

Displacement, Velocity And Acceleration

- Vectors and Scalars
- Position Vectors
- Displacement
- Speed and Velocity
- Acceleration
- Complete Motion Diagrams

Scalars vs. vectors

Scalar : a real number, no "direction"

Examples : mass, charge, energy,
temperature, time . . .

Vector : a scalar (its *magnitude*) and a *direction in space*

Examples : position displacement, velocity,
force, torque, momentum . . .

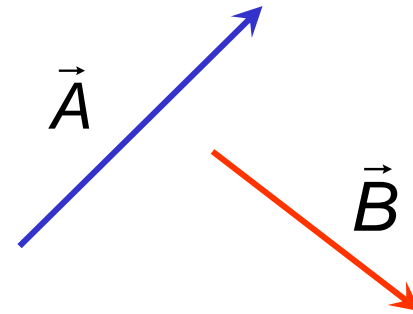
Vectors have different rules of arithmetic

If you add 2 students to a group of 3 students, how many students do you have?

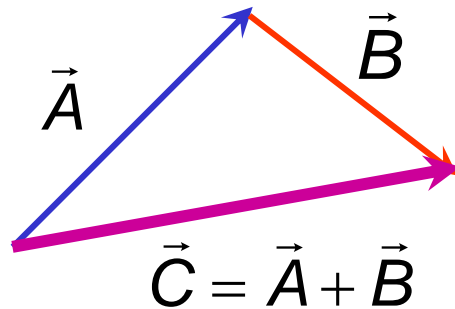
If you walk North 3 km and then walk West 4 km, what is your displacement from where you started?

Vector Addition: Vector + Vector = Vector

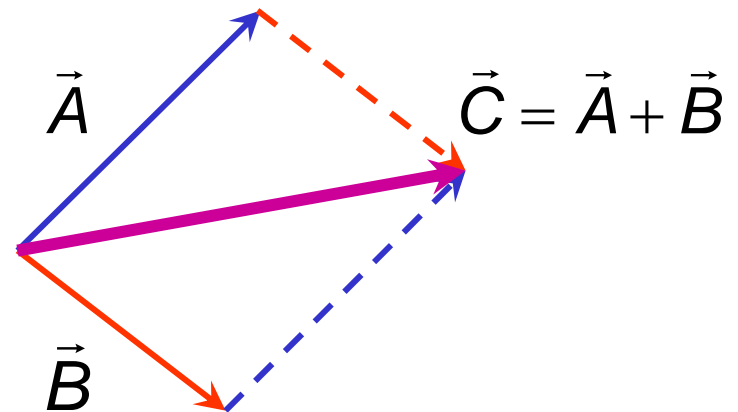
$$\vec{A} + \vec{B} = \vec{C}$$



Triangle Method

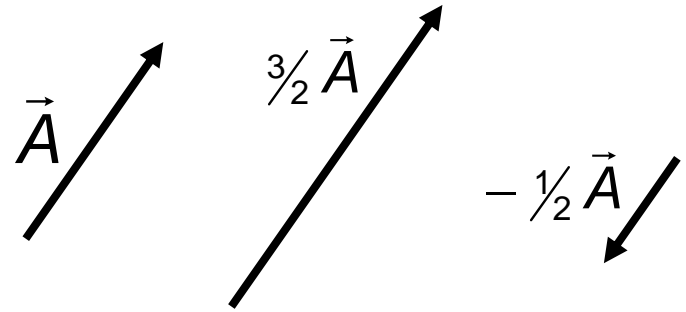


Parallelogram Method



Vector Multiplication:

i) scalar \times vector = vector



ii) vector \bullet vector = scalar (dot product)

$$\vec{F} \bullet \vec{s} = W$$

iii) vector \times vector = vector (cross product)

$$\vec{r} \times \vec{p} = \vec{L}$$

Vector Subtraction: Vector - Vector = Vector

$$\vec{A} - \vec{B} = \vec{A} + (-\vec{B})$$

Just like: $3 - 2 = 3 + (-2)$

Delta → Δ

- Greek letter for capital D
- Physicists use it to represent "change" in a quantity

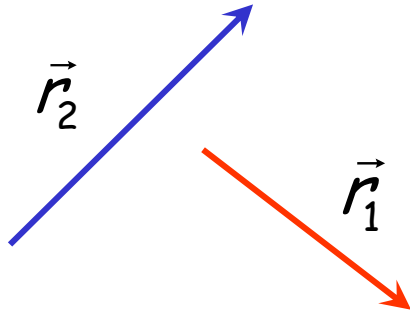
$$\Delta \vec{r} = \vec{r}_2 - \vec{r}_1$$

- Not a symbol which we will use by itself

$$\frac{\Delta \vec{r}}{\Delta t} \neq \frac{\vec{r}}{t}$$

- Where there is a Δ , subtraction is always involved

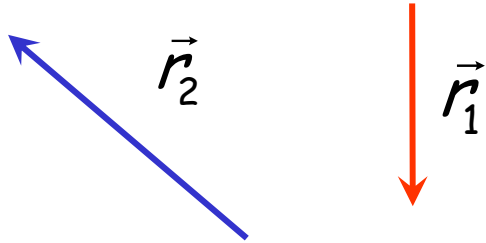
Vector Subtraction Example:



$$\Delta\vec{r} = ?$$

Quick Quiz 6

Which answer best represents $\Delta \vec{r}$?



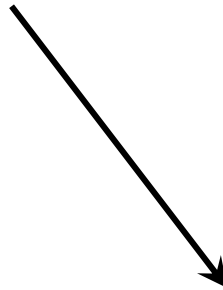
(A)



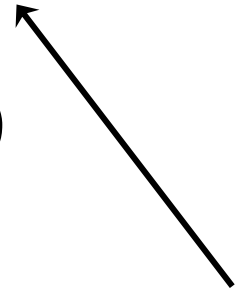
(B)



(C)



(D)

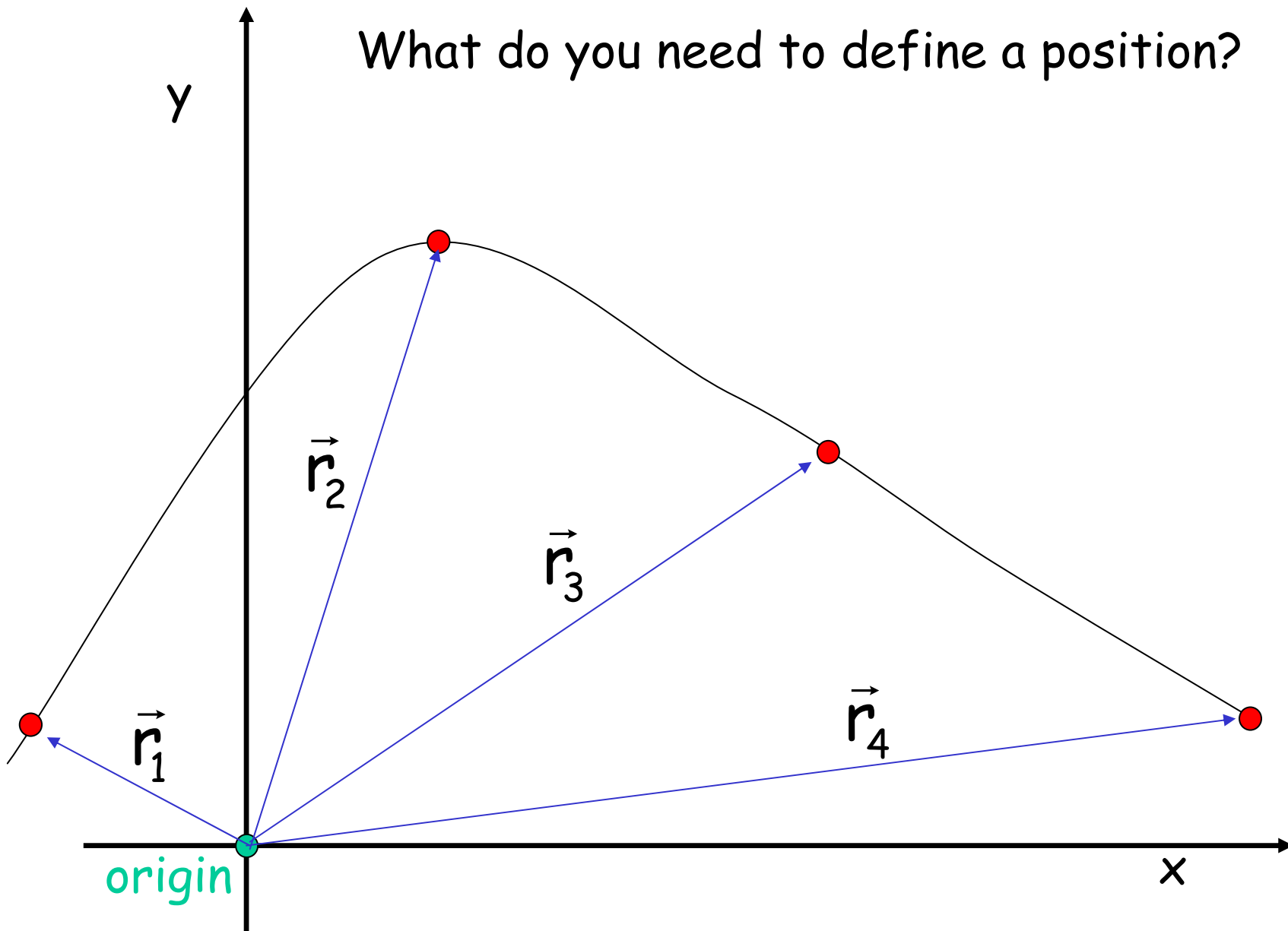


Position Vectors

- Tells where something is relative to the origin of position graph (usually 2-D or 3-D)
- The origin is just a convenient choice of place to measure from
- The origin could be anywhere, but if you choose it carefully, you will likely end up doing less work

A position vector is ALWAYS measured from the ORIGIN

What do you need to define a position?

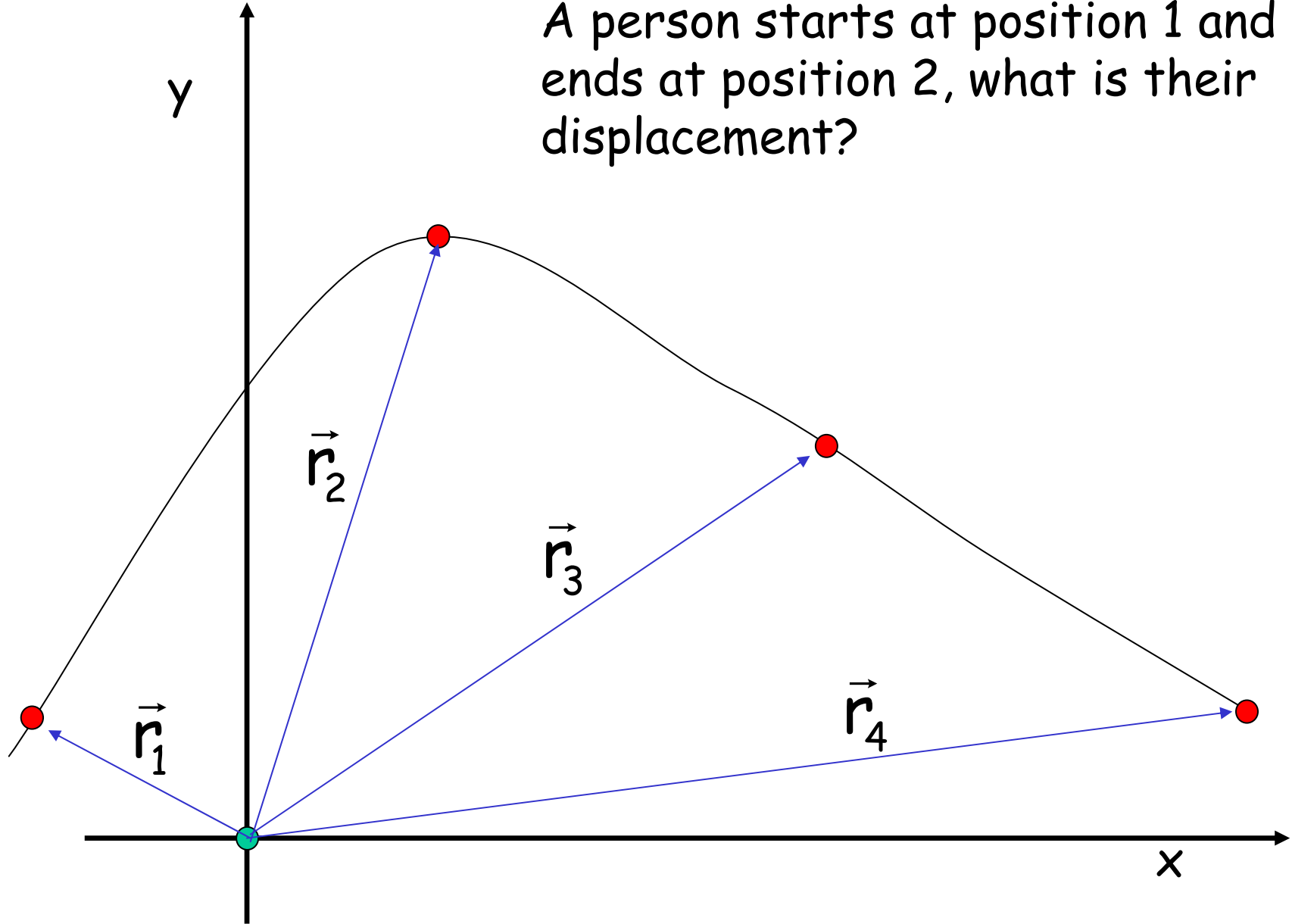


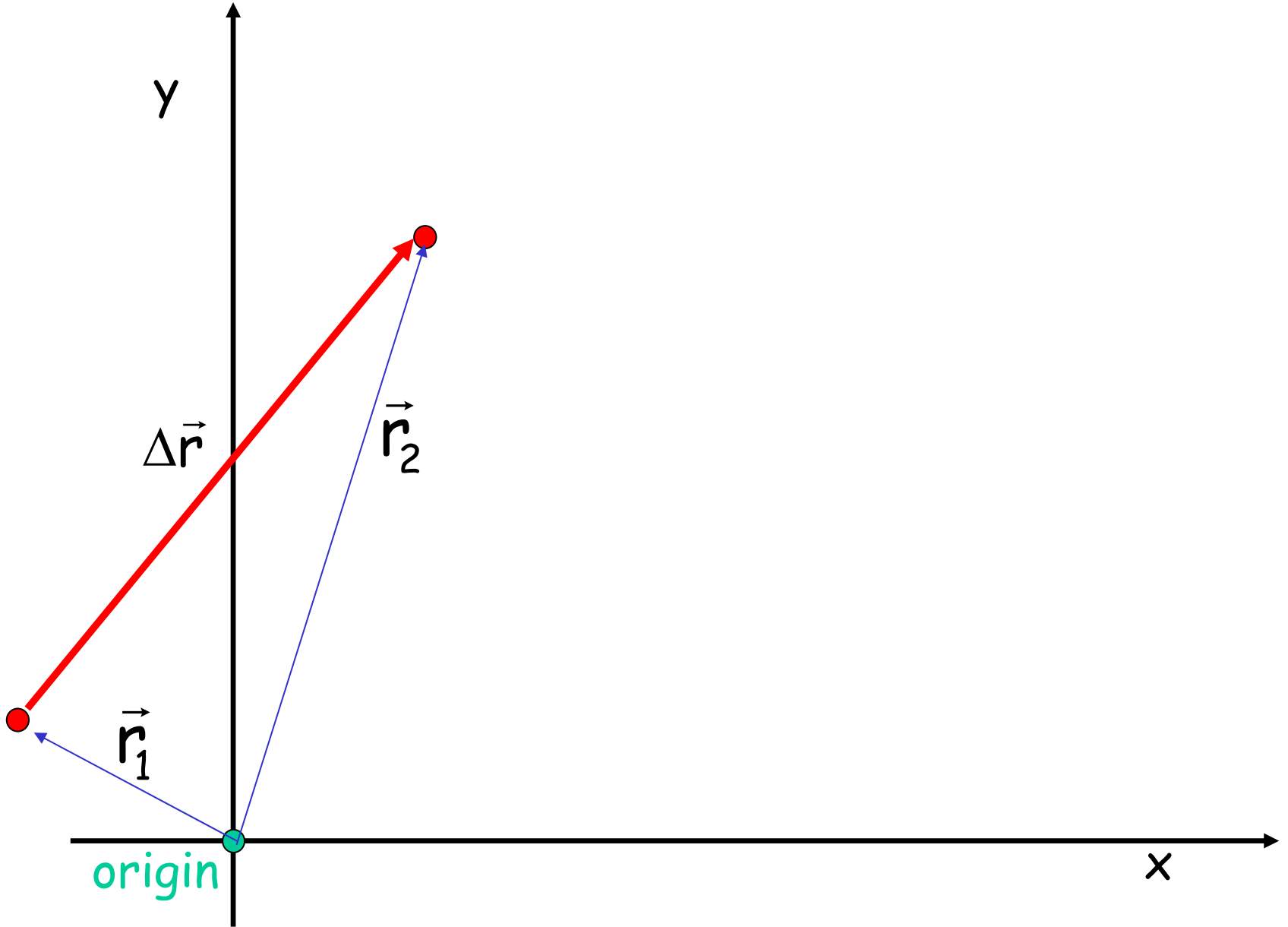
Displacement

- The point of making position vectors is to make it easier to discuss how things *CHANGE* their positions
- A change in position is called a *displacement*
- The displacement vector is typically written as $\Delta\vec{r}$

A displacement vector is *ALWAYS* measured from the tip of the initial position vector to the tip of the final position vector

A person starts at position 1 and ends at position 2, what is their displacement?

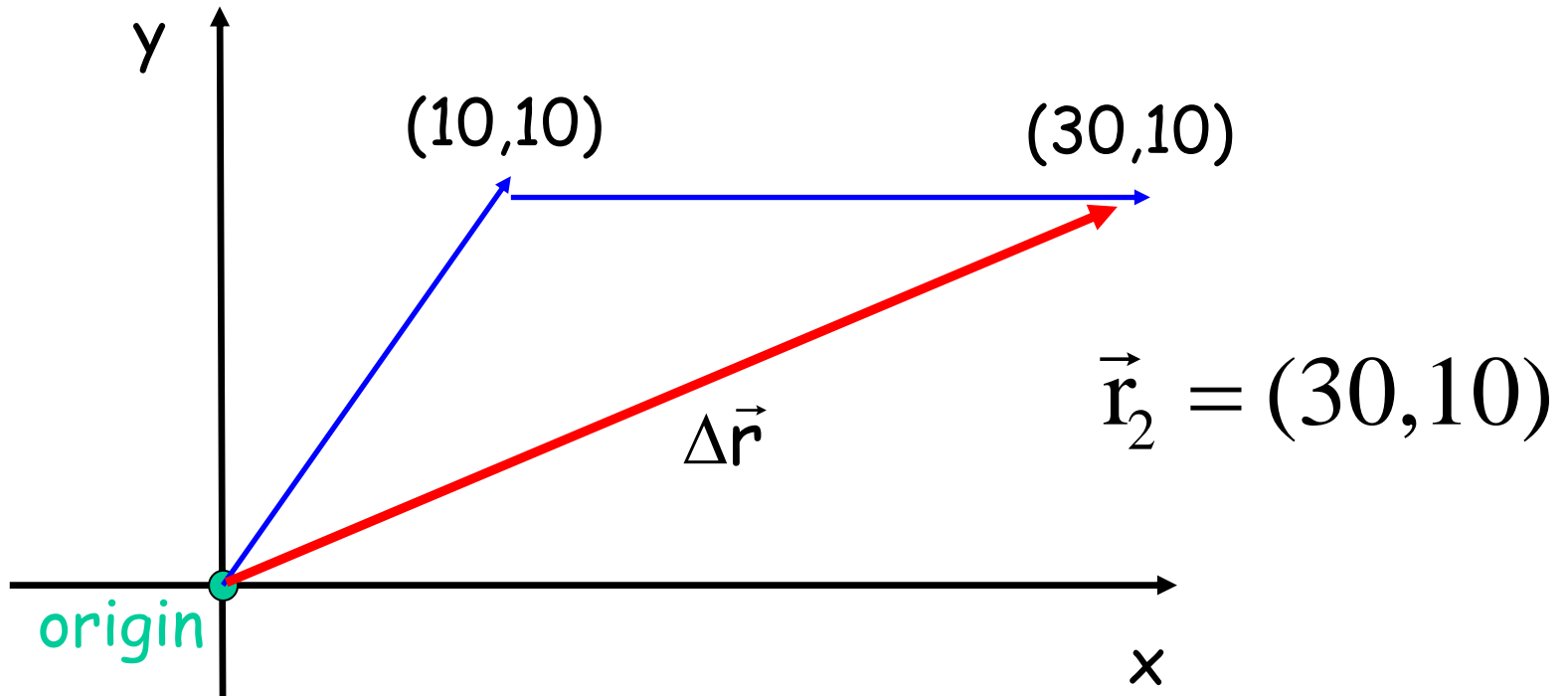




Quick Quiz 7

If $\Delta\vec{r} = \vec{r}_2 - \vec{r}_1$, what was \vec{r}_1 ?

- A. (10,10) B. (20,0) C. (40, 20)
D. (0,0) E. (0,20)



Average Speed

$$\text{Average speed} = \frac{\text{Distance traveled}}{\text{Time spent traveling}}$$

OR

$$v_{avg} = \frac{\Delta r}{\Delta t}$$

Not a vector!

Not a vector!

Example 1 - Average Speed

If a car travels 100 km/h for an hour, and then travels 50 km/h for an hour. The average speed is given by:

$$v_{avg} = \frac{\text{total distance traveled}}{\text{time spent traveling}}$$

Quick Quiz 8

Sharon Donnelly is competing against in a triathlon. She must first swim 1.5 km, then bike 40 km, then run 10 km back to the spot where the race began.

Sharon's average speeds are 0.75 km/h for swimming, 40 km/h on bicycle, and 10 km/h running. What is Sharon's average speed over the entire triathlon?

- A) 1 km/h
- B) 9 km/h
- C) 13 km/h
- D) 20 km/h
- E) 32 km/h

Average Velocity

Average velocity = $\frac{\text{Displacement}}{\text{Time spent traveling}}$

OR

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

Vector!

Vector!

Quick Quiz 9

Sharon Donnelly and Samantha McGlone were competing against each other in the triathlon described in Quick Quiz 8. Samantha's average speeds are 0.75 km/h for swimming, 40 km/h on bicycle, and 10 km/h running.

Who has the higher average velocity for the triathlon?

- (A) Sharon has the higher average velocity
- (B) Samantha has the higher average velocity
- (C) They both have the same average velocity
- (D) You need to know the direction of travel for the swimming, bicycling and running portions.

Position from Velocity

$$\vec{v}_{avg} = \frac{\Delta \vec{r}}{\Delta t} \quad \rightarrow \quad \Delta \vec{r} = \vec{v}_{avg} \cdot \Delta t$$



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

$$\rightarrow \vec{r}_2 - \vec{r}_1 = \vec{v}_{avg} \cdot \Delta t$$

$$\rightarrow \vec{r}_2 = \vec{r}_1 + (\vec{v}_{avg} \Delta t)$$

Acceleration

- Acceleration is the rate of change of velocity

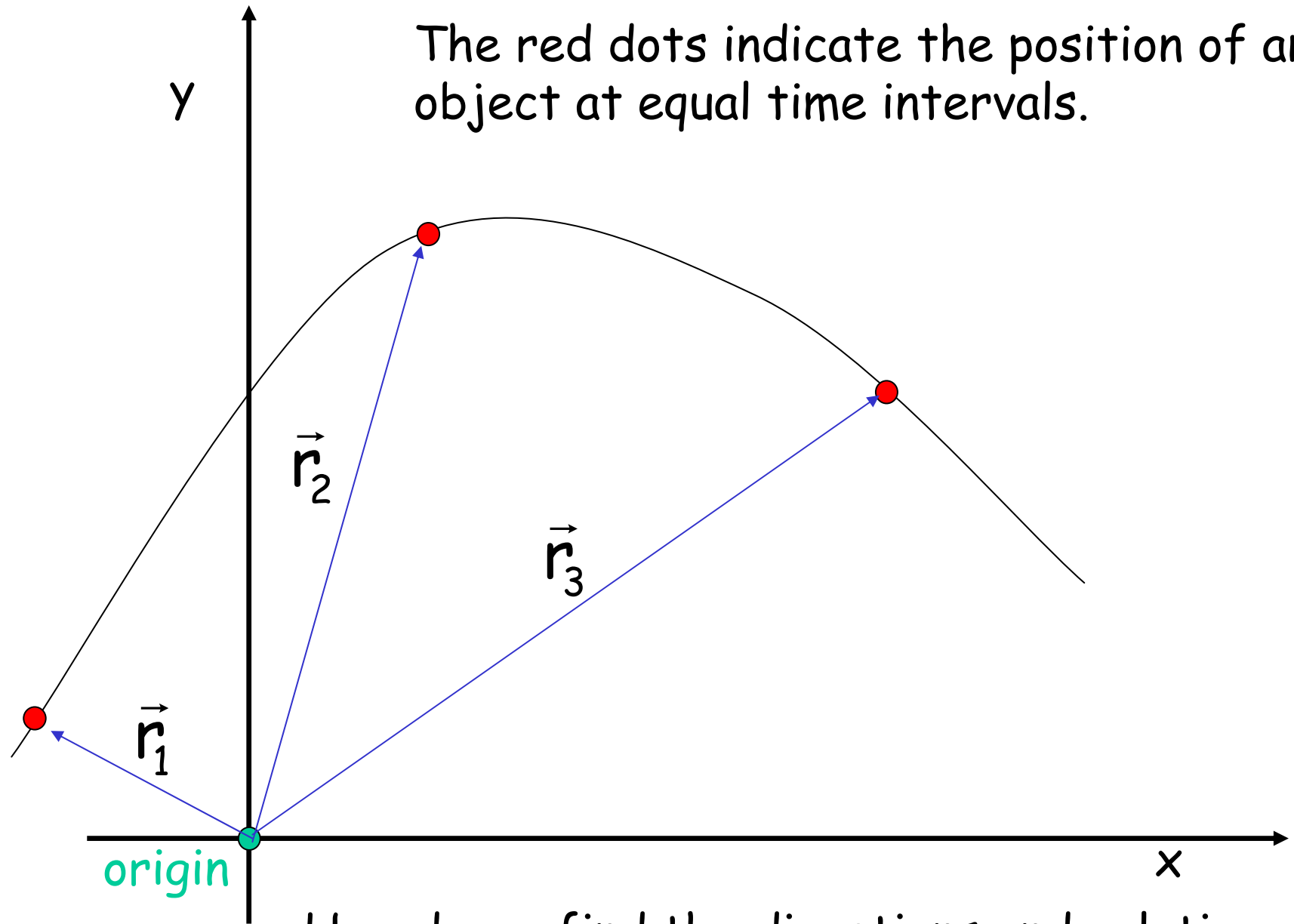
$$\vec{a}_{avg} = \frac{\Delta \vec{v}_{avg}}{\Delta t}$$

The acceleration vector **ALWAYS** points in the same direction as the **CHANGE** in velocity.

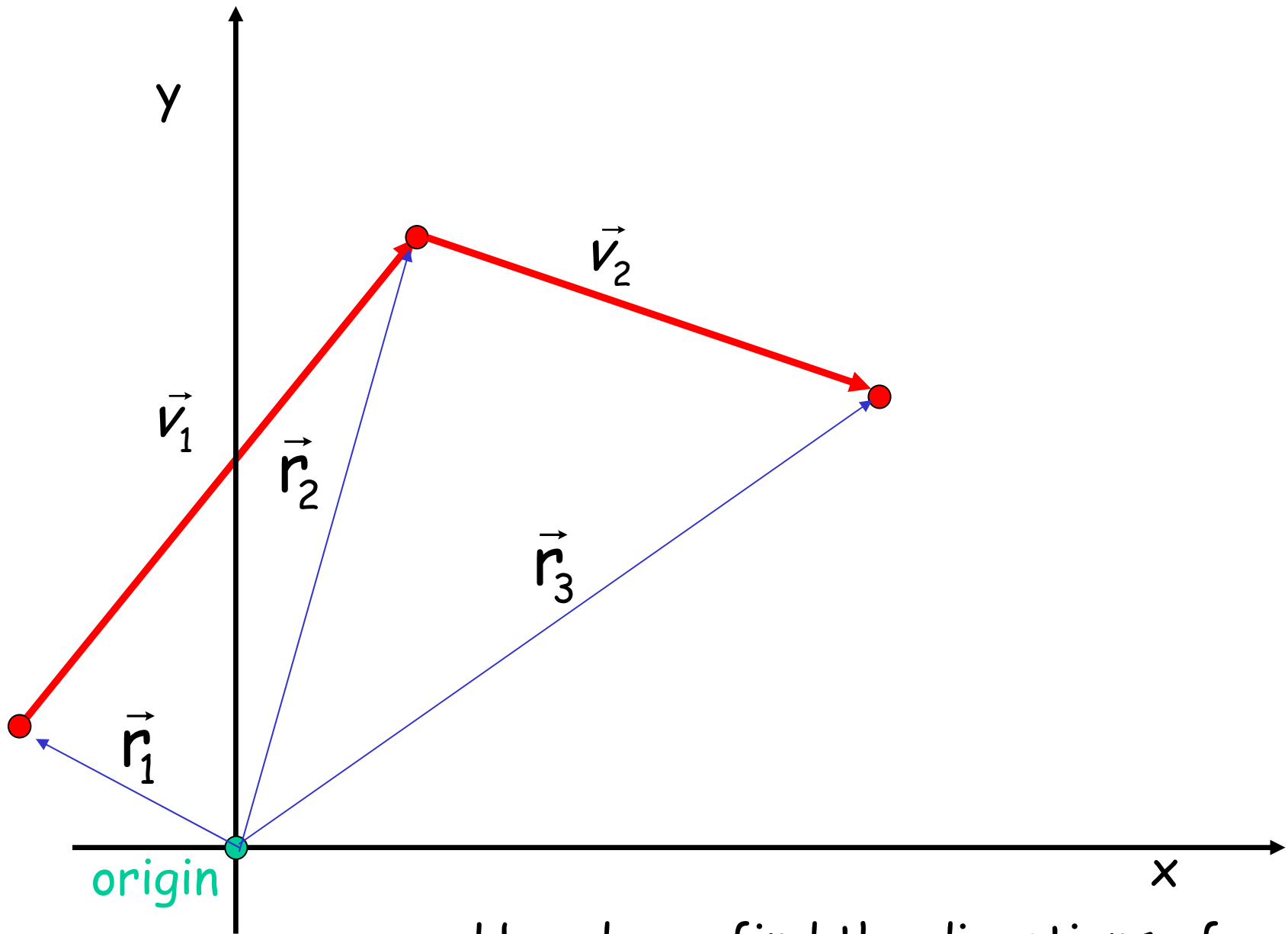
Change in Velocity $\rightarrow \Delta v$

$$\Delta \vec{v} = \vec{v}_2 - \vec{v}_1$$

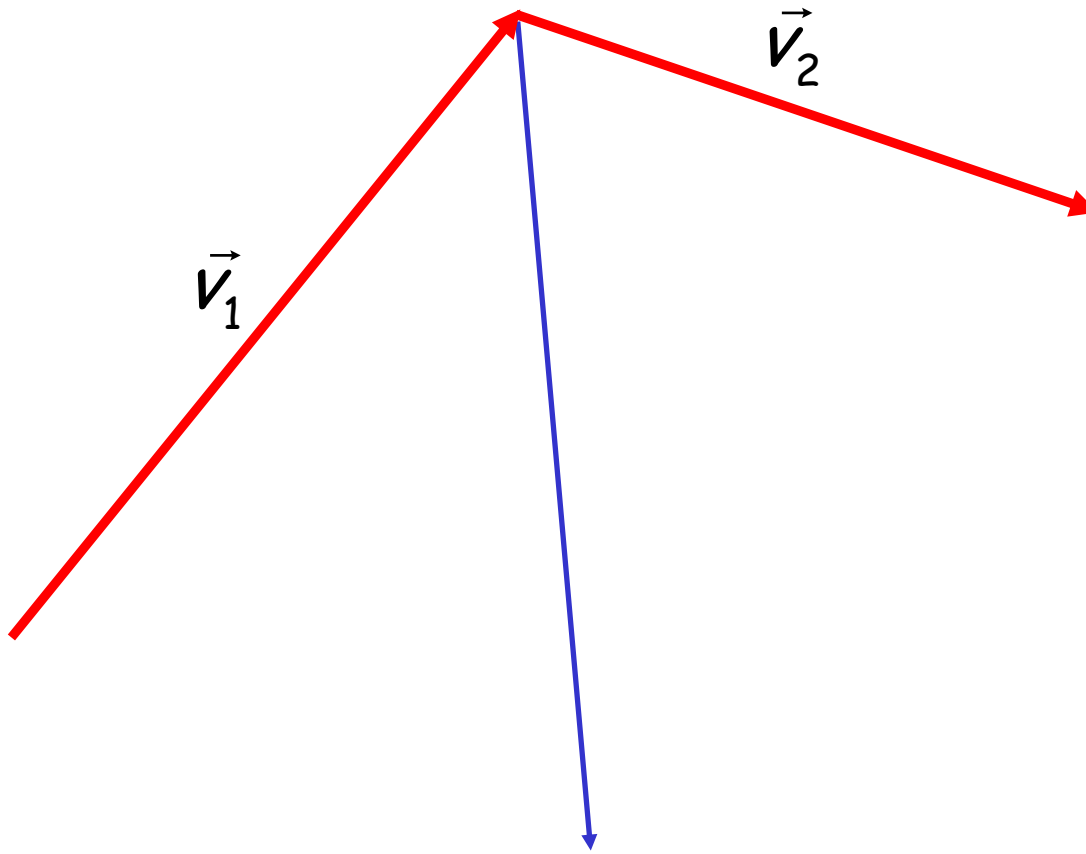
The red dots indicate the position of an object at equal time intervals.



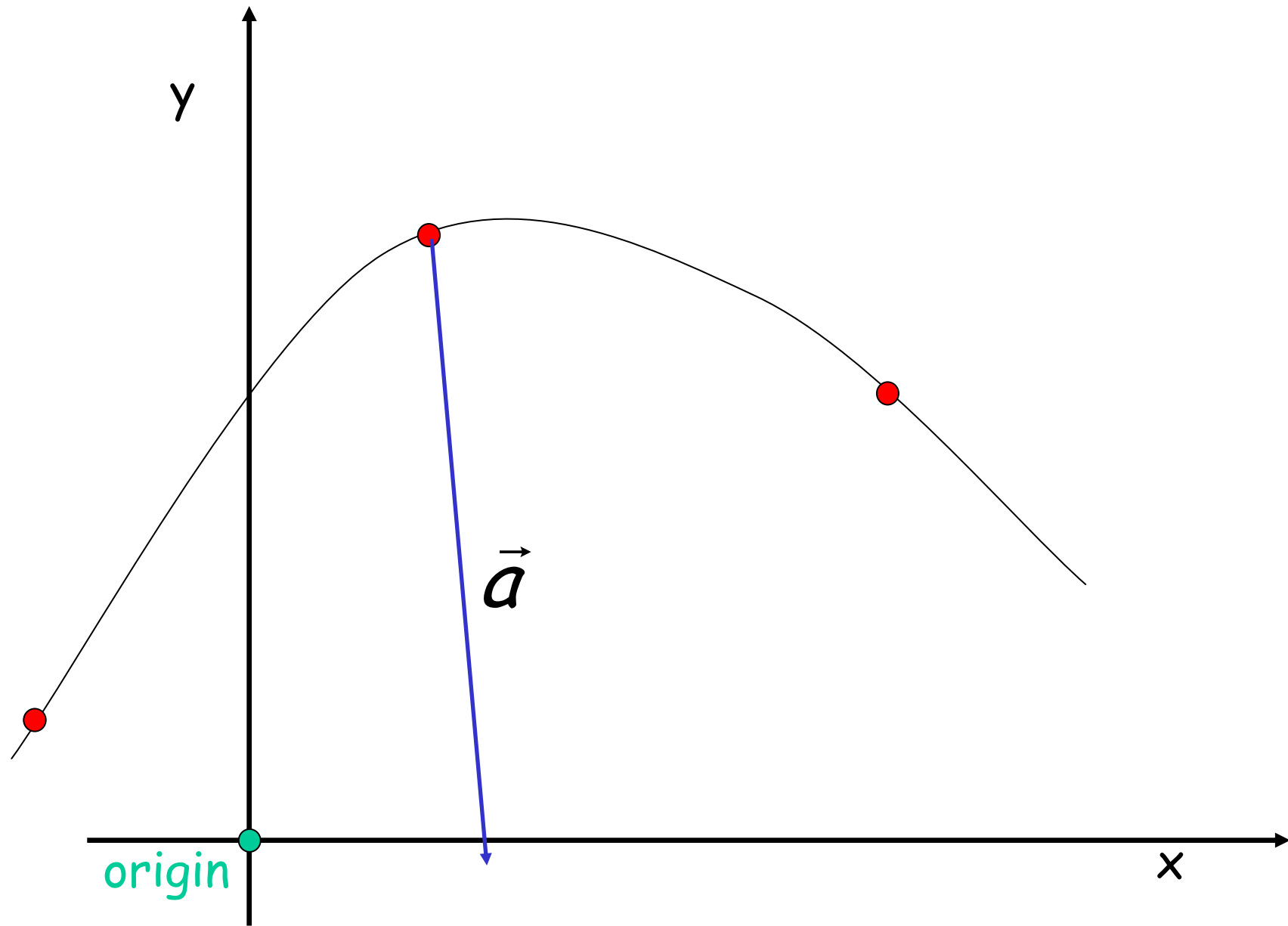
How do we find the directions and relative magnitudes of the average velocity vectors?



How do we find the directions of the average acceleration vector?



\vec{a} is in the direction of $\Delta\vec{v}$



Predicting Motion

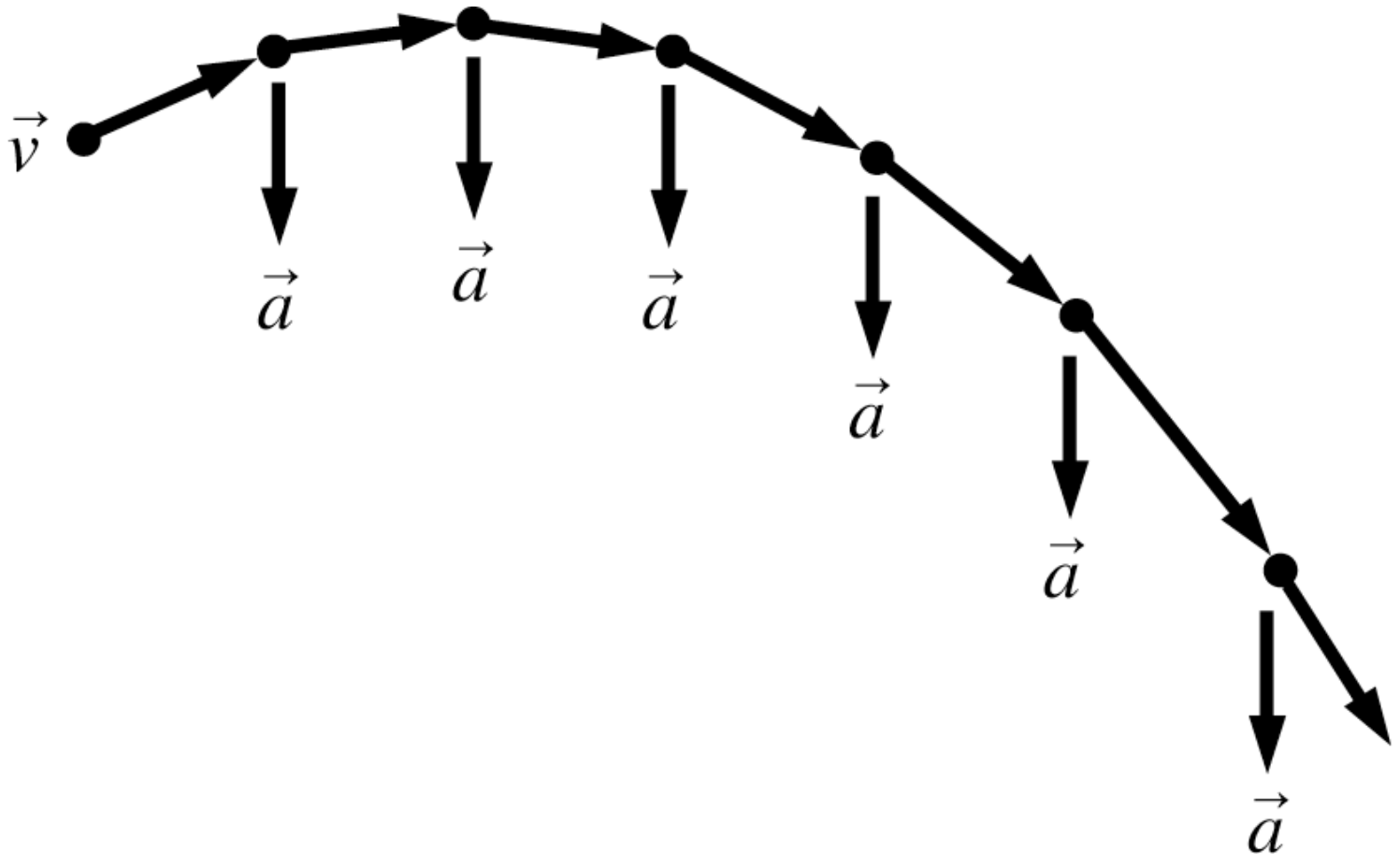
$$\vec{v}_{avg} = \frac{\Delta \vec{r}}{\Delta t} \quad \rightarrow \quad \vec{r}_2 = \vec{r}_1 + (\vec{v}_{avg} \Delta t)$$

$$\vec{a}_{avg} = \frac{\Delta \vec{v}}{\Delta t} \quad \rightarrow \quad \vec{v}_2 = \vec{v}_1 + (\vec{a}_{avg} \Delta t)$$

Complete Motion Diagrams

- Dots represent positions at uniformly spaced time intervals
- An arrow that connects two dots represents the direction and relative magnitude of the average velocity for the time interval between those two dots
- Arrows drawn at the dots represent the average acceleration for the time interval between the previous dot and the next dot

Complete Motion Diagrams



QQ10 Motion Diagram

A plane flies in a horizontal circle without changing speed. Draw the motion diagram for the plane. What direction does the acceleration vector point?

- A) Toward the centre of the circle
- B) Away from the centre of the circle
- C) Along the tangent to the circle
- D) There is no acceleration, since its speed is constant