Class test (CH21201) 11th Nov. 2022

Q1. A heat engine takes heat from a hot reservoir and rejects heat to cold thermal reservoir (maintained at temperature 280 K). The heat engine has a thermal efficiency (first law efficiency) of 25 percent and a second-law efficiency of 50 percent.

a) Determine the temperature of the hot reservoir that supplies heat to this engine.

b) Is heat engine working reversibly or irreversibly? (provide mathematical support to your answer).

c) Find out the lost work (in Watt) if the energy input to heat engine 1000 kW.

d) Find out the rate of entropy generation (in Watt) due to the imperfect design of engine, if the energy input to heat engine 1000 kW. Consider the cold thermal reservoir (280K) as environment.

(10+4+4+2)

Hint: second law efficiency is defined as the **ratio** of **actual work output by a device** is to **work output if device would have been worked in a reversible manner**, keeping **the energy input to device** *same for both scenarios (actual and reversible).*

(Second law of efficiency= work output in actual condition/work output in reversible condition, **for same input energy to device**).

Keep in mind that heat engine is a cyclic device, so property change over the cyclic process is always zero

Class Test 1

Time: 40 minutes

Date: 08/02/2023

Full Marks: 20

1. A 3 cm diameter sphere containing hot liquid at 180^0C is to be insulated to reduce the heat loss to the ambient ($h=2W/m^2C$) at 30^0C. If fiberglass [$k=0.04 W/m(^0C)$] is selected as the insulating material, compare the heat losses when the sphere is covered with the critical radius of insulation and when the sphere does not have an insulation. Please provide the derivation for critical radius of insulation for a sphere. **(10)**

2. Heat is generated uniformly at a rate of 500 MW/m^3 in a SS plate (k =20 W/m.°C) of thickness 1 cm. Derive an expression for the temperature profile in the plate when the two sides of the plate are maintained at 100 °C and 200 °C. Also estimate the temperature at the center of the plate. Mention all assumptions. **(10)**

The generalized heat conduction equation in Cartesian, cylindrical and spherical coordinates

$$\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}+\frac{\partial^2 T}{\partial z^2}+\frac{\dot{q}}{k}=\frac{1}{\alpha}\frac{\partial T}{\partial t}$$

$$\frac{\partial^2 T}{\partial r^2}+\frac{1}{r}\frac{\partial T}{\partial r}+\frac{1}{r^2}\frac{\partial^2 T}{\partial \phi^2}+\frac{\partial^2 T}{\partial z^2}+\frac{\dot{q}}{k}=\frac{1}{\alpha}\frac{\partial T}{\partial t}$$

$$\frac{1}{r^2}\frac{\partial^2 (rT)}{\partial r^2}+\frac{1}{r^2 \sin\theta}\frac{\partial}{\partial \theta}\left(\sin\theta\frac{\partial T}{\partial \theta}\right)+\frac{1}{r^2 \sin^2\theta}\frac{\partial^2 T}{\partial \phi^2}+\frac{\dot{q}}{k}=\frac{1}{\alpha}\frac{\partial T}{\partial t}$$

Class Test 2

Time: 45 minutes

Date: 21/03/2023 at 5 p.m.

Full Marks: 25

1. Evaluate the effectiveness of a fin (k=500 W/m K) of 5 mm diameter and 250 mm length. The fin can be assumed to adiabatic at the end and the heat-transfer coefficient is 250W/m^{2}K. (5)

2. Oil with flow rate of 1000 kg/hr. and temperature of 80°C is to be cooled to 50°C. A double pipe heat exchanger is used where cooling water enters the tube at 30°C and exits at 45°C. Assuming the overall heat transfer coefficient to be 0.2kW/m^2(K) and specific heat of oil and water as 2kJ/kg (K) and 4.2kJ/kg (K) respectively, estimate the percentage saving in the heat transfer area for counter w.r.t co current flow of the two liquids. (10)

3. An aluminum rod 5.0 cm in diameter and 15 cm long protrudes from the wall that is maintained at 250°C. The rod is exposed to an environment at 25°C. The convection heat-transfer coefficient is 12 W/m^2 (°C). Calculate (i) the heat lost by the rod (ii) the temperature profile in the rod. (5+5)

$\kappa A d\theta = hA($