**Chapter 21**

1. During each cycle, a refrigerator ejects 625 kJ of energy to a high-temperature reservoir and takes in 550 kJ of energy from a low-temperature reservoir. Determine (a) the work done on the refrigerant in each cycle and (b) the coefficient of performance of the refrigerator.

Solution:

2. One of the most efficient heat engines ever built is a coal-fired steam turbine in the Ohio River valley, operating between 1 870°C and 430°C. (a) What is its maximum theoretical efficiency? (b) The actual efficiency of the engine is 42.0%. How much mechanical power does the engine deliver if it absorbs 1.40 x 105 J of energy each second from its hot reservoir?

Solution:

3. A gasoline engine has a compression ratio of 6.00. (a) What is the efficiency of the engine if it operates in an idealized Otto cycle? (b) What If? If the actual efficiency is 15.0%, what fraction of the fuel is wasted as a result of friction and energy transfers by heat that could be avoided in a reversible engine? Assume complete combustion of the air–fuel mixture.

Solution:

**Chapter 22**

1. (a) Find the magnitude of the electric force between a Na+ ion and a Cl- ion separated by 0.50 nm. (b) Would the answer change if the sodium ion were replaced by Li+ and the chloride ion by Br-? Explain.

Solution:

A diagram of a line with a ball and a number of problems

Description automatically generated2. Two small beads having positive charges q1 = 3q and q2 = q are fixed at the opposite ends of a horizontal insulating rod of length d = 1.50 m. The bead with charge q1 is at the origin. As shown in Figure P22.7, a third small, charged bead is free to slide on the rod. (a) At what position x is the third bead in equilibrium? (b) Can the equilibrium be stable?

Solution:

**Solutions for Chapter 21**

1. During each cycle, a refrigerator ejects 625 kJ of energy to a high-temperature reservoir and takes in 550 kJ of energy from a low-temperature reservoir. Determine (a) the work done on the refrigerant in each cycle and (b) the coefficient of performance of the refrigerator.

Solution:

(a) The work done on the refrigerant in each cycle is



(b) The coefficient of performance of a refrigerator is:



Solving numerically:



2. One of the most efficient heat engines ever built is a coal-fired steam turbine in the Ohio River valley, operating between 1 870°C and 430°C. (a) What is its maximum theoretical efficiency? (b) The actual efficiency of the engine is 42.0%. How much mechanical power does the engine deliver if it absorbs 1.40 x 105 J of energy each second from its hot reservoir?

Solution:

We use the Carnot expression for maximum possible efficiency, and the definition of efficiency to find the useful output. The engine is a steam turbine in an electric generating station with



(a) 

(b) 

for one second of operation, so



and the power is



3. A gasoline engine has a compression ratio of 6.00. (a) What is the efficiency of the engine if it operates in an idealized Otto cycle? (b) What If? If the actual efficiency is 15.0%, what fraction of the fuel is wasted as a result of friction and energy transfers by heat that could be avoided in a reversible engine? Assume complete combustion of the air–fuel mixture.

Solution:

Compression ratio = 6.00, *γ* = 1.40

(a) Efficiency of an Otto engine: 



(b) If actual efficiency *e’* = 15.0%, the fraction of fuel wasted is (assuming complete combustion of the air-fuel mixture) .

**Solutions for Chapter 22**

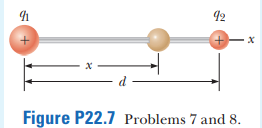
1. (a) Find the magnitude of the electric force between a Na+ ion and a Cl- ion separated by 0.50 nm. (b) Would the answer change if the sodium ion were replaced by Li+ and the chloride ion by Br-? Explain.

Solution:

(a) The two ions are both singly charged, , one positive and one negative. Thus,



1. No. The electric force depends only on the magnitudes of the two charges and the distance between them.

2. Two small beads having positive charges q1 = 3q and q2 = q are fixed at the opposite ends of a horizontal insulating rod of length d = 1.50 m. The bead with charge q1 is at the origin. As shown in Figure P22.7, a third small, charged bead is free to slide on the rod. (a) At what position x is the third bead in equilibrium? (b) Can the equilibrium be stable?

Solution:

(a) Let the third bead have charge *Q* and be located distance *x* from the left end of the rod. This bead will experience a net force given by

, where *d* = 1.50 m

The net force will be zero if , or .

This gives an equilibrium position of the third bead of

*x* = 0.634*d* = 0.634(1.50 m) = 

(b)  The equilibrium would be stable because if charge *Q* were displaced either to the left or right on the rod, the new net force would be opposite to the direction *Q* has been displaced, causing it to be pushed back to its equilibrium position.