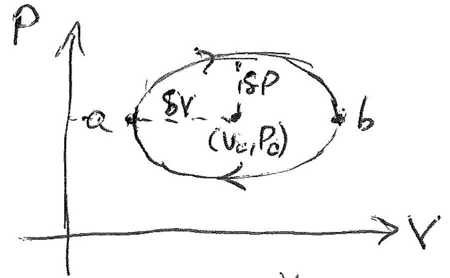
*. (4 points) A particular system executes a cyclical process whose P-V graph is a clockwise-directed ellipse centered at (V_0, P_0) and ~~half~~-radii δV and δP, respectively. Calculate the net work done and the net heat flow into / out of this system during one cycle.



Area of ellipse $= \pi\, \delta V\, \delta P$

$$W_{a\to b} = -\int_{V_a}^{V_b} P\, dV = -(\text{area under top curve})$$
$$= -\left(\tfrac{1}{2}\pi\, \delta V \delta P + P_0 (2\delta V)\right)$$

$$W_{b\to a} = -\int_{V_b}^{V_a} P\, dV = +(\text{area under bottom curve})$$
$$= +\left(-\tfrac{1}{2}\pi\, \delta V \delta P + P_0 (2\delta V)\right)$$

$$W_{cycle} = W_{a\to b} + W_{b\to a} = -\pi\, \delta V \delta P \quad (= -\text{Area of ellipse})$$

net flow of mechanical energy <u>out</u>

$$\Delta E_{int} = W_{cycle} + Q_{cycle} = 0 \quad (\text{cyclic process})$$

$$\Rightarrow Q_{cycle} = -W_{cycle} = +\pi\, \delta V \delta P$$

net flow of heat <u>in</u>

<u>Note</u>: This system is acting as a <u>heat engine</u>, converting heat into work. It <u>cannot</u> be isothermal, since that would violate the 2nd Law of Thermodynamics. It must be the case that more than $\pi\, \delta V \delta P$ amount of heat is drawn from higher temperatures (while the system is at higher temperature) and the excess heat deposited into lower temperatures.