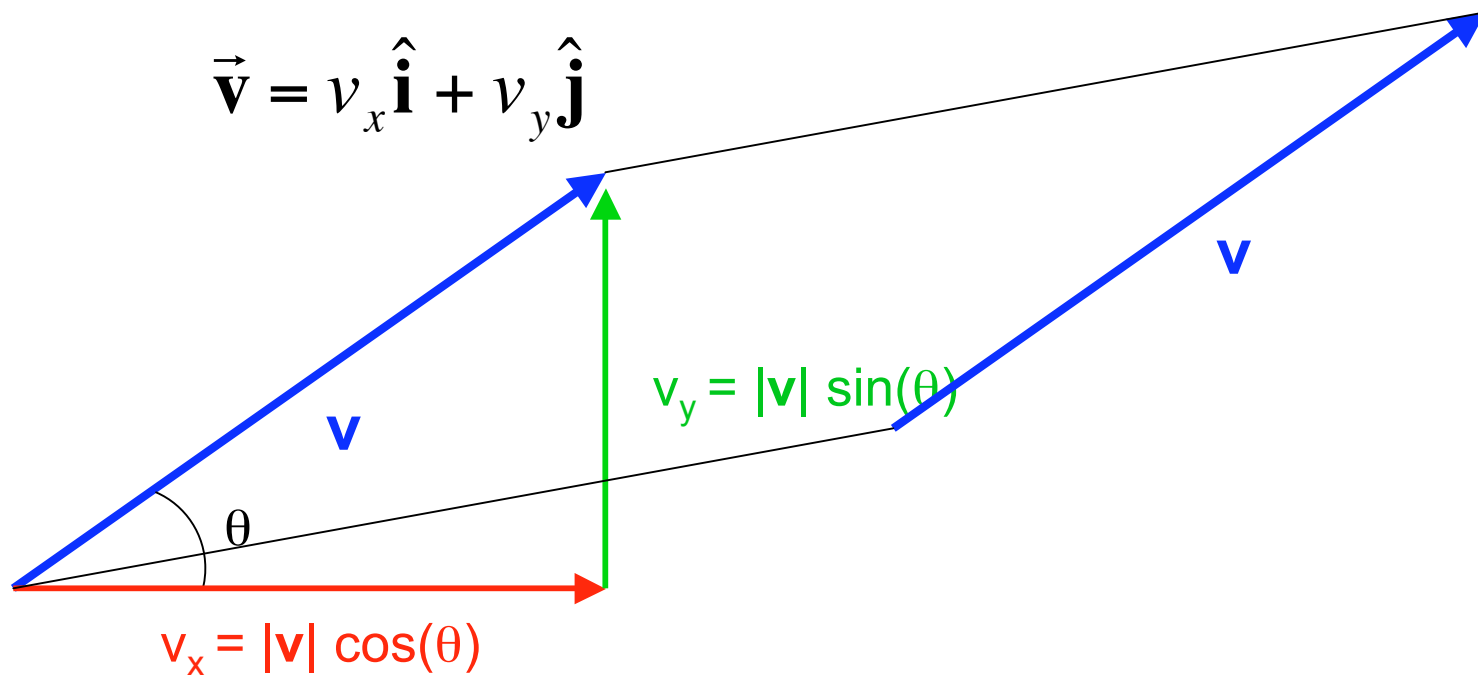


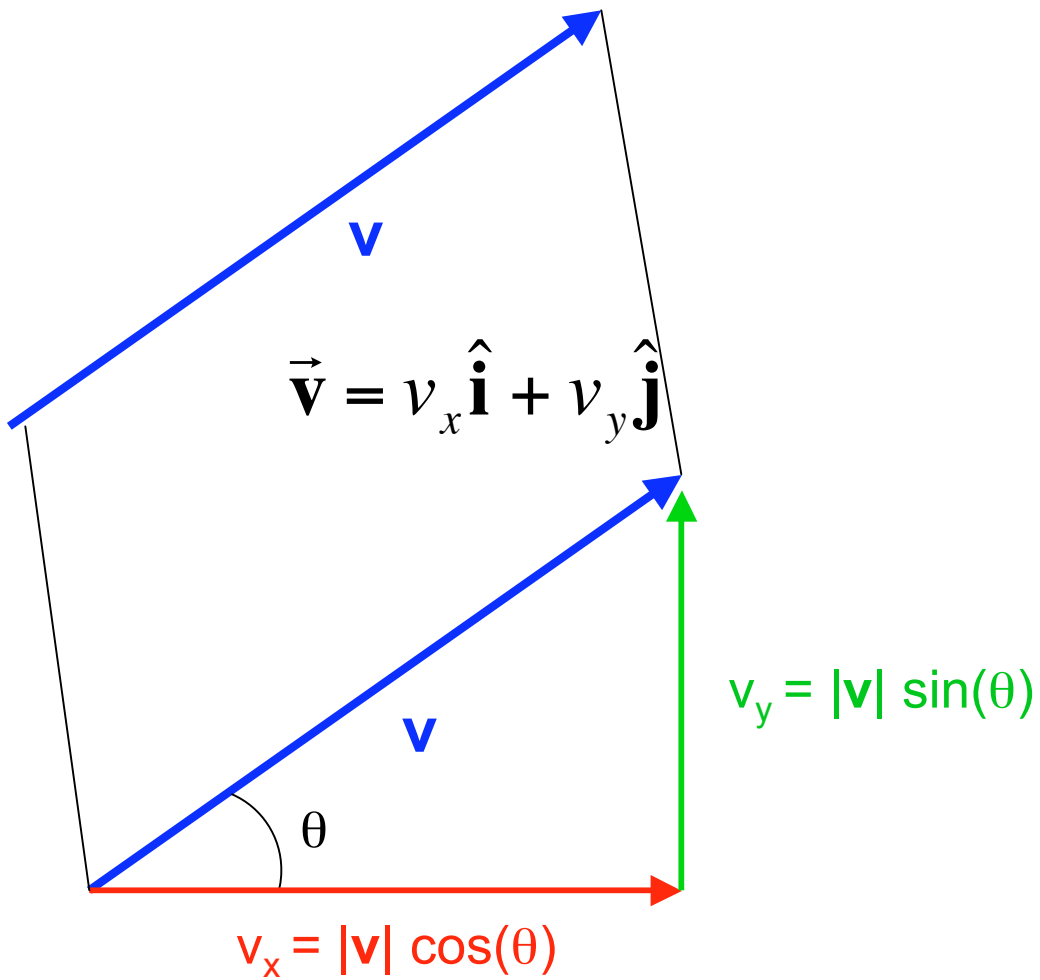
Motion in 2 & 3 dimensions



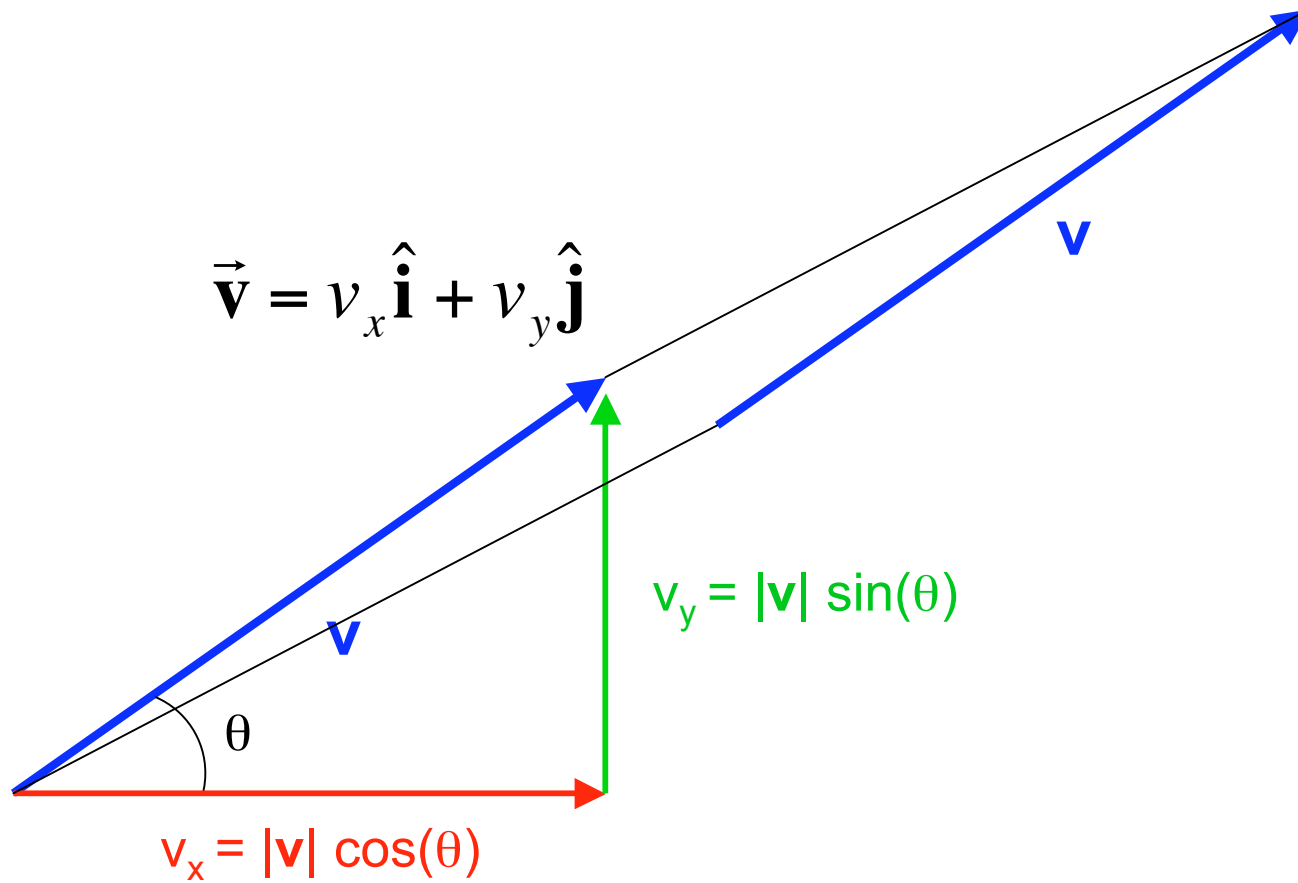
vectors



vectors

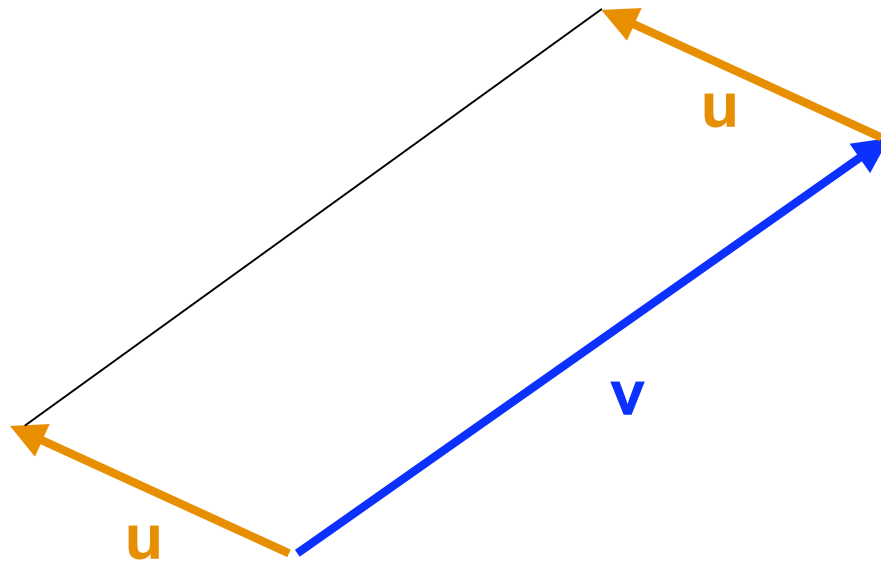


vectors



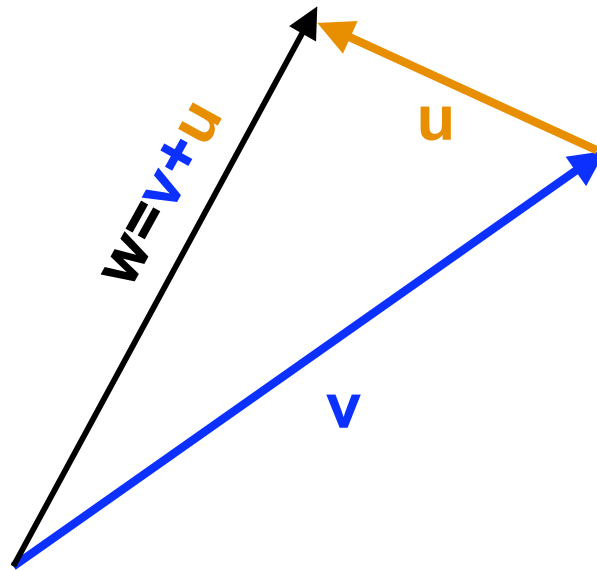
vectors

addition



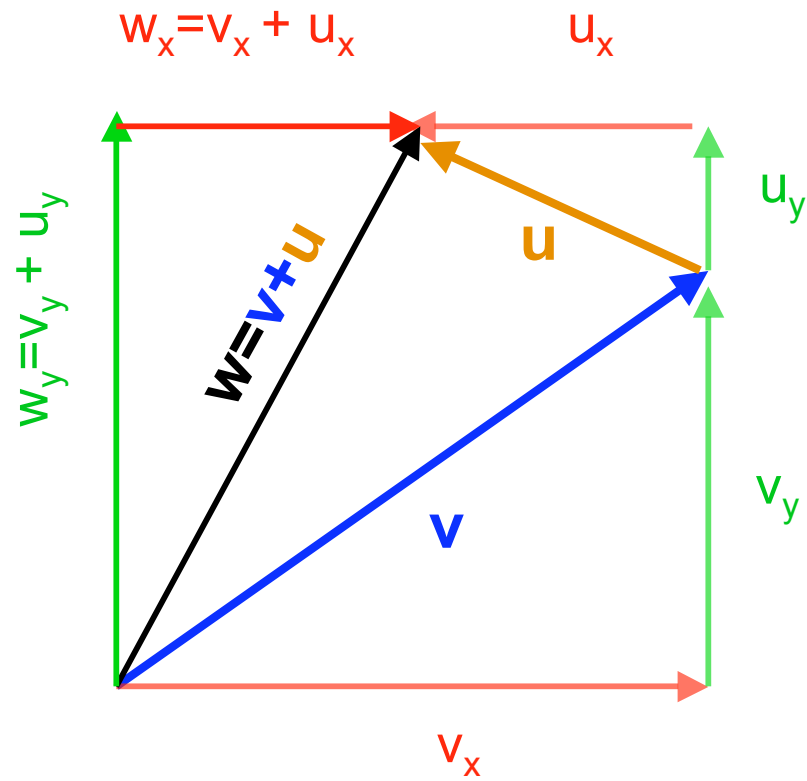
vectors

addition



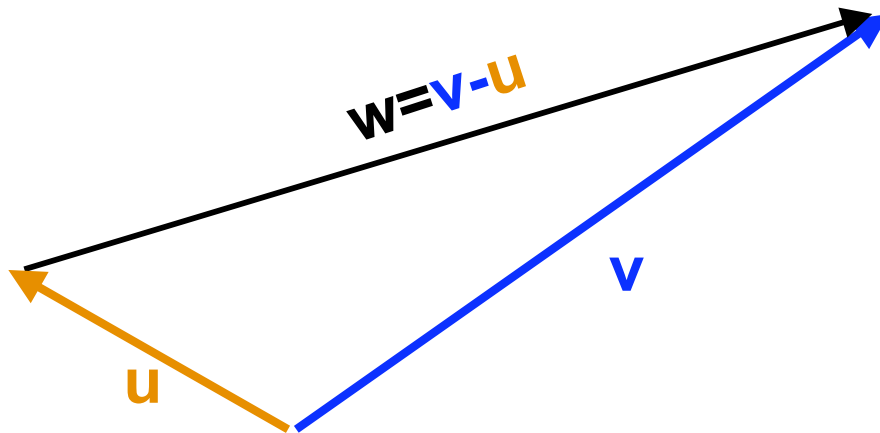
vectors

addition



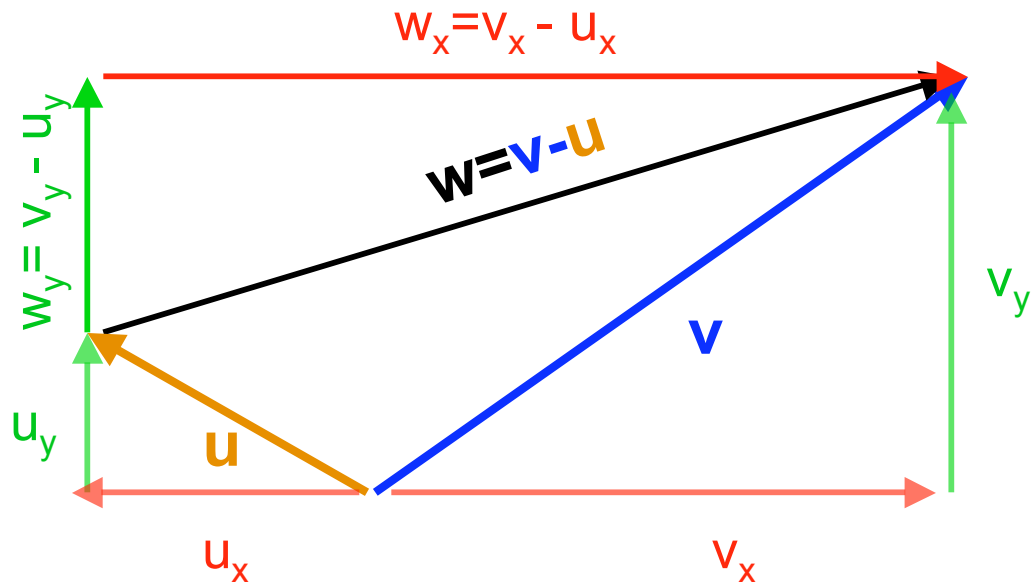
vectors

subtraction



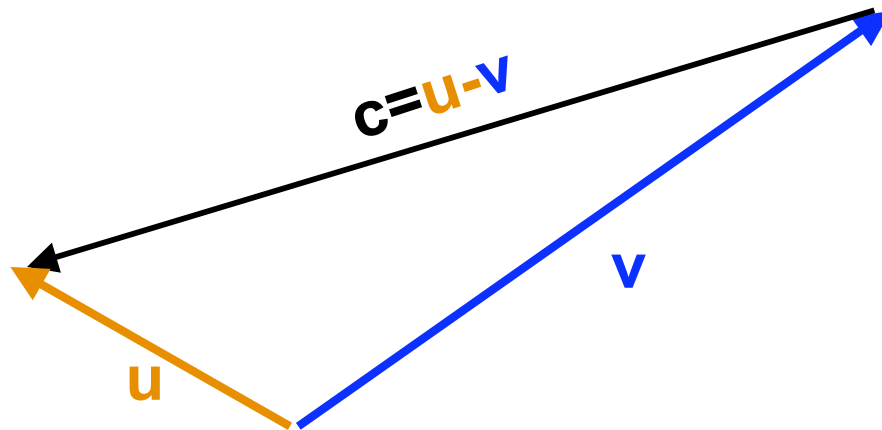
vectors

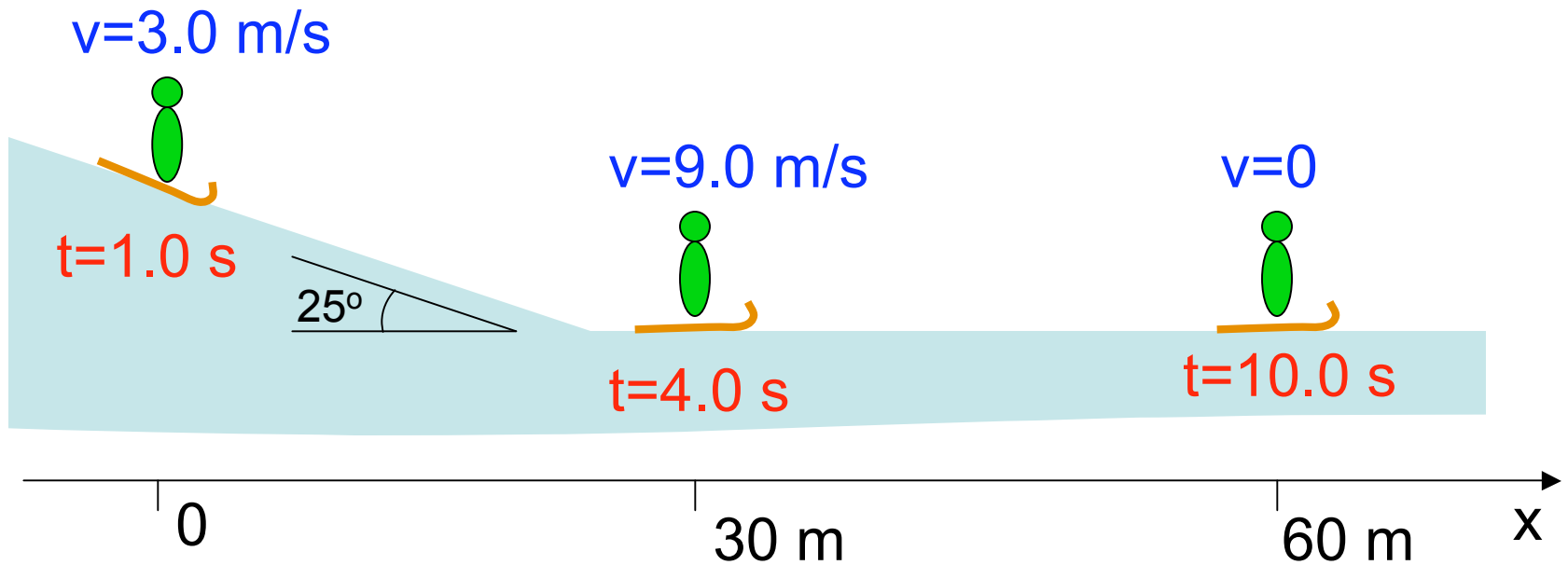
subtraction



vectors

subtraction





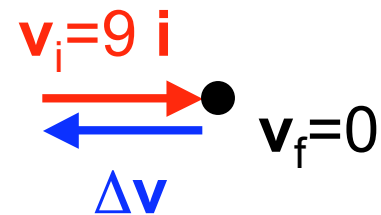
What is the **average acceleration** between $t=4$ and $t=10$ s?

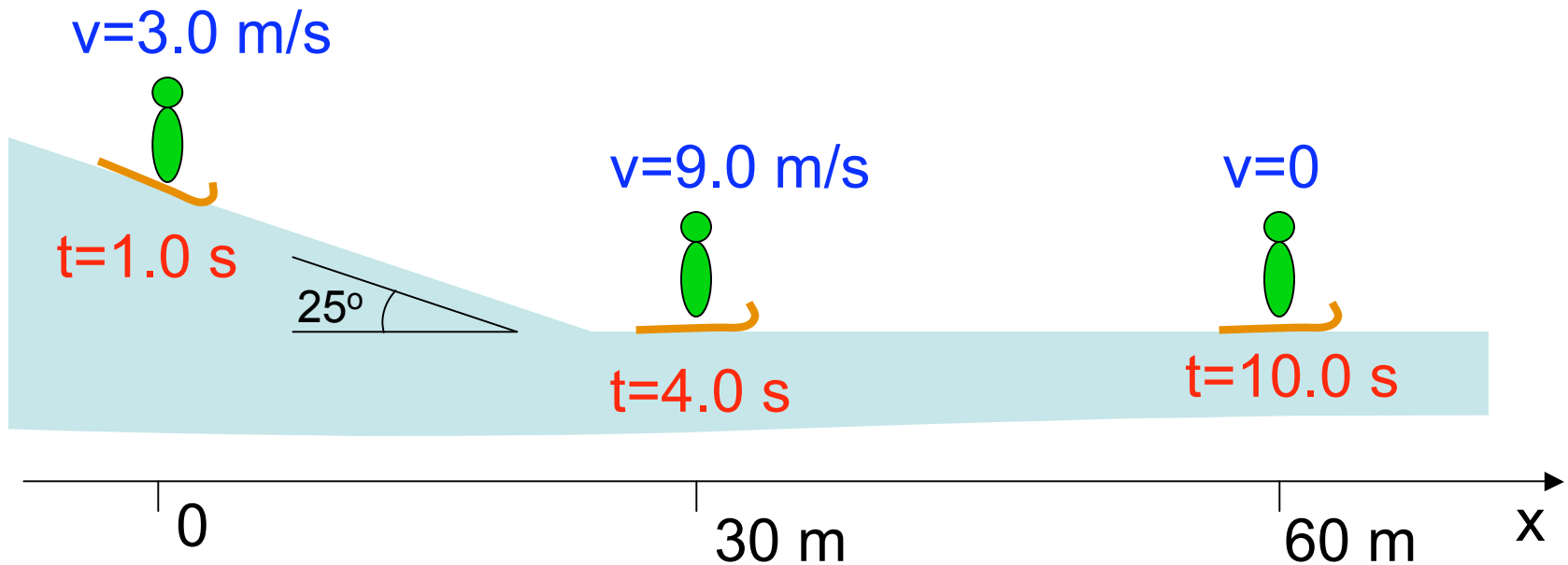
A $\mathbf{a} = -9 \mathbf{i}$ m/s

B $\mathbf{a} = 1.5 \mathbf{i}$ m/s²

C $\mathbf{a} = -1.5 \mathbf{i}$ m/s²

D $\mathbf{a} = -1.5 \mathbf{j}$ m/s²





Express the **instantaneous velocity** at $t=1$ s in Cartesian components

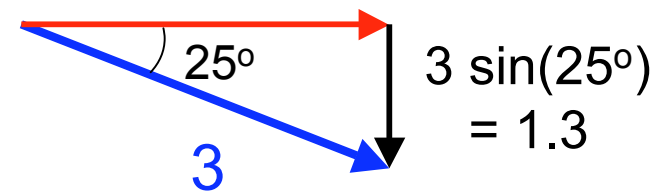
A $\mathbf{v} = 3 \mathbf{i} \text{ m/s}^2$

B $\mathbf{v} = (2.7 \mathbf{i} - 1.3 \mathbf{j}) \text{ m/s}$

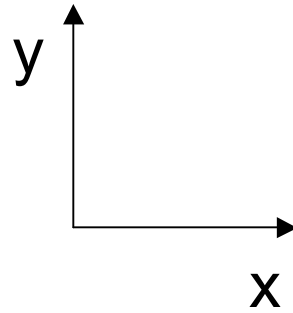
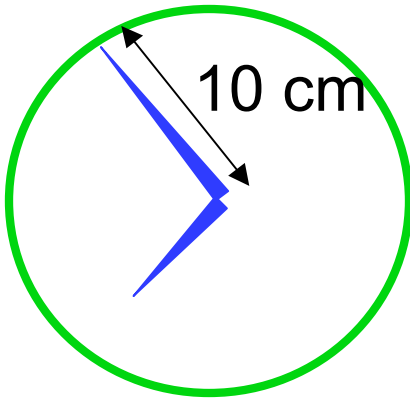
C $\mathbf{v} = (3.0 \mathbf{i} - 1.5 \mathbf{j}) \text{ m/s}^2$

D $\mathbf{v} = (2.7 \mathbf{i} + 1.3 \mathbf{j}) \text{ m/s}^2$

$$3 \cos(25^\circ) = 2.7$$

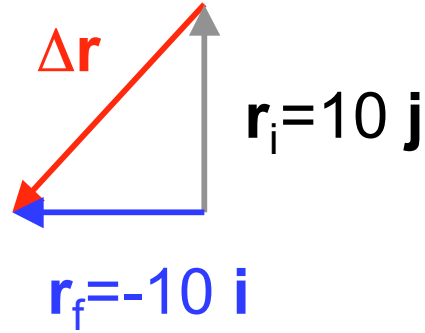
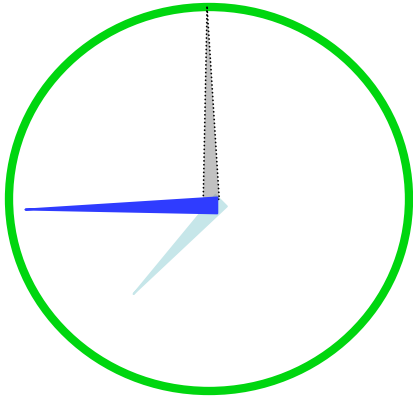


$$\mathbf{v}_i = 2.7 \mathbf{i} - 1.3 \mathbf{j}$$



A clock has a minute hand 10 cm long. What is the displacement of its tip between 8:00 and 8:45?

- A $\Delta \mathbf{r} = 10 \text{ cm } \mathbf{i} + 10 \text{ cm } \mathbf{j}$
- B $\Delta \mathbf{r} = -10 \text{ cm } \mathbf{i} + 10 \text{ cm } \mathbf{j}$
- C $\Delta \mathbf{r} = 10 \text{ cm } \mathbf{i} - 10 \text{ cm } \mathbf{j}$
- D $\Delta \mathbf{r} = -10 \text{ cm } \mathbf{i} - 10 \text{ cm } \mathbf{j}$
- E $\Delta \mathbf{r} = -10 \text{ cm } \mathbf{i}$



A clock has a minute hand 10 cm long. What is the displacement of its tip between 8:00 and 8:45?

$$\Delta \mathbf{r} = \mathbf{r}_f - \mathbf{r}_i = -10 \mathbf{i} - 10 \mathbf{j}$$

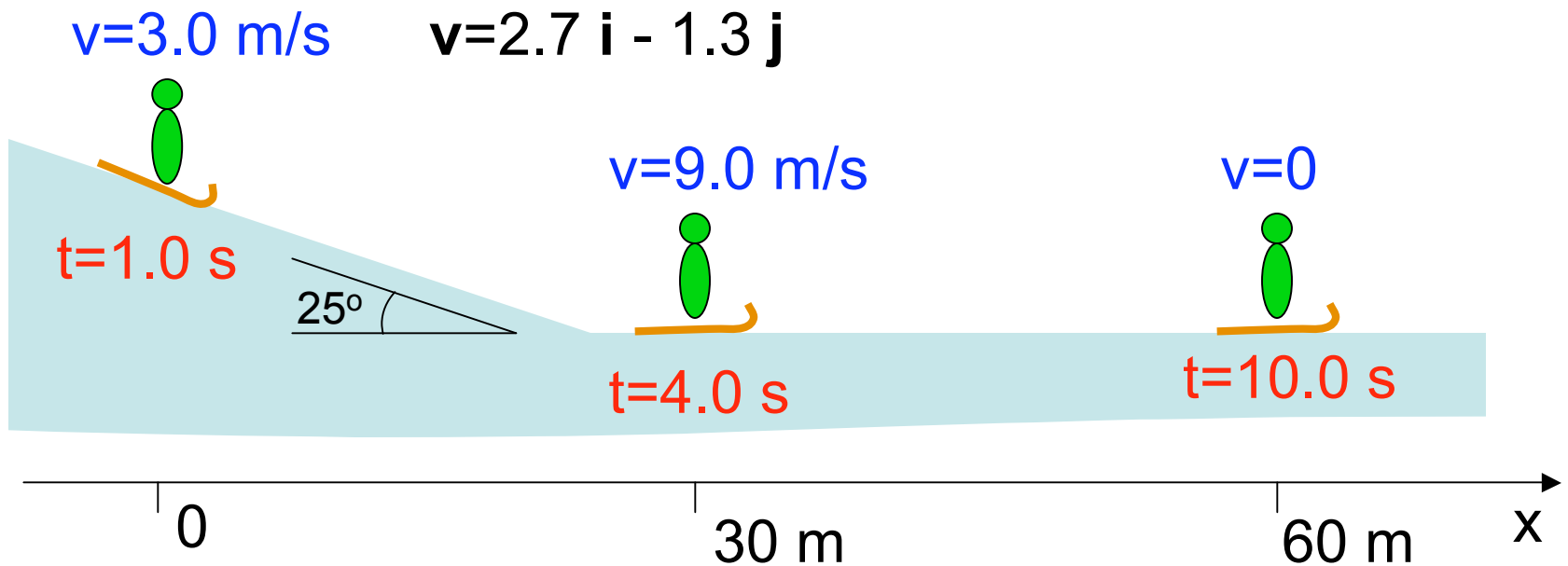
A $\Delta \mathbf{r} = 10 \text{ cm } \mathbf{i} + 10 \text{ cm } \mathbf{j}$

B $\Delta \mathbf{r} = -10 \text{ cm } \mathbf{i} + 10 \text{ cm } \mathbf{j}$

C $\Delta \mathbf{r} = 10 \text{ cm } \mathbf{i} - 10 \text{ cm } \mathbf{j}$

D $\Delta \mathbf{r} = -10 \text{ cm } \mathbf{i} - 10 \text{ cm } \mathbf{j}$

E $\Delta \mathbf{r} = -10 \text{ cm } \mathbf{i}$



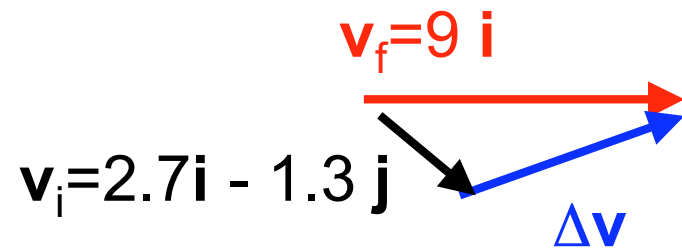
What is the **average acceleration** between $t=1$ and $t=4$ s?

A $\mathbf{a} = 2\mathbf{i} \text{ m/s}^2$

B $\mathbf{a} = (2.9\mathbf{i} - 0.4\mathbf{j}) \text{ m/s}^2$

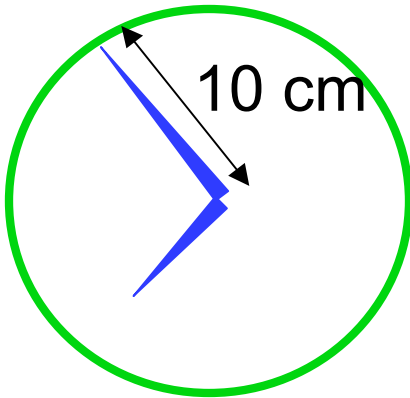
C $\mathbf{a} = (-2.1\mathbf{i} - 0.4\mathbf{j}) \text{ m/s}^2$

D $\mathbf{a} = (2.1\mathbf{i} + 0.4\mathbf{j}) \text{ m/s}^2$



$$\Delta\mathbf{v} = \mathbf{v}_f - \mathbf{v}_i = 6.3\mathbf{i} + 1.3\mathbf{j}$$

$$\bar{\mathbf{a}} = \frac{\Delta\mathbf{v}}{\Delta t} = \frac{6.3\hat{\mathbf{i}} \text{ m/s} + 1.3\hat{\mathbf{j}} \text{ m/s}}{3\text{s}}$$



What is the magnitude of its displacement?

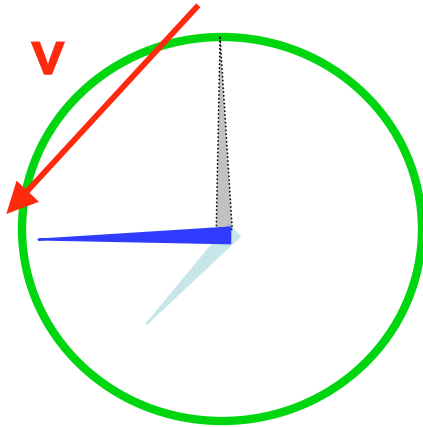
A $|\Delta \mathbf{r}| = 10 \text{ cm}$

B $|\Delta \mathbf{r}| = 14 \text{ cm}$

C $|\Delta \mathbf{r}| = 20 \text{ cm}$

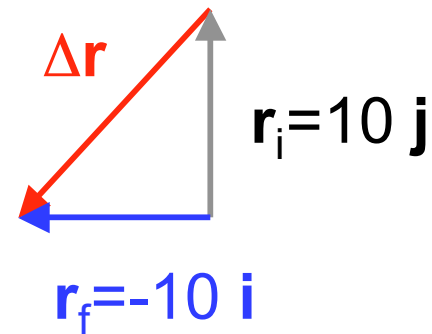
D $|\Delta \mathbf{r}| = 200 \text{ cm}^2$

$$\Delta \mathbf{r} = -10 \text{ cm } \mathbf{i} - 10 \text{ cm } \mathbf{j}$$



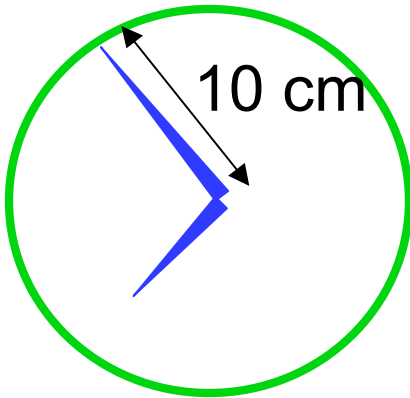
Calculate the average velocity (in units of cm/hr) of the tip of the minute hand between 8:00 and 8:45.

- A $\mathbf{v} = (7.5 \mathbf{i} + 7.5 \mathbf{j}) \text{ cm/hr}$
- B $\mathbf{v} = (-7.5 \mathbf{i} + -7.5 \mathbf{j}) \text{ cm/hr}$
- C $\mathbf{v} = (13 \mathbf{i} + 13 \mathbf{j}) \text{ cm/hr}$
- D $\mathbf{v} = (-13 \mathbf{i} - 13 \mathbf{j}) \text{ cm/hr}$**
- E none of the above



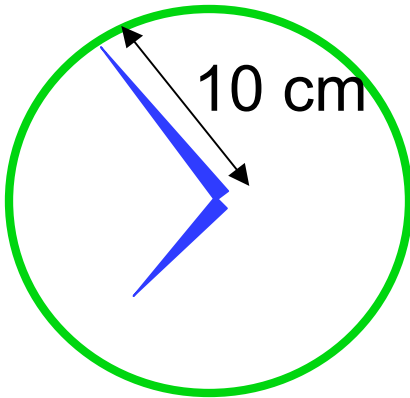
$$\Delta \mathbf{r} = -10 \mathbf{i} - 10 \mathbf{j}$$

$$\bar{\mathbf{v}} = \frac{\Delta \mathbf{r}}{\Delta t} = \frac{-10 \hat{\mathbf{i}} \text{ cm} - 10 \hat{\mathbf{j}} \text{ cm}}{0.75 \text{ hr}}$$



The tip of the minute hand traverses the entire 63 cm circumference in exactly one hour. Which is true of the tip?

- A Its speed is constant
- B Its velocity is constant
- C Its acceleration is 0
- D Its acceleration is constant



The tip of the minute hand traverses the entire 63 cm circumference in exactly one hour. Which is true of the tip?

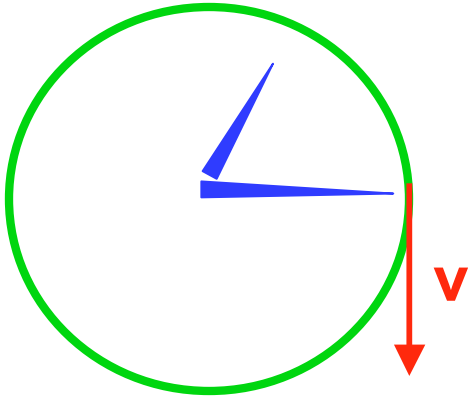
63 cm/hr →

A Its speed is constant

B Its velocity is constant

C Its acceleration is 0

D Its acceleration is constant



What is the instantaneous velocity of the tip of the minute hand at 1:15?

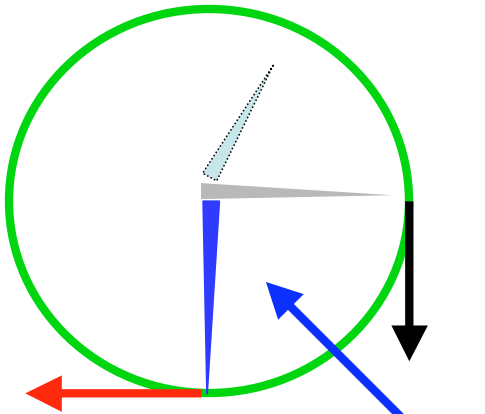
A $\mathbf{v} = 63 \mathbf{j}$ cm/hr

B $\mathbf{v} = 63 \mathbf{i}$ cm/hr

C $\mathbf{v} = -63 \mathbf{j}$ cm/hr

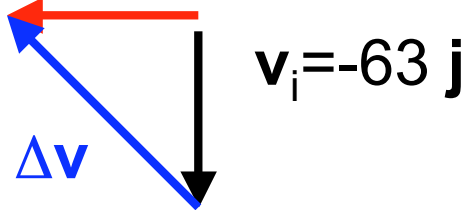
D $\mathbf{v} = -63 \mathbf{i}$ cm/hr

E $\mathbf{v} = 63$ cm/hr



What is the **average acceleration** of the tip of the minute hand between 1:15 and 1:30? (express answer in units of cm/hr^2)

$$\mathbf{v}_f = -63 \mathbf{i}$$



$$\mathbf{v}_i = -63 \mathbf{j}$$

$$\Delta \mathbf{v}$$

$$\Delta \mathbf{v} = \mathbf{v}_f - \mathbf{v}_i = -63 \mathbf{i} - (-63 \mathbf{j})$$

A $\mathbf{a} = -63 \mathbf{j} \text{ cm/hr}^2$

B $\mathbf{a} = -251 \mathbf{i} \text{ cm/hr}^2$

C $\mathbf{a} = (-251 \mathbf{i} + 251 \mathbf{j}) \text{ cm/hr}^2$

D $\mathbf{a} = (-251 \mathbf{i} - 251 \mathbf{j}) \text{ cm/hr}^2$

E $\mathbf{a} = (251 \mathbf{i} - 251 \mathbf{j}) \text{ cm/hr}^2$

$$\bar{\mathbf{a}} = \frac{\Delta \mathbf{v}}{\Delta t} = \frac{-63 \hat{\mathbf{i}} \text{ cm/hr} + 63 \hat{\mathbf{j}} \text{ cm/hr}}{0.25 \text{ hr}}$$

A particle's position is

$$\vec{\mathbf{r}} = (2t - 4)\hat{\mathbf{i}} + (2t^2 - 4t + 1)\hat{\mathbf{j}}$$

What is its velocity?

A $\vec{\mathbf{v}} = 2\hat{\mathbf{i}} + (4t - 4)\hat{\mathbf{j}}$

B $\vec{\mathbf{v}} = -4\hat{\mathbf{i}} + (2t - 4)\hat{\mathbf{j}}$

C $\vec{\mathbf{v}} = \left(2 - \frac{4}{t}\right)\hat{\mathbf{i}} + \left(2t - 4 + \frac{1}{t}\right)\hat{\mathbf{j}}$

D $\vec{\mathbf{v}} = 2t\hat{\mathbf{i}} + (2t^2 - 4t)\hat{\mathbf{j}}$

A particle's position is

$$\vec{r} = (2t - 4)\hat{i} + (2t^2 - 4t + 1)\hat{j}$$

How fast is it traveling when it crosses $x=0$?

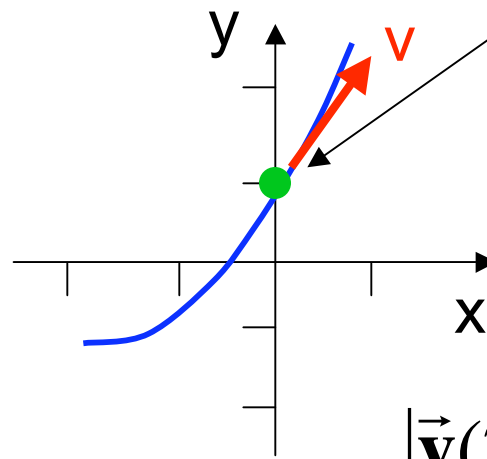
A $v = 2.0$

B $v = 4.0$

C $v = 4.5$

D $v = 6.0$

E $v = 20$



$$x(t) = (2t - 4)$$

$$x=0 \quad @ \quad t=2$$

$$\vec{v}(t) = 2\hat{i} + (4t - 4)\hat{j}$$

$$\vec{v}(2) = 2\hat{i} + 4\hat{j}$$

$$|\vec{v}(2)| = \sqrt{2^2 + 4^2} = \sqrt{20}$$

A particle's position is

$$\vec{r} = (2t - 4)\hat{i} + (2t^2 - 4t + 1)\hat{j}$$

Which direction is it traveling when it crosses $x=0$?

express the direction in degrees from the x-axis.

A $\theta = 0^\circ$ $x(t) = (2t - 4) = 0 \implies t = 2$

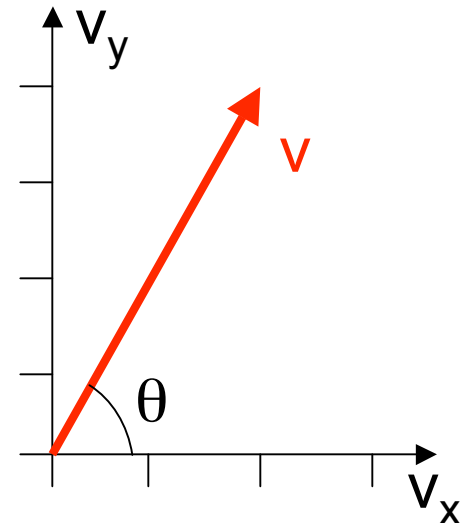
B $\theta = 27^\circ$ $\vec{v}(t) = 2\hat{i} + (4t - 4)\hat{j}$

C $\theta = 45^\circ$

D $\theta = 63^\circ$ $\vec{v}(2) = 2\hat{i} + 4\hat{j}$

E $\theta = 90^\circ$

$$\theta = \tan^{-1}\left(\frac{v_y}{v_x}\right) = \tan^{-1}(2)$$



A particle's position is

$$\vec{\mathbf{r}} = (2t - 4)\hat{\mathbf{i}} + (2t^2 - 4t + 1)\hat{\mathbf{j}}$$

What is its acceleration?

A $\vec{\mathbf{a}} = 2\hat{\mathbf{i}} + (4t - 4)\hat{\mathbf{j}}$

B $\vec{\mathbf{a}} = 2\hat{\mathbf{i}} + 4\hat{\mathbf{j}}$

C $\vec{\mathbf{a}} = 2\hat{\mathbf{i}}$

D $\vec{\mathbf{a}} = 4\hat{\mathbf{j}}$

A particle's velocity is $\vec{v}(t) = (-2t + 1)\hat{i} - \hat{j}$

At $t=0$ the particle is at $\vec{r}_i = 4\hat{j}$

Find its position at $t=2$

A $\vec{r}_f = -2\hat{i}$

B $\vec{r}_f = 2\hat{j}$

C $\vec{r}_f = -2\hat{i} + 2\hat{j}$

D $\vec{r}_f = -2\hat{i} - 2\hat{j}$

$$\Delta x = \int_0^2 v_x(t) dt = \int_0^2 (-2t + 1) dt = (-t^2 + t) \Big|_0^2 = -2$$

$$\Delta y = \int_0^2 v_y(t) dt = \int_0^2 (-1) dt = (-t) \Big|_0^2 = -2$$

$$\Delta \vec{r} = -2\hat{i} - 2\hat{j}$$

$$\vec{r}_f = \vec{r}_i + \Delta \vec{r} = -2\hat{i} + 2\hat{j}$$

A particle has constant acceleration $\vec{a} = -2\hat{j}$

At $t=0$ it has velocity $\vec{v}_i = \hat{i} + 3\hat{j}$

and position $\vec{r}_i = -2\hat{i}$

Where is this particle at $t=2$?

A $\vec{r}_f = -2\hat{i}$

B $\vec{r}_f = 2\hat{j}$

C $\vec{r}_f = 4\hat{i} + 2\hat{j}$

D $\vec{r}_f = -2\hat{i} - 2\hat{j}$