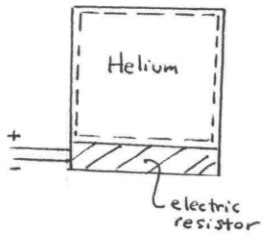
PROBLEM 2.68

KNOWN: Data are provided for helium contained in a closed, rigid tank fitted with an electrical resistance.

FIND: Plot the change in energy of the helium, in kJ, for $t \geq 0$ and comment.

SCHEMATIC & GIVEN DATA:



ENGR. MODEL:

1. The helium is the system.
2. For the system, $\dot{W} = 0$.

ANALYSIS: An energy rate balance reads

$$\frac{dE}{dt} = \dot{Q} - \cancel{\dot{W}}^{0}$$

As the system receives energy by heat transfer from the resistor at a rate of 1 kW and loses energy by heat transfer to its surroundings at the rate of $5t$ W,

$$\dot{Q} = [1000 - 5t]\ \text{W}$$

(t in min.; W/min.)

Thus,

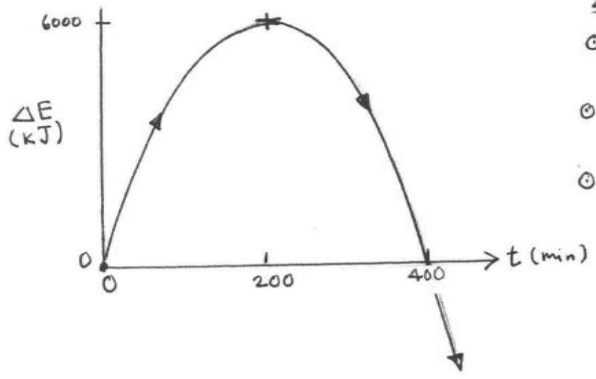
$$\frac{dE}{dt} = 1000 - 5t$$

and

$$\Delta E = \int_0^t \frac{dE}{dt}\,dt = \int_0^t (1000 - 5t)\,dt = \left[1000t - \frac{5t^2}{2}\right] \text{W} \cdot \text{min}$$

$$= \left[1000t - \frac{5t^2}{2}\right] \text{W} \cdot \text{min} \left| \frac{1\ \text{kJ/s}}{10^3\ \text{W}} \right| \left| \frac{60\ \text{s}}{\text{min}} \right| = \left[60t - 0.15t^2\right] \text{kJ}$$

(t in min.)



$\Delta E = E(t) - E(0) = E(t) - E_0$

① 0 → 200 min. Energy increases from the initial value at $t = 0$: E_0.

② 200 → 400 min. Energy decreases to its initial value, E_0.

③ 400 min → . Energy decreases from its initial value, E_0.

Note that since any arbitrary value E_0 can be assigned to the energy of the system at $t = 0$, no particular significance can be attached to the value of energy at the initial state or at any other state. Only changes in the energy of the system have significance.