# Mech 262 - Entropy Tutorial Questions

**6.69** An electric motor operating at steady state draws a current of 10 amp with a voltage of 220 V. The output shaft rotates at 1000 RPM with a torque of 16 N·m applied to an external load. The rate of heat transfer from the motor to its surroundings is related to the surface temperature $T_b$ and the ambient temperature $T_0$ by $\dot{Q} = hA(T_b - T_0)$, where h = 100 W/m²·K, A = 0.195 m², and $T_0$ = 293 K. Energy transfers are considered positive in the directions indicated by the arrows on Fig. P6.69.

(a) Determine the temperature $T_b$, in K.
(b) For the motor as the system, determine the rate of entropy production, in kW/K.
(c) If the system boundary is located to take in enough of the nearby surroundings for heat transfer to take place at temperature $T_0$, determine the rate of entropy production, in kW/K, for the enlarged system.

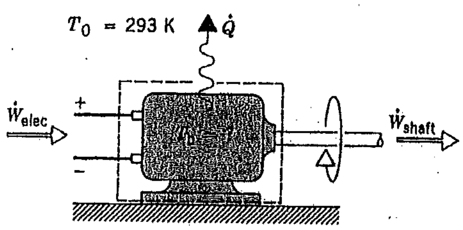



**Figure P6.69**

**6.100** Figure P6.100 shows a proposed device to develop power using energy discharged from a high-temperature industrial process. The figure provides property data for steady-state operation. All surfaces are well insulated except for one at 227°C, through which heat transfer to the steam occurs at a rate of 100 kJ per kg of steam flowing through the device. Ignoring changes in kinetic and potential energy, evaluate the maximum theoretical work that can be developed, in kJ per kg of steam.

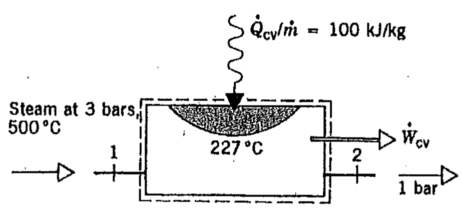



**Figure P6.100**

**6.102** Figure P6.102 shows a 30-ohm electrical resistor located in an insulated duct carrying a stream of air. At steady state, an electric current of 15 amp passes through the resistor, whose temperature remains constant at 28°C. The air enters the duct at 15°C, 1 atm and exits at 25°C with a negligible change in pressure. Kinetic and potential energy changes can be ignored.

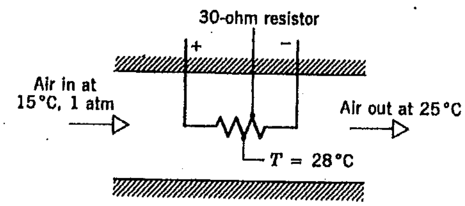



**Figure P6.102**

(a) For the resistor as the system, determine the rate of entropy production, in kW/K.
(b) For a control volume enclosing the air in the duct and the resistor, determine the mass flow rate of the air, in kg/s, and rate of entropy production, in kW/K.

TUTORIAL #1

6.69. $V_{in} = 220$ V

$I = 10$ AMPS.

$n = 1000$ RPM.

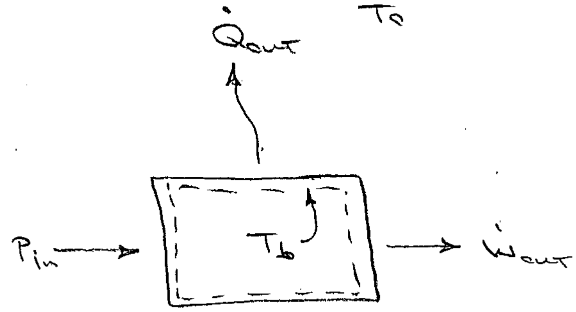
$T = 16$ N-m

$Q_b = hA(T_b - T_o)$

$h = 100$ W/m²-K

$A = 0.195$ m²

$T_o = 293$ K




STEADY STATE ? YES.

RECALL: $0 = Q - W + \cancel{\dot{m}}\left(\Delta h + \frac{\Delta V^2}{2} + \Delta g z\right)$.

OR STORED = IN − OUT = 0

$\therefore$ IN = OUT

$P_{in} = \dot{Q}_{OUT} + \dot{W}_{OUT}$.

$P_{in} = VI = 220 \times 10 = 2200$ Watts.

$\dot{W}_{OUT} = \omega T = \frac{2\pi n}{60} T = \frac{2\pi(1000)}{60}(16) = 1675.5 \ \frac{N\text{-}m}{s} = \frac{J}{s} = W.$

$\therefore$ $Q_{OUT} = P_{in} - \dot{W}_{OUT} = 2200 - 1675.5 = \underline{524.53 \text{ Watts}}$

(OR $Q_{OUT} = -524.53$ W BECAUSE ITS LEAVING THE SYSTEM)

a) $T_b = \frac{Q_b}{hA} + T_o = \frac{524.53}{(100)(0.195)} + 293 = 319.9$ K

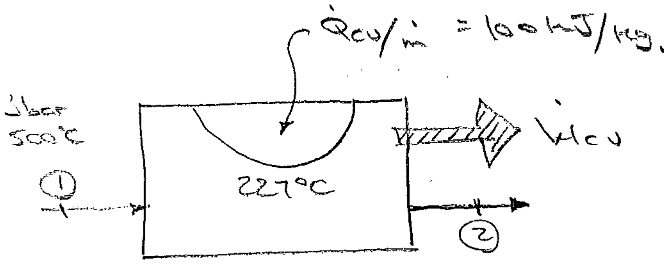
b) $\sigma = ?$ RECALL: $\left(\frac{dQ}{T}\right)_b + \sigma_{cv} = 0.$

$\therefore -\frac{Q_b}{T_b} = \underline{\sigma_{cv.}} = -\frac{-524.53}{319.9} = \underline{1.64 \text{ W/K}}$

c) $T_b = T_o = 293$

THEN $-\left(\frac{dQ}{T}\right)_b = -\frac{Q_b}{T_b} = \sigma_{cv} = -\frac{-524.53}{293} = 1.79$ W/K

P6.100




$$0 = \dot{Q}_{cv} - \dot{W}_{cv} + (h_1 - h_2).$$ ~~$\dot{Q}_{cv} = 100\,kJ/kg + (h_1 - h_2)$.~~

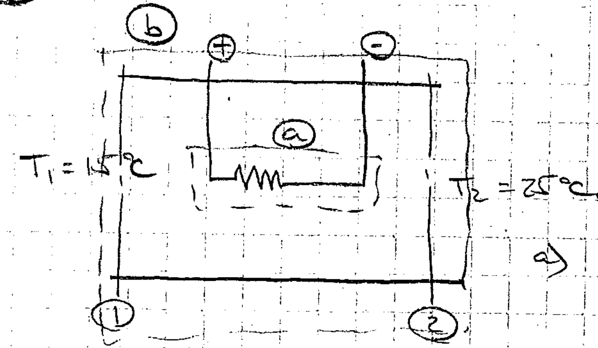
$$0 = \frac{Q}{T} + (S_1 - S_2) + \cancel{\sigma}^{\,0}$$ FOR MAX.

SO $W_{cv} = Q_{cv} + (h_1 - h_2)$.

$$-\frac{Q}{T} = S_1 - S_2$$ FROM THIS GET CONDITION @ 2 THEN GET h

| | T | P | v | h | S | CONDITION |
|---|---|---|---|---|---|---|
| 1 | 500 | 0.3M | | | | |
| 2 | | 0.1M | | | | |

# 6.102




$i = 15$ AMPS.
$R = 30\,\Omega$.
$\Big\}$ $P = i^2 R = 6750$ WATTS $= Q_{RES}$

$T_{RES} = 28\,°C$

a) $0 = -\dfrac{Q_{RES}}{T_{b\,RES}} + \sigma$

$$\sigma = \frac{6.750 \text{ kJ/s}}{28 + 273} = \boxed{0.0224 \text{ kJ/s-K} = \sigma_a}$$

b) $0 = \dot{m}\,(s_1 - s_2) + \sigma$

$\dot{Q}_{RES} = \dot{m}\, C_p\, \Delta T =$

$$\text{so} \quad \dot{m} = \frac{Q_{RES}}{C_p\, \Delta T} = \frac{6.750 \text{ kJ/s}}{1.005 \text{ kJ/kg-K} \times (25 - 15)\,°C} = \boxed{0.6716 \text{ kg/s}}$$

AT 2 $\quad T = 25 + 273 = 298 \text{ K} \rightarrow s_2 = 1.69517 \text{ kJ/kg-K}$

AT 1 $\quad T = 15 + 273 = 288 \text{ K} \rightarrow s_1 = 1.66085 \text{ kJ/kg-K}$.

$$\sigma = -\dot{m}\,(1.66085 - 1.69517) = 0.023 \text{ kJ/s-K}$$

A BIT BIGGER Hmm!