ENGINEERING 2C3 Assignment #6 SOLUTION

1. [Serway Chapter 22 Problem 2, pg 640]
A heat engine performs 200 J of work in each cycle and has an efficiency of 30%. For each cycle, how much thermal energy is
a. absorbed and
b. expelled?

Solution:

a. Efficiency = e = 0.3 = 1 - Q_c/Q_h = W / Q_h.
Therefore, Q_h = 200 J / 0.3 = 666.7 J.

b. Q_c = Q_h - W = 466.7 J.

2. [Serway Chapter 22 Problem 8, pg 640]
A heat engine operates between two reservoirs at 20°C and 300°C. What is the maximum efficiency possible for this engine?

Solution:

e_{max} = 1 - (20+273.15) / (300+273.15) = 0.488

3. [Serway Chapter 22 Problem 12, pg 640]
A heat engine operates in a Carnot cycle between 80°C and 350°C. It absorbs 2.0 x 10^4 J of thermal energy per cycle from the hot reservoir. The duration of each cycle is 1.0 s.
a. What is the maximum power output of this engine?
b. How much thermal energy does it expel in each cycle?

Solution:

a. Q_h = 2.0x10^4 J
e = 1 - (80+273.15)/(350+273.15) = .4333
therefore, W = 0.4333 x 2.0x10^4 J = 8665 J per cycle
therefore, Power = 8.665 kJ/cycle x 1 cycle/s = 8.665 kW

b. Q_c = Q_h - W = 2.0x10^4 J - 8665 J = 11,334 J

4. [Serway Chapter 22 Problem 15, pg 641]
The efficiency of a 1000 MW nuclear power plant is 33%; that is, 2000 MW of heat is rejected to the environment for every 1000 MW of electrical energy produced. If a river of flow rate 10^6 kg/s were used to transport the excess thermal energy away, what would be the average temperature increase of the river?

Solution:

An energy balance on a segment of the river yields:
2000 MW = 2000 MJ/s = 2x10^6 kJ/s
= flow (kg/s) x heat capacity (kJ/kg/°C)x)T(°C)
= 10^6 kg/s x 4.186 kcal/kg x)T(°C)
Therefore,)T = 2 x 10^6 / (10^6 x 4.186) = 0.478 °C

5. [Serway Chapter 22 Problem 20, pg 641]

A gasoline engine has a compression ratio of 6 and uses a gas for which $\gamma = 1.4$.

a. What is the efficiency of the engine if it operates in an idealized Otto cycle?

b. If the actual efficiency is 15%, what fraction of the fuel is wasted as a result of friction and unavoidable heat losses? (Assume complete combustion of the air-fuel mixture.)

Solution:

a. $e_{max} = 1 - 1/(V_1/V_2)^{(-1} = 1 - 1/(6)^{0.4} = 0.512$

b. $e_{actual} = 0.15$, thus if $Q_h = 1$, then 0.15 is used for work and 0.85 is rejected or wasted. Compare this to the maximum efficiency situation where 0.512 is used and 0.488 is wasted: the extra waste caused by friction and other unavoidable losses is 0.85 - 0.488 = 0.362. Thus, the extra wastage is 36.2%.

6. [Serway Chapter 22 Problem 25, pg 641]

A refrigerator has a coefficient of performance equal to 5. If the refrigerator absorbs 120 J of thermal energy from a cold reservoir in each cycle, find

a. the work done in each cycle and

b. the thermal energy expelled to the hot reservoir.

Solution:

a. $COP = Q_c / W$, therefore $W = Q_c / COP = 120/5 = 24$ J.

b. $W = Q_h - Q_c$, therefore, $Q_h = 24 + 120 = 144$ J.