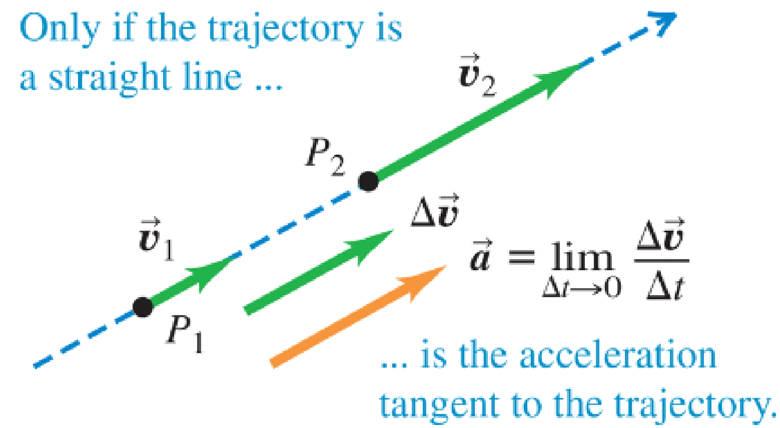
(a) Acceleration: curved trajectory





Acceleration Vector

$$\vec{a} = a_x\hat{i} + a_y\hat{j} + a_z\hat{k}$$

Acceleration Vector

$\vec{a} = a_x\hat{i} + a_y\hat{j} + a_z\hat{k}$, where

$a_x = \frac{\partial V_x}{\partial t}$

Acceleration Vector

$$\vec{a} = a_x\hat{i} + a_y\hat{j} + a_z\hat{k}$$, where

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ASU

Acceleration Vector

$\vec{a} = a_x\hat{i} + a_y\hat{j} + a_z\hat{k}$, where

$a_x = \frac{\partial v_x}{\partial t}$, $a_y = \frac{\partial v_y}{\partial t}$, $a_z = \frac{\partial v_z}{\partial t}$

ASU

Acceleration vector

$$\vec{a} = a_x\hat{i} + a_y\hat{j} + a_z\hat{k}$$, where

$$a_x = \frac{\partial v_x}{\partial t}, \quad a_y = \frac{\partial v_y}{\partial t}, \quad a_z = \frac{\partial v_z}{\partial t}$$ & since

$$v_x = \frac{\partial x}{\partial t}$$

ASU

Acceleration Vector

$\vec{a} = a_x \hat{i} + a_y \hat{j} + a_z \hat{k}$, where

$a_x = \frac{\partial V_x}{\partial t}$, $a_y = \frac{\partial V_y}{\partial t}$, $a_z = \frac{\partial V_z}{\partial t}$ $ since

$V_x = \frac{\partial x}{\partial t}$ then $a_x = \frac{\partial}{\partial t}\left[\frac{\partial x}{\partial t}\right]$

ASU

Acceleration Vector

$\vec{a} = a_x\hat{i} + a_y\hat{j} + a_z\hat{k}$, where

$a_x = \frac{\partial v_x}{\partial t}$, $a_y = \frac{\partial v_y}{\partial t}$, $a_z = \frac{\partial v_z}{\partial t}$ & since

$v_x = \frac{\partial x}{\partial t}$ then $a_x = \frac{\partial}{\partial t}\left[\frac{\partial x}{\partial t}\right] = \frac{\partial^2 x}{\partial t^2}$

Acceleration Vector

$\vec{a} = a_x\hat{i} + a_y\hat{j} + a_z\hat{k}$, where

$a_x = \frac{dv_x}{dt}$, $a_y = \frac{dv_y}{dt}$, $a_z = \frac{dv_z}{dt}$ & since

$v_x = \frac{dx}{dt}$ then $a_x = \frac{d}{dt}\left[\frac{dx}{dt}\right] = \frac{d^2x}{dt^2}$

so $a_x = \frac{d^2x}{dt^2}$

Acceleration Vector

$\vec{a} = a_x\hat{i} + a_y\hat{j} + a_z\hat{k}$, where

$a_x = \frac{dv_x}{dt}$, $a_y = \frac{dv_y}{dt}$, $a_z = \frac{dv_z}{dt}$ & since

$v_x = \frac{dx}{dt}$ then $a_x = \frac{d}{dt}\left[\frac{dx}{dt}\right] = \frac{d^2x}{dt^2}$

So $a_x = \frac{d^2x}{dt^2}$, $a_y = \frac{d^2y}{dt^2}$

ASU

Acceleration vector

$\vec{a} = a_x\hat{i} + a_y\hat{j} + a_z\hat{k}$, where

$a_x = \frac{dv_x}{dt}$, $a_y = \frac{dv_y}{dt}$, $a_z = \frac{dv_z}{dt}$ & since

$v_x = \frac{dx}{dt}$ then $a_x = \frac{d}{dt}\left[\frac{dx}{dt}\right] = \frac{d^2x}{dt^2}$

so $a_x = \frac{d^2x}{dt^2}$, $a_y = \frac{d^2y}{dt^2}$ & $a_z = \frac{d^2z}{dt^2}$

ASU

Example: Given $v_x = \left(-\frac{1}{2}\right)\frac{m}{s^2}t$ &

$v_y = 1\frac{m}{s} + \left(\frac{3}{40}\right)\frac{m}{s^3}t^2$

__Example:__ Given $v_x = \left(-\frac{1}{2}\right)\frac{m}{s^2}t$ &

$v_y = 1\frac{m}{s} + \left(\frac{3}{40}\right)\frac{m}{s^3}t^2$

__Find $\vec{a}_{AVE}$ between $t_1 = 0$ & $t_2 = 2\,s$:__

Example: Given $v_x = \left(-\frac{1}{2}\right)\frac{m}{s^2}t$ &

$v_y = 1\frac{m}{s} + \left(\frac{3}{40}\right)\frac{m}{s^3}t^2$

Find $\vec{a}_{AVE}$ between $t_1 = 0$ & $t_2 = 2s$:

$v_x(0) = 0$

Example: Given $V_x = \left(-\frac{1}{2}\right)\frac{m}{s^2}t$ \& $V_y = 1\frac{m}{s} + \left(\frac{3}{40}\right)\frac{m}{s^3}t^2$

Find $\vec{a}_{AVE}$ between $t_1 = 0$ \& $t_2 = 2s$:

$V_x(0) = \emptyset$, $V_y(0) = 1\frac{m}{s}$

Example: Given $V_x = \left(-\frac{1}{2}\right)\frac{m}{s^2}t$ &

$V_y = 1\frac{m}{s} + \left(\frac{3}{40}\right)\frac{m}{s^3}t^2$

Find $\vec{a}_{AVE}$ between $t_1 = 0$ & $t_2 = 2s$:

$V_x(0) = 0$, $V_y(0) = 1\frac{m}{s}$

$V_x(2s) = -1\frac{m}{s}$

Example: Given $V_x = \left(-\frac{1}{2}\right)\frac{m}{s^2}t$ &

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Find $\vec{a}_{AVE}$ between $t_1 = 0$ & $t_2 = 2s$:

$V_x(0) = 0$, $V_y(0) = 1\frac{m}{s}$

$V_x(2s) = -1\frac{m}{s}$, $V_y(2s) = 1\frac{m}{s} + \left(\frac{3}{40}\right)\frac{m}{s^3}(4s^2)$

Example: Given $v_x = \left(-\frac{1}{2}\right)\frac{m}{s^2}t$ & $v_y = 1\frac{m}{s} + \left(\frac{3}{40}\right)\frac{m}{s^3}t^2$

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$V_x(0) = 0$, $V_y(0) = 1\frac{m}{s}$

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So $\Delta\vec{V} = \vec{V}(2s) - \vec{V}(0)$

ASU

Example: Given $V_x = \left(-\frac{1}{2}\right)\frac{m}{s^2}t$ & $V_y = 1\frac{m}{s} + \left(\frac{3}{40}\right)\frac{m}{s^3}t^2$

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$V_x(0) = 0$, $V_y(0) = 1\frac{m}{s}$

$V_x(2s) = -1\frac{m}{s}$, $V_y(2s) = 1\frac{m}{s} + \left(\frac{3}{40}\right)\frac{m}{s^3}(4s^2) = 1.3\frac{m}{s}$

So $\Delta\vec{V} = \vec{V}(2s) - \vec{V}(0) = \left[-1\frac{m}{s} - 0\right]\hat{i}$

Example: Given $V_x = \left(-\frac{1}{2}\right)\frac{m}{s^2}t$ &

$V_y = 1\frac{m}{s} + \left(\frac{3}{40}\right)\frac{m}{s^3}t^2$

Find $\vec{a}_{AVE}$ between $t_1 = 0$ & $t_2 = 2s$:

$V_x(0) = 0$, $V_y(0) = 1\frac{m}{s}$

$V_x(2s) = -1\frac{m}{s}$, $V_y(2s) = 1\frac{m}{s} + \left(\frac{3}{40}\right)\frac{m}{s^3}(4s^2) = 1.3\frac{m}{s}$

So $\Delta\vec{V} = \vec{V}(2s) - \vec{V}(0) = \left[-1\frac{m}{s} - 0\right]\hat{i} + \left[1.3\frac{m}{s} - 1\frac{m}{s}\right]\hat{j}$

ASU

Example: Given $V_x = \left(-\frac{1}{2}\right)\frac{m}{s^2}t$ &

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Example: Given $V_x = \left(-\frac{1}{2}\right)\frac{m}{s^2}t$ &

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So $\Delta\vec{V} = \vec{V}(2s) - \vec{V}(0) = \left[-1\frac{m}{s} - 0\right]\hat{i} + \left[1.3\frac{m}{s} - 1\frac{m}{s}\right]\hat{j}$

$\Rightarrow \Delta\vec{V} = -1\frac{m}{s}\hat{i} + 0.3\frac{m}{s}\hat{j}$ & Since $\Delta t = 2s$

Example: Given $V_x = \left(-\frac{1}{2}\right)\frac{m}{s^2}t$ &

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Find $\vec{a}_{AVE}$ between $t_1 = 0$ & $t_2 = 2s$:

$V_x(0) = 0$, $V_y(0) = 1\frac{m}{s}$

$V_x(2s) = -1\frac{m}{s}$, $V_y(2s) = 1\frac{m}{s} + \left(\frac{3}{40}\right)\frac{m}{s^3}(4s^2) = 1.3\frac{m}{s}$

So $\Delta\vec{V} = \vec{V}(2s) - \vec{V}(0) = \left[-1\frac{m}{s} - 0\right]\hat{i} + \left[1.3\frac{m}{s} - 1\frac{m}{s}\right]\hat{j}$

$\Rightarrow \Delta\vec{V} = -1\frac{m}{s}\hat{i} + 0.3\frac{m}{s}\hat{j}$ & since $\Delta t = 2s$

$$\vec{a}_{AVE} = \frac{\Delta\vec{V}}{\Delta t} = \frac{-1\frac{m}{s}\hat{i} + 0.3\frac{m}{s}\hat{j}}{2s}$$

ASU

Example: Given $V_x = \left(-\frac{1}{2}\right)\frac{m}{s^2}t$ &

$V_y = 1\frac{m}{s} + \left(\frac{3}{40}\right)\frac{m}{s^3}t^2$

Find $\vec{a}_{AVE}$ between $t_1 = 0$ & $t_2 = 2s$:

$V_x(0) = 0$, $V_y(0) = 1\frac{m}{s}$

$V_x(2s) = -1\frac{m}{s}$, $V_y(2s) = 1\frac{m}{s} + \left(\frac{3}{40}\right)\frac{m}{s^3}(4s^2) = 1.3\frac{m}{s}$

So $\Delta\vec{V} = \vec{V}(2s) - \vec{V}(0) = \left[-1\frac{m}{s} - 0\right]\hat{i} + \left[1.3\frac{m}{s} - 1\frac{m}{s}\right]\hat{j}$

$\Rightarrow \Delta\vec{V} = -1\frac{m}{s}\hat{i} + 0.3\frac{m}{s}\hat{j}$ & since $\Delta t = 2s$

$$\vec{a}_{AVE} = \frac{\Delta\vec{V}}{\Delta t} = \frac{-1\frac{m}{s}\hat{i} + 0.3\frac{m}{s}\hat{j}}{2s} = -\frac{1}{2}\frac{m}{s^2}\hat{i} + 0.15\frac{m}{s^2}\hat{j}$$

Example: Given $v_x = \left(-\frac{1}{2}\right)\frac{m}{s^2}t$ &

$v_y = 1\frac{m}{s} + \left(\frac{3}{40}\right)\frac{m}{s^3}t^2$

Find $\vec{a}_{AVE}$ between $t_1 = 0$ & $t_2 = 2s$:

$v_x(0) = 0$, $v_y(0) = 1\frac{m}{s}$

$v_x(2s) = -1\frac{m}{s}$, $v_y(2s) = 1\frac{m}{s} + \left(\frac{3}{40}\right)\frac{m}{s^3}(4s^2) = 1.3\frac{m}{s}$

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ASU

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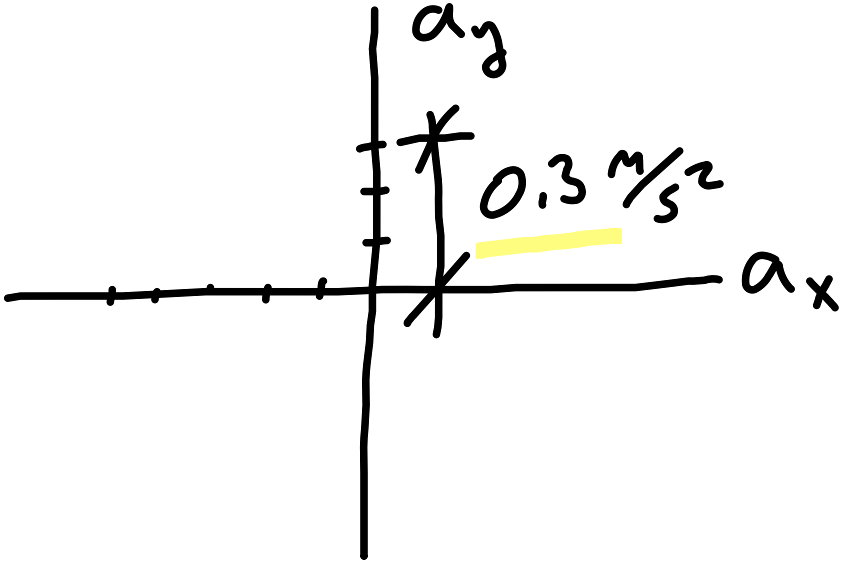
$$a = \sqrt{a_x^2 + a_y^2} = [0.25 + 0.09]^{1/2} m/s^2 = 58\, m/s^2$$



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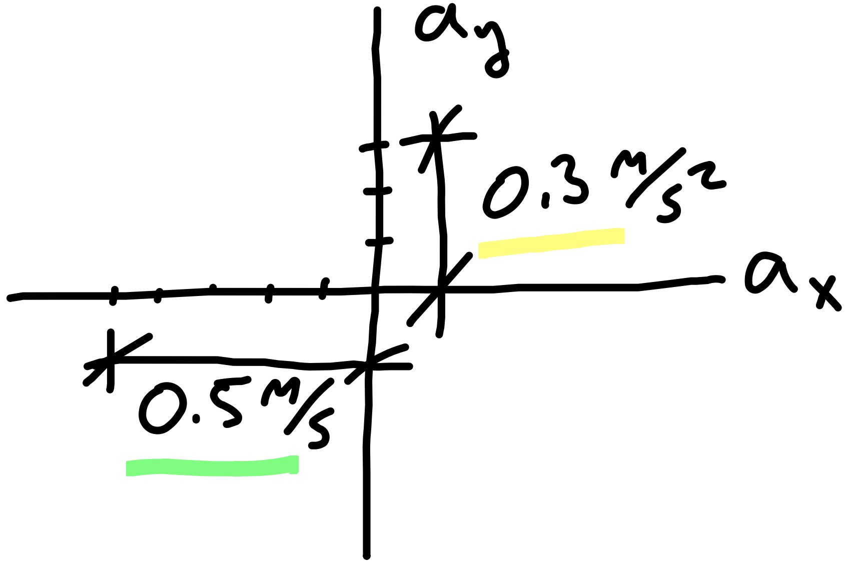

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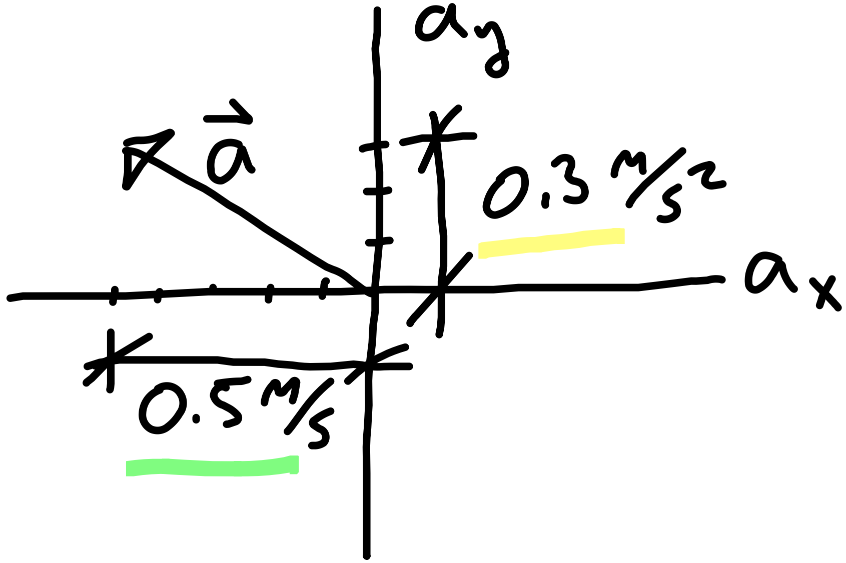

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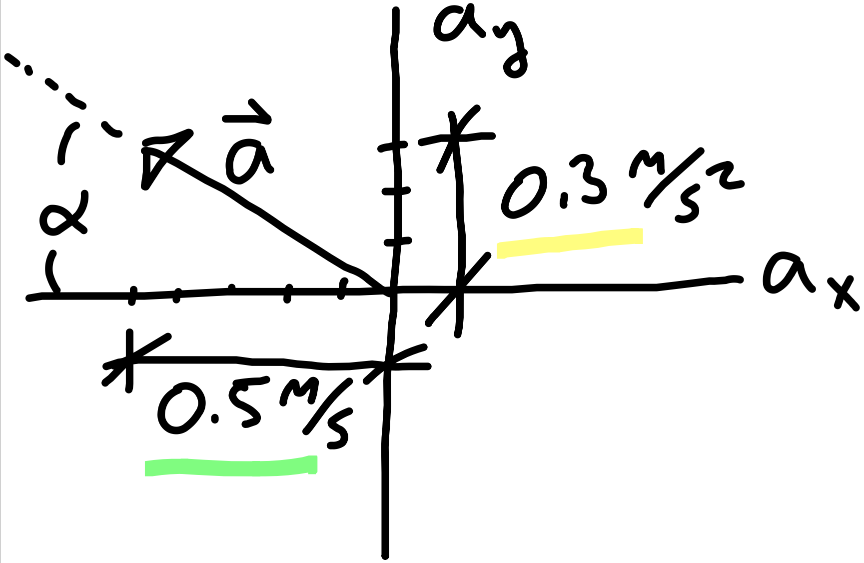

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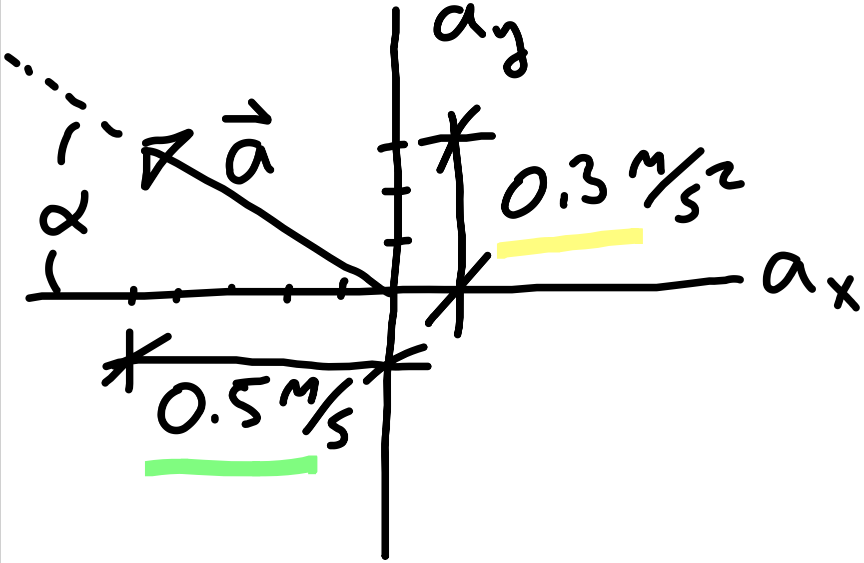

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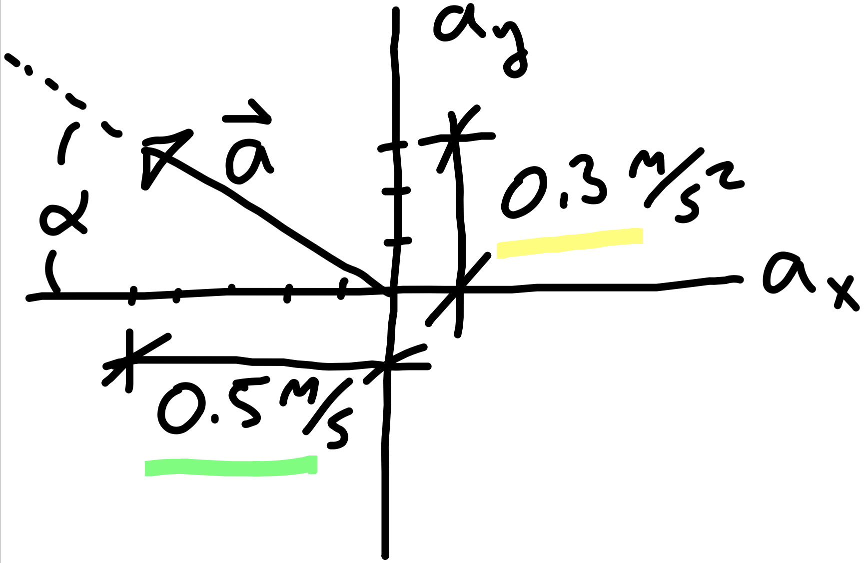

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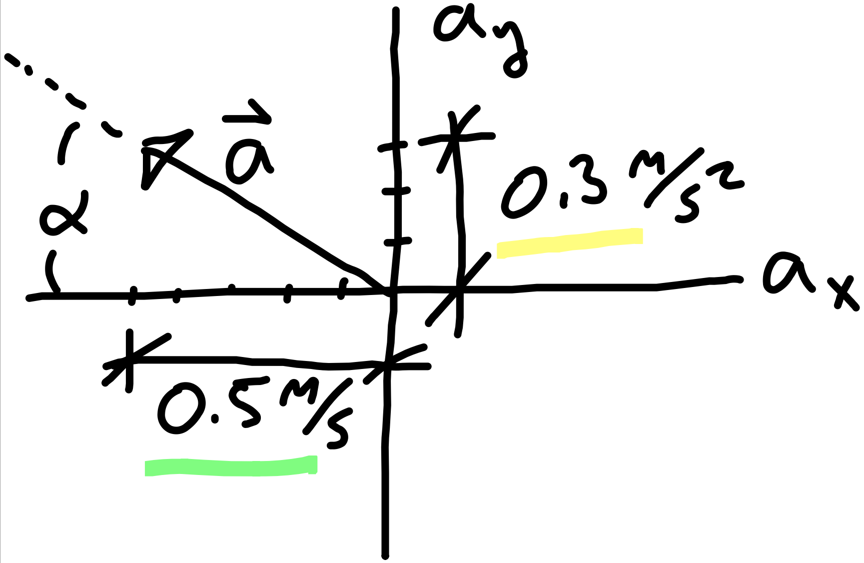

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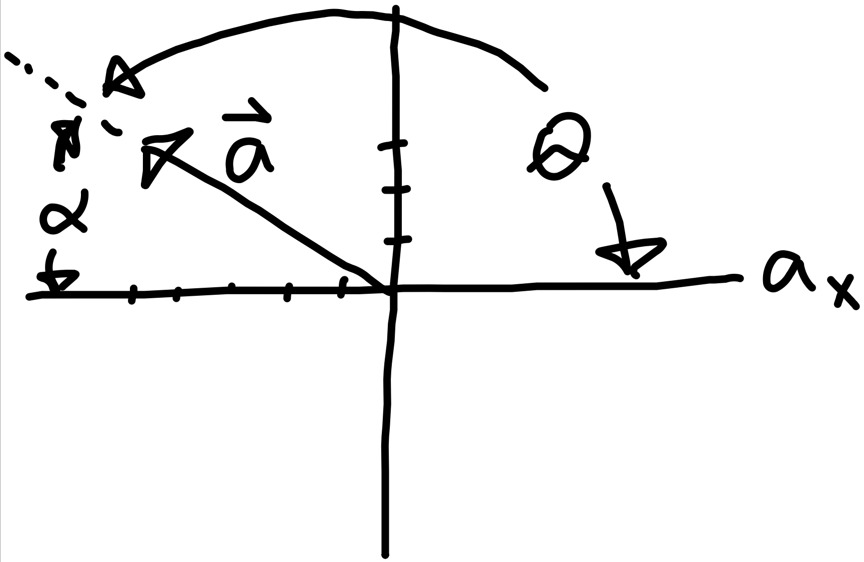

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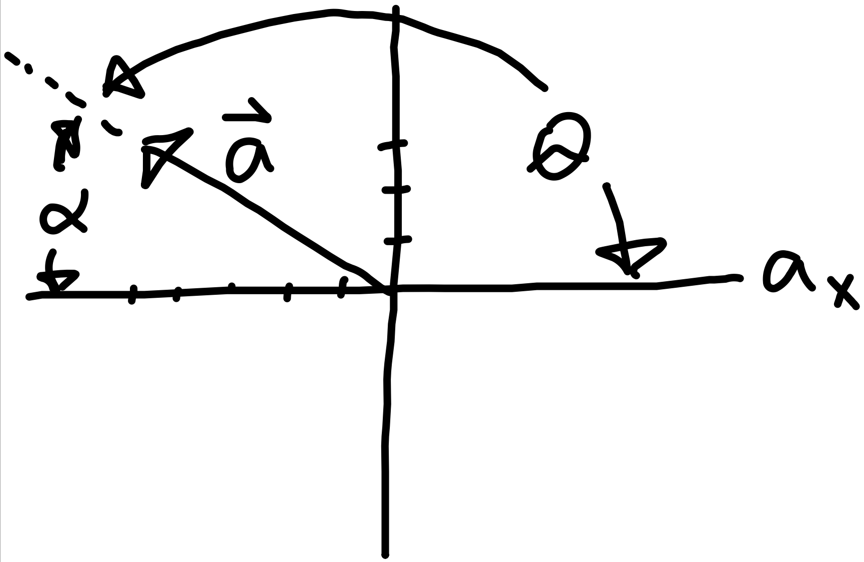

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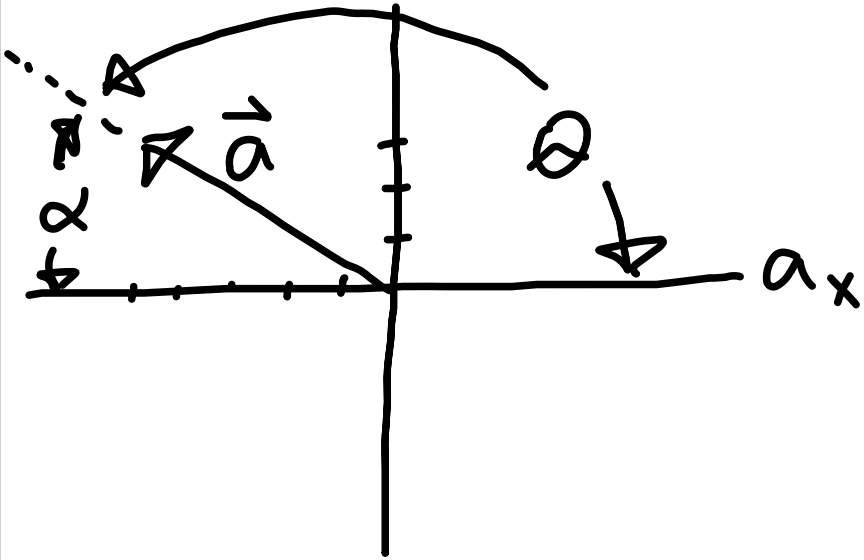
ASU



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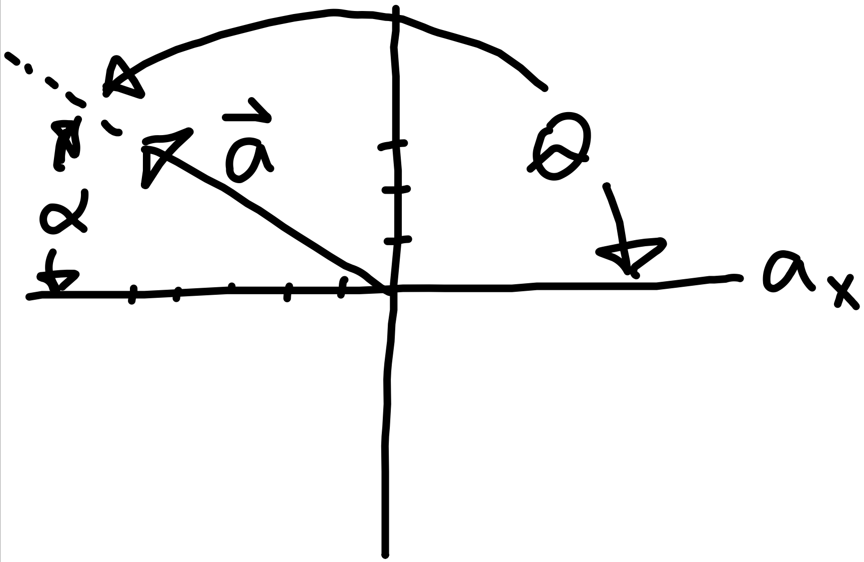

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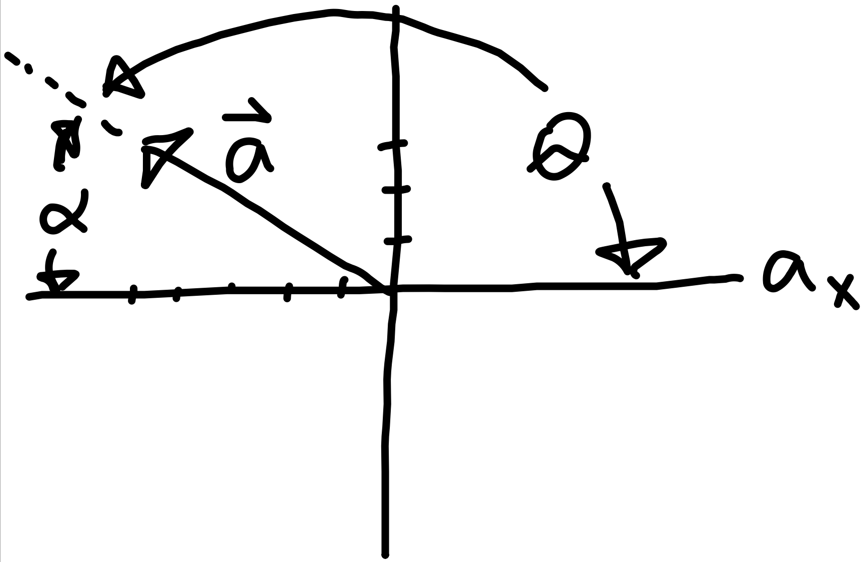

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