

Entropy and the Second Law + Heat Transfer

Question 1 (Entropy & The Second Law)

Steam at 3.0 MPa, 500°C, 70 m/s enters an insulated turbine operating at steady state and exits at 0.3 MPa, 140 m/s. The work developed per kg of steam flowing is claimed to be 667 kJ/kg.

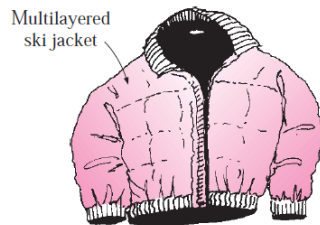
Can this claim be correct? Discuss.

Question 2 (Heat Transfer)

Clothing made of several thin layers of fabric with trapped air in between, often called ski clothing, is commonly used in cold climates because it is light, fashionable, and a very effective thermal insulator. So it is no surprise that such clothing has largely replaced thick and heavy old-fashioned coats.

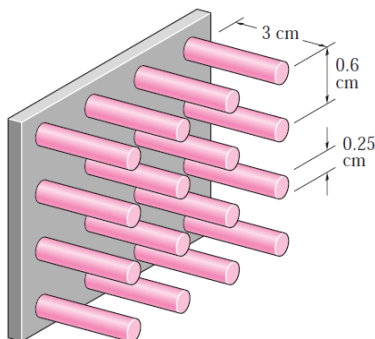
Consider a jacket made of five layers of 0.1-mm-thick synthetic fabric ($k = 0.13 \text{ W/m} \cdot ^\circ\text{C}$) with 1.5-mm-thick air space ($k = 0.026 \text{ W/m} \cdot ^\circ\text{C}$) between the layers. Assuming the inner surface temperature of the jacket to be 28°C and the surface area to be 1.1 m², determine the rate of heat loss through the jacket when the temperature of the outdoors is -5°C and the heat transfer coefficient at the outer surface is 25 W/m² · °C.

What would your response be if the jacket is made of a single layer of 0.5-mm-thick synthetic fabric? What should be the thickness of a wool fabric ($k = 0.035 \text{ W/m} \cdot ^\circ\text{C}$) if the person is to achieve the same level of thermal comfort wearing a thick wool coat instead of a five-layer ski jacket?



Question 3 (Heat Transfer)

A hot surface at 100°C is to be cooled by attaching 17-cm-long, 0.25-cm-diameter aluminum pin fins ($k = 237 \text{ W/m} \cdot ^\circ\text{C}$) to it, with a center-to-center distance of 0.6 cm. The temperature of the surrounding medium is 30°C, and the heat transfer coefficient on the surfaces is 35 W/m² · °C. Determine the rate of heat transfer from the surface for a 1-m × 1-m section of the plate. Also determine the overall effectiveness of the fins.



Question 4 (Heat Transfer)

A 1.5-m-diameter, 4-m-long cylindrical propane tank is initially filled with liquid propane, whose density is 581 kg/m³. The tank is exposed to the ambient air at 25°C in calm weather. The outer surface of the tank is polished so that the radiation heat transfer is negligible. Now a crack develops at the top of the tank, and the pressure inside drops to 1 atm while the temperature drops to -42°C, which is the boiling temperature of propane at 1 atm. The heat of vaporization of propane at 1 atm is 425 kJ/kg. The propane is slowly vaporized as a result of the heat transfer from the ambient air into the tank, and the propane vapor escapes the tank at -42°C through the crack. Assuming the propane tank to be at about the same temperature as the propane inside at all times, determine how long it will take for the tank to empty if it is not insulated.

