gy in the universe available for

bility of energy. Perhaps it is be a negative concept. This ducing the negative of entropy gy is usually introduced when otential or velocity potential.* the nature of entropy; it will rder in the universe and to the articles of a system.

amics may be summarized as

nstant. $\delta Q - \delta W$ is an exact f a system is a function of its

g. $\delta Q/T$, in a reversible process, S of a system is also a function

e the specific heat capacity c in es/gm-deg at each temperature. Should one conclude from this that s not constant? Explain.

. Explain why you would not invest the development of an engine for ich the inventor claimed either of following sets of data: (a) $T_2 =$ °K, $T_1 = 300$°K, $Q_2 = 20{,}000$ les, $Q_1 = 15{,}000$ joules, $W =$ 000 joules, or (b) $T_2 = 400$°K, $= 300$°K, $Q_2 = 20{,}000$ joules, $Q_1 =$ 000 joules, $W = 10{,}000$ joules.

5. A Carnot engine operates between $= 500$°K and $T_1 = 300$°K. Compute the increase in efficiency when (a) is increased 10% (or 50°), (b) T_1

is decreased 10% (30°), (c) T_1 is decreased 50°.

6. A Carnot refrigerator is operated between 250°K and 300°K and requires 250 joules of work per cycle. Find (a) the heat absorbed from the low-temperature reservoir, (b) the heat ejected at the higher temperature, (c) the coefficient of performance.

7. A refrigerator operates between 250°K and 300°K, requiring 250 joules of work per cycle, but it has only one-half the coefficient of performance of the Carnot refrigerator in problem 6. Find the heat absorbed from the cold box and the heat ejected into the room, per cycle.

8. Compute the net gain in entropy, ΔS_u, per cycle (a) in problem 6, (b) in problem 7.

9. A reversible engine takes in 2000 joules from a reservoir at 400°K; it then gives up Q_1' joules to a reservoir at 300°K and Q_1 joules to a reservoir at 200°K, doing 750 joules of work per cycle. (a) Compute the efficiency and compare with that of a Carnot engine working between 400°K and 200°K. (b) Find Q_1' and Q_1. (c) Draw the cycle on a p-V diagram. (d) Find the entropy change per cycle of each reservoir and that of the universe.

10. A 1-kg stone at 27°C falls 102 meters into a lake whose temperature is 27°C. Find the entropy change of (a) the stone, (b) the lake, and (c) the universe.

11. Repeat problem 10 for the case where the stone is lowered reversibly into the lake. Compare the loss in available energy in the two cases.

12. Compute the entropy per kilogram-mole of ice at −20°C relative to that of water at 0°C, using $\bar{C} = 37{,}500$ joules/kg-mole-deg and, for the heat to melt ice, $L_f = 6 \times 10^6$ joules/kg-mole.

13. A kilogram-mole of an ideal gas is compressed reversibly at constant T to half its original volume. Compute the change in entropy of (a) the gas, (b) the surroundings, and (c) the universe.

14. Repeat problem 13 for the cycle consisting of a reversible compression to half volume followed by a free expansion back to the original volume.

15. Draw a Carnot cycle on a T-S diagram.

(5) (Constant 2.9)

$Q_2 = 2000\,[J]$ Takes in 2000 [J] from reservoir

$T_2 = 400\,[K]$ at 400 [K]

Then gives up Q_1' to reservoir @ 300[K] &

Q_1 to reservoir @ 200 [K], doing

750 [J] of work per cycle.

For the complete cycle, $U_a = U_b$, net heat taken is

$$Q = \sum \delta Q = Q_2 - Q_1' - Q_1 = W$$

(a) $$\eta = \frac{W}{Q_2} = \frac{Q_2 - Q_1' - Q_1}{Q_2} = \frac{750}{2000} = \frac{3}{8}$$

$$\eta_{carnot} = \frac{T_2 - T_1}{T_2} = \frac{200}{400} = \frac{1}{2} = \frac{4}{8} \qquad \eta_{carnot} > \eta$$

(b) $$2000\,[J] - Q_1' - Q_1 = 750\,[J]$$

$$\sum \frac{\delta Q}{T} = \sum \frac{\delta Q'}{T} = 0$$

$$\frac{Q_2}{T_2} - \frac{Q_1'}{T_1'} - \frac{Q_1}{T_1} = 0 \qquad Q_2 - Q_1' - Q_1 = W$$

$$Q_1' = Q_2 - Q_1 - W \Rightarrow \frac{Q_2}{T_2} - \frac{(Q_2 - Q_1 - W)}{T_1'} - \frac{Q_1}{T_1} = 0$$

$$Q_1 = \frac{T_1(T_2 W + Q_2(T_1' - T_2))}{T_2(T_1' - T_1)} \qquad T_1 = 200\,[K] \quad T_1' = 300\,[K]$$

$$= \boxed{500\,[J]}$$

$$Q_1' = Q_2 - Q_1 - W = \boxed{750\,[J]}$$