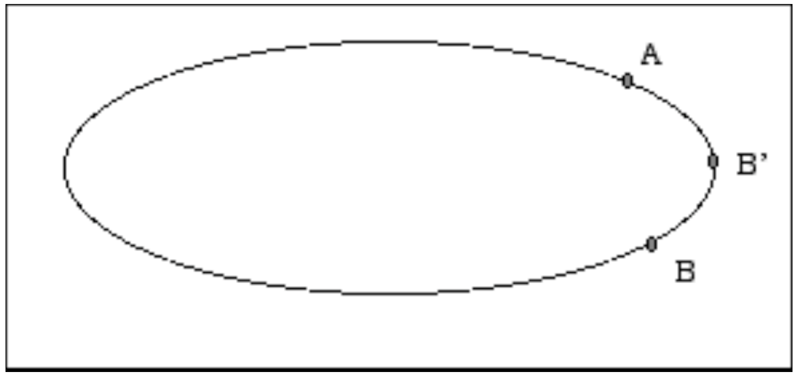
Motion in Two Dimensions : Group Names : ____

Terms:

Trajectory = path traveled, position = location relative to origin, displacement = difference between two positions

I. Velocity



A car is moving along an oval track in a clockwise direction. Make a large diagram of this trajectory on a blank piece of paper.

A. Pick a point to serve as the origin of your coordinate system. This **point should be outside of the oval**. Points A and B are shown where B is later in time than A.

1. Draw and label the **position vectors**, $\vec{r}_A$, $\vec{r}_B$, for each point. Then draw and label the **displacement vector**, $\Delta\vec{r}$ (= $r_B - r_A$). Discuss your result with your partners and sketch a small version on this paper.

2. How is the direction of the <u>displacement vector</u> related to the direction of the <u>average velocity vector</u> for motion from A to B?

3. Consider a point B' between A and B, and closer to A. Draw the displacement vector for the car moving from A to B'. As B' gets closer and closer to A, what is the mathematical term for the direction of the displacement relative to the trajectory?

4. What is the direction of the instantaneous velocity relative to the trajectory at any point? Draw and label vectors showing the instantaneous velocity at points A and B.

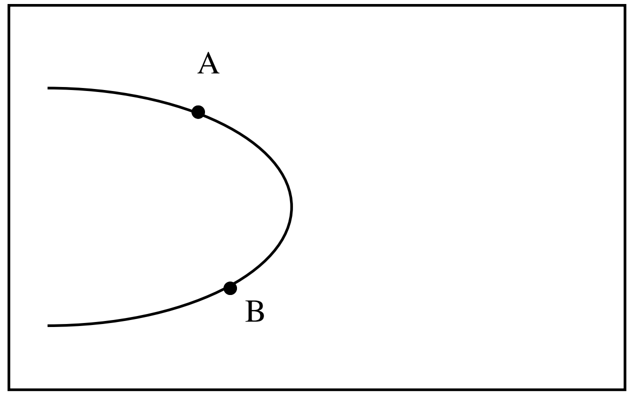
   Does your answer depend on whether the object is speeding up, slowing down, or moving at constant speed?

B. Suppose you choose a different location for the origin. Circle the vectors that would change.

Position of A, position of B, displacement from A to B, instantaneous velocity at B.

II Acceleration for car moving at constant speed around the oval.

Suppose the car is driving around the oval at a **constant speed.** Draw a large version of the diagram to the right. Again consider the points A and B, with B later in time than A. Draw and label velocity vectors, $\vec{v}_A, \vec{v}_B$ for the car at points A and B.



A. Move (redraw) the velocity vectors **tail to tail** on a separate part of your paper and determine the vector change in velocity, $\Delta\vec{v}$. Copy the diagram on this sheet.

1. Is the angle between velocity at A and the change in velocity, $\Delta\vec{v}$, less than, equal to, or greater than 90°? Subtract using the vectors tail-to-tail, and **clearly indicate the angle that you are measuring**.

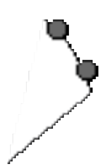
2. If Point B is closer to A, will the angle in part 1 change? If so will it be closer to or farther from 90°?

3. What is the limiting value for this angle as point B approaches point A (remember that this is case of constant speed.) Can you prove your result?

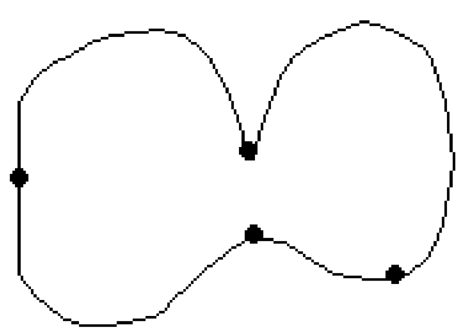
4. For the case of constant speed, how are the directions of <u>average acceleration</u> and <u>change in velocity</u> related?

5. For the car moving at <u>constant speed</u>, what is the angle between <u>velocity</u> and <u>acceleration</u>? Draw and label the accelerations, $\vec{a}$ at points A and B.

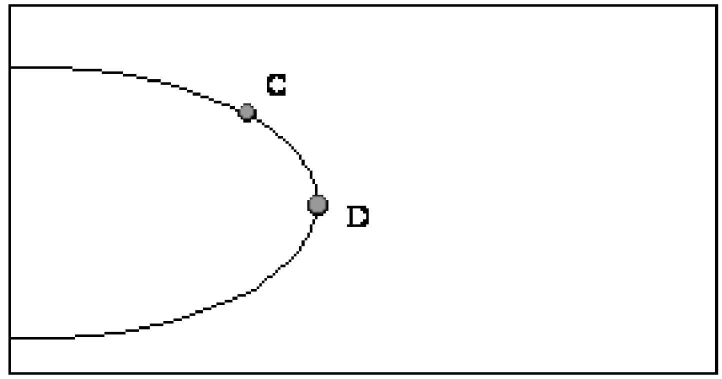
B. Parts of two ovals are shown below. The points are separated by the same distance measured along the ovals, and the speed of the car is the same in both. Make a sketch of the change in velocity in the two cases. Is it the same, or is it larger in one case, and if so which? What does this say about the magnitude of the accelerations? Make a clear statement. Also describe the direction of the acceleration in clear terms.



C. A car moves at **constant speed** around the "peanut" shaped track shown. Draw acceleration vectors at the points indicated with dots. Use long arrows where the acceleration is large, short arrows where it is small. Use a = 0 if needed.



III Acceleration for a car increasing speed.



Once more around the oval, and this time the car moves from C to D. The car is moving **twice as fast at D as at C**. Draw and label velocity vectors at C and D, $\vec{v}_C$, $\vec{v}_D$. (Faster means longer vectors.)

A. Draw the velocity vectors tail to tail, draw and label the change in velocity, $\prod\vec{v}$. Copy the tail-to-tail vectors on this paper.

1. Is the angle between the velocity at C and the change in velocity less than, equal to, or greater than 90°? (Draw vectors tail-to-tail to decide.)

2. If point D is moved closer to point C, does this angle approach 90°?

3. When the car is speeding up, is the angle between acceleration and velocity less than, equal to, or greater than 90°?

B. A car is driving clockwise around the two ovals shown below. On the left the car is moving at **constant speed**, on the right it is **speeding up starting from rest at point A**. At the points marked draw the velocity vector (- - - >) and the acceleration vector (===>) for the car. Make lengths of vectors consistent with magnitudes. Write v=0 or a=0 if needed.