GX660

OLLSCOIL NA hÉIREANN

The National University of Ireland

National University of Ireland, Galway.

Trinity Examinations, 1998/99.

First Year Mechanical & Biomedical Engineering Examination

THERMODYNAMICS

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Attempt *Three* Questions
Time allowed: 2 Hours

The following are available:

Copies of Property Tables A-1 to A-8, A11 to A-13, A15 to A-17, and Figures A-9, A-10, and A-14 from Thermodynamics – An Engineering Approach by Cengel and Boles.

1(a) Although balloons have been around since 1783 when the first balloon took to the skies in France, a real breakthrough in ballooning occurred in 1960 with the design of the modern hot air balloon fuelled by inexpensive propane and constructed of lightweight nylon fabric. Unlike balloons filled with helium gas, hot-air balloons are open to the atmosphere. Therefore, the pressure in the balloon is always the same as the local atmospheric pressure, and the balloon is never in danger of exploding. Consider a 20-m diameter hot-air balloon, which, together with its cage, has a mass of 80 kg when empty. The balloon is hanging still in the air at a location where the atmospheric pressure and temperature are 90 kPa and 15 °C, respectively, while carrying three 65-kg people. Determine :

(i) the buoyancy force in the balloon, (5)
(ii) the mass of air in the balloon, and (5)
(iii) the average temperature of the air in the balloon (5)

1 (b) The pressure in a car tyre depends on the temperature of the air in the tyre. When the air temperature is 25 °C, the pressure gauge reads 150 kPa (gauge). Assume atmospheric pressure is 100 kPa.

(i) If the volume of the tyre is 0.025 m^3, determine the pressure rise in the tyre when the air temperature in the tyre rises to 50 °C. (7)
(ii) Also determine the amount of air that must be bled off to restore pressure to its original value at this temperature. (8)

2(a) Write a mathematical equation for the first law of thermodynamics for a "closed system" ? Label all variables used. (5)

(b) The radiator of a steam heating system has a volume of 20 L and is filled with superheated vapour at 300 kPa and 250 °C. At this moment both the inlet and exit valves to the radiator are closed.

(i) What is the mass of steam in the radiator ? (5)
(ii) Determine the 'quality' and the amount of heat (in kJ) that will be transferred to the room when the steam pressure drops to 100 kPa. (15)
(iii) Draw a schematic diagram of the system and show the process on a P-v diagram with respect to saturation lines. (5)

3. Steam enters a small electric power plant turbine steadily at 10 MPa and 550 °C with a velocity of 60 m/s and leaves at 25 kPa with a quality of 95%. A heat loss to the surroundings of 30 kJ/kg occurs during the process. The inlet area of the turbine is 150 cm^2, and the exit area is 1400 cm^2.

(a) Draw a schematic diagram of the system. (4)

(b) Determine :

(i) the mass flowrate of steam in kg/s, (8)
(ii) the exit velocity in m/s, and (8)
(iii) using the First Law of Thermodynamics for "open control volumes", the power output in kW. (10)

4(a) What are the three modes of heat transfer ?
Write a mathematical equation for each mode, and label all the variables used in the equations. (15)

(b) It is well known that wind makes the cold air feel much colder as a result of the 'wind-chill' effect, which is due to the increase in convection heat transfer coefficient as a result of the increase in air velocity. The wind-chill effect is usually expressed in terms of the wind-chill factor, which is the difference between the actual air temperature and the equivalent calm-air temperature.
For heat transfer purposes, a standing person can be modelled as a 30-cm diameter, 170-cm long vertical cylinder with both the top and bottom surfaces insulated and with the side surface at an average temperature of 34 °C.

(i) For a convection heat transfer coefficient 15 W/m^2-°C, determine the rate of heat loss from this person by convection in still air at 20 °C. (5)
(ii) What would your answer be if the convection heat transfer coefficient were increased to 50 W/m^2-°C as a result of winds ? (5)
(iii) What is the wind-chill factor in this case ? (5)