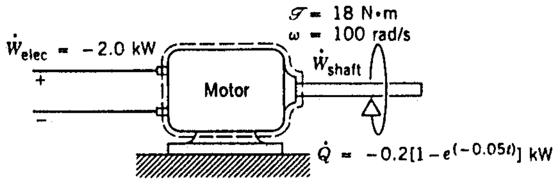
1. (18%) The rate of heat transfer between a certain electric motor and its surroundings varies with time as

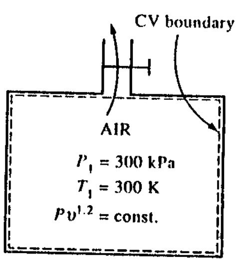
$$\dot{Q} = -0.2\left[1 - e^{(-0.05t)}\right]$$

where t is in seconds and $\dot{Q}$ is in kilowatts. The shaft of the motor rotates at a constant speed of $\omega = 100 \text{rad/s}$, and applies a constant torque of $\Im = 18 \text{N.m}$ to an external load. The motor draws a constant electric power input equal to 2.0 kw as shown. Obtain an expression for the time rate of change of energy of the motor.



2. (12%) A household freezer operates in a room at 20°C. Heat must be transferred from the cold space at a rate of 2 kw to maintain its temperature at -30 °C. What is the theoretically smallest (power) motor required to operate this freezer?

3. (20%) A 1 m^3 rigid tank contains air initally at 300 kpa and 300 k. A valve is opened and air is allowed to escape slowly until the pressure in the tank drops to the atmospheric pressure of 100 kpa. The air in the tank is observed to have undergone a polytropic process ($Pv^n = \text{constant}$) with n = 1.2. Determine the heat transfer for this process. R = 0.287 $\text{kpa.m}^3/\text{kg.k}$



Ideal-gas properties of air

T K	h kJ/kg	P_r	u kJ/kg	v_r	s° kJ/(kg · K)
200	199.97	0.3363	142.56	1707.0	1.295 59
210	209.97	0.3987	149.69	1512.0	1.344 44
220	219.97	0.4690	156.82	1346.0	1.391 05
230	230.02	0.5477	164.00	1205.0	1.435 57
240	240.02	0.6355	171.13	1084.0	1.478 24
250	250.05	0.7329	178.28	979.0	1.519 17
260	260.09	0.8405	185.45	887.8	1.558 48
270	270.11	0.9590	192.60	808.0	1.596 34
280	280.13	1.0889	199.75	738.0	1.632 79
285	285.14	1.1584	203.33	706.1	1.650 55
290	290.16	1.2311	206.91	676.1	1.668 02
295	295.17	1.3068	210.49	647.9	1.685 15
300	300.19	1.3860	214.07	621.2	1.702 03
305	305.22	1.4686	217.67	596.0	1.718 65
310	310.24	1.5546	221.25	572.3	1.734 98
315	315.27	1.6442	224.85	549.8	1.751 06
320	320.29	1.7375	228.42	528.6	1.766 90
325	325.31	1.8345	232.02	508.4	1.782 49
330	330.34	1.9352	235.61	489.4	1.797 83
340	340.42	2.149	242.82	454.1	1.827 90

(背面仍有題目,請繼續作答)

4. (15 %) Consider a Carnot-cycle heat pump having 1 kg of nitrogen gas in a cylinder/piston arrangement. This heat pump operates between reservoirs at 300 K and 400 K. At the beginning of the low-temperature heat addition, the pressure is 1 MPa. During this process the volume triples. Analyze each of the four processes in the cycle and determine

$(Cp_0 = 1.0416\ \text{kJ/kg-K},\quad Cv_0 = 0.7448\ \text{kJ/kg-K},\quad k = 1.4)$

(a) The pressure, volume, and temperature at each point
(b) The work and heat transfer for each process

5. (15%) In an air-standard Otto cycle, all the heat transfer q_H occurs at constant volume. It would be more realistic to assume that part of the q_H occurs after the piston has started to move downward in the expansion stroke. Therefore, consider a cycle identical to the Otto cycle except that the first two-thirds of the total q_H occurs at constant volume and the final one-third occurs at constant pressure.. Assume that the total q_H in this cycle is 2400 kJ/kg, the pressure and temperature at the beginning of the compression process are 100 kPa, 25°C, and the compression ratio is 10. Calculate the maximum pressure and temperature and the thermal efficiency of this cycle, and compare the results with a conventional Otto cycle having the same given variables.

$(Cp_0 = 1.0035\ \text{kJ/kg-K},\quad Cv_0 = 0.7165\ \text{kJ/kg-K},\quad k = 1.4)$

6. (20%) Dteremine the low-pressure Joule-Thomson inversion temperature

$$\lim_{P\to 0} \mu_J = 0$$

as predicted by an equation of state, using the van der Waals equation

$$P = \frac{RT}{v-b} - \frac{a}{v^2} \text{ in which } a = \frac{27}{64}\frac{R^2T_c^2}{P_c},\quad b = \frac{RT_c}{8P_c}.$$