2. [12 points] Consider a particle whose trajectory in the $xy$-plane is given by the parametric curve defined by the equations

$$x(t) = t^4 - 4t^2, \quad y(t) = t^2 - 2t,$$

for $-3 \leq t \leq 3$. Show all your work to receive full credit.

(a) [3 points] Is there any value of $t$ at which the particle ever comes to a stop? Justify.

(b) [2 points] For what values of $t$ does the path of the particle have a vertical tangent line?

c. [3 points] What is the lowest point $(x, y)$ on the curve?

d. [2 points] At what values of $t$ does the particle pass through the origin?

e. [2 points] The graph of the curve traced by these parametric equations is shown below. Find an expression for the length of the closed loop marked in the graph.