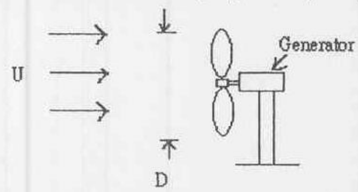
1. A wind turbine is rotating due to a wind of constant velocity U (see Figure). The shaft of the turbine is connected to a generator to produce electricity. The air density is ρ, and temperature T. The turbine has a diameter D and efficiency η, with $\eta < 1$ (due to friction in the gear box, and other sources).



a) (10%) From first principle, find the power that the generator produces.

b) (10%) If you were the engineer for the wind turbine and you are trying to maximize the power output, would you place more emphasis on building a bigger machine or finding a site with stronger wind? You MUST justify your answer based on your result in part a).

2. The ideal gas law is $P = \rho RT$, where P is the pressure, ρ the gas density, R the gas constant, T the temperature. A piston, with frictionless and massless top plate of area A, is pressed down by a weight W (see Figure). Inside the piston is air with mass M, volume V, and temperature T. The outside air has a constant temperature T_0. The initial state of air inside is P_1, ρ_1, T_1.

a) (10%) Consider the situation when the sidewall is NOT insulated, i.e., heat can flow freely through the side-wall. If the weight is increased twice, i.e., to 2W, what is the final volume?

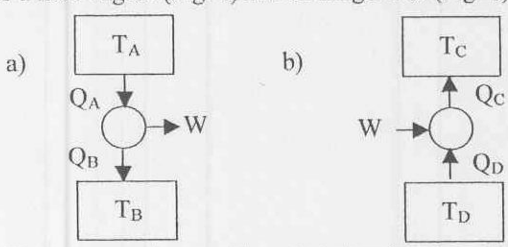
b) (5%) For the case of a), what is the final temperature?

c) (10%) Starting from the initial state, consider the entire system (sidewall and top moveable piston) are all now well insulated, with initial air temperature of $T = T_0$, if the weight is increased twice, i.e., to 2W, what is the final volume? (Hint: you need another thermodynamic principle here.)

d) (10%) For the case of c), what is the final temperature?

e) (15%) Again, starting from the initial state, with initial air temperature of $T = T_0$, heat of amount Q is applied to the air (through the sidewall) and quickly insulated all surface so that no heat loss results, with weight W applied, what is the final volume? (Hint: C_p is the specific heat at constant pressure.)

3. Consider a heat engine (Fig. a) and a refrigerator (Fig. b). Temperature, heat, and work are as shown.



a) (10%) From first and second law, find the efficiency of the heat engine.

b) (10%) From first and second law, find the efficiency of the refrigerator.

c) (10%) Is it possible to combine the heat engine and refrigerator together, i.e., use work out from the heat engine to drive the refrigerator? You MUST explain your answer in thermodynamic terms.

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