

Course Name: Engineering Thermodynamics

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Solved Problems on Second-Law Analysis for a Control Volume

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Q#1. An engine manufacturer claims that he has developed an engine that will produce 210kw of power while taking 0.5kg/min of fuel of C_V of 4200kj/kg. The engine receives heat at 527⁰C and rejects heat at 77⁰C. Find if this claim is true or false.

Q#2. The food compartment of a refrigerator is maintained at 4⁰C by removing heat from it at a rate of 360kj/min. If the required power input to the refrigerator is 2kw, draw a schematic diagram and determine. **(a)** The coefficient of performance of the refrigerator **(b)** the rate of heat rejection to the room.

Q#3. A reversed Carnot cycle operating as a refrigerator has a refrigeration capacity of 1000kj/s. it operates between -20⁰C and 35⁰C. Determine **(a)** Power input, **(b)** (COP)_{rev}, if the system is used for heating purposes, and find its COP. what will be its efficiency if it is used as a heat engine?

Q#4. A domestic food freezer maintains a temperature of -15⁰C. The ambient air temperature is 30⁰C. if heat leaks into the freezer at a continuous rate of 1.75kj/s. What is the least power to pump this heat out continuously?

Q#5. A heat pump is used to meet the heating requirements of a house and maintain it at 20⁰C. on a day when the outdoor air temperature drops to 20C, the house is estimated to lose heat at the rate of 80,000 kJ/hr. if the heat pump under these conditions has a COP of 2.5, determine the power consumed by the heat pump in kw. Compare COP of heat pump if it works on Carnot principle between the same temperature limits.

Q#6. A power cycle operating between two thermal reservoirs receives energy Q_H by heat transfer from a hot reservoir at $T_H = 2000$ K and rejects energy Q_C by heat transfer to a cold reservoir at $T_C = 400$ K. For each of the following cases determine whether the cycle operates reversibly, operates irreversibly, or is impossible.

Q#7. Consider the heat engine that receives a heat transfer rate of 1 MW at a high temperature of 550⁰C and rejects energy to the ambient surroundings at 300 K. Work is produced at a rate of 450 kW. We would like to know how much energy is discarded to the ambient surroundings and the engine efficiency and compare both of these to a Carnot heat engine operating between the same two reservoirs.

Q#8. A 600-MW steam power plant, which is cooled by a nearby river, has a thermal efficiency of 40 percent. Determine the rate of heat transfer to the river water. Will the actual heat transfer rate be higher or lower than this value? Why?

Q#9. A steam power plant with a power output of 150 MW consumes coal at a rate of 60 tons/h. If the heating value of the coal is 30,000 kJ/kg, determine the overall efficiency of this plant.

Q#10. A household refrigerator that has a power input of 450 W and a COP of 1.5 is to cool 5 large watermelons, 10 kg each, to 8⁰C. If the watermelons are initially at 28⁰C, determine how long it will take the refrigerator to cool them. The watermelons can be treated as water whose specific heat is 4.2 kJ/kg·°C. Is your answer realistic or optimistic? Explain.

Q#11. An inventor claims to have developed a heat engine that receives 700 kJ of heat from a source at 500 K and produces 300 kJ of a network while rejecting the waste heat to a sink at 290 K. Is this a reasonable claim? Why?

Q#12. A Carnot heat engine operates between a source at 1000 K and a sink at 300 K. If the heat engine is supplied with heat at a rate of 800 kJ/min, determine **(a)** the thermal efficiency and **(b)** the power output of this heat engine.

Q#13. A coal-burning steam power plant produces net power of 300 MW with an overall thermal efficiency of 32 percent. The actual gravimetric air-fuel ratio in the furnace is calculated to be 12 kg air/kg fuel. The heating value of the coal is 28,000 kJ/kg. Determine **(a)** the amount of coal consumed during 24 hours and **(b)** the rate of air flowing through the furnace.

Q#14. A heat pump that is used to heat a house has a COP of 2.5. That is, the heat pump delivers 2.5 kWh of energy to the house for each 1 kWh of electricity it consumes. Is this a violation of the first law of thermodynamics? Explain.

Q#15. You are an engineer in an electric-generation station. You know that the flames in the boiler reach a temperature of 1200 K and that cooling water at 300 K is available from a nearby river. What is the maximum efficiency your plant will ever achieve?

Q#16. Someone proposes that the entire refrigerator/freezer requirements of a store be met using a large freezer that supplies sufficient cold air at -20°C instead of installing separate refrigerators and freezers. What do you think of this proposal?