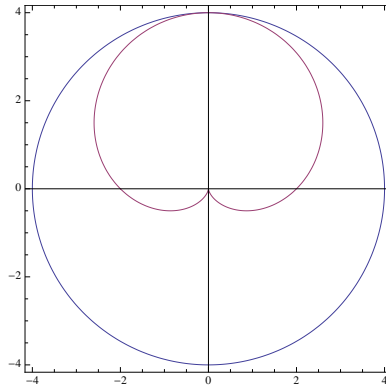


2. [14 points] The graph of the circle $r = 4$ and the cardioid $r = 2 \sin \theta - 2$ are shown below.



- a. [3 points] Write a formula for the area inside the circle and outside the cardioid in the first quadrant.
- b. [7 points] At what angles $0 \leq \theta < 2\pi$ is the minimum value of the y coordinate on the cardioid attained? No credit will be given for answers without proper mathematical justification.
- c. [4 points] Write an integral that computes the value of the length of the piece of the cardioid lying below the x -axis.