Heat and Thermodynamics Supplementary Questions

Study Guide 23

Part 1 - Specific Heat Capacity

Unless otherwise stated, use 4200 J kg^{-1} K^{-1} as the specific heat capacity of water.

1. How much energy would be required to heat 2.0 kg of cooking oil from 20 °C to 50 °C, if the specific heat capacity of cooking oil is 2300 J kg^{-1} K^{-1}.

2. Calculate the heat energy required to raise the temperature of a 3.5 kg lump of steel by 23.4 °C if the specific heat capacity of steel is 510 J kg^{-1} K^{-1}.

3. When 60 J of heat energy is added to a mass of copper, the temperature of the copper increases by 10.4 °C. The specific heat capacity of copper is 385 J kg^{-1} K^{-1}. What mass of copper was heated?

4. Calculate the heat energy radiated by a 750 kg bath of water if the water decreases from 60 °C to 25 °C. The specific heat capacity of water is 4200 J kg^{-1} K^{-1}.

5. An instant hot water heater is capable of raising the temperature of 2.5 kg of water by 45 K each minute. Using c_{water} = 4200 J kg^{-1} K^{-1}, determine the power rating of the water heater.

6. How long would it take a 2.4 kW heater to warm the air in a room from 6 °C to 21 °C? The dimensions of the room are 5m by 7 m by 2.5 m, the density of air is 1.2 kg/m^3 and the specific heat capacity of air is 1100 J kg^{-1} K^{-1}.

7. A squash ball of mass 50 g is struck so that it hits a wall at a speed of 35 m/s. If the ball rebounds with a speed of 25 m/s, determine:
   i) the impulse applied to the ball by the wall;
   ii) the loss of kinetic energy of the ball;
   iii) the rise in temperature of the ball, if the specific heat capacity of rubber is 1880 J kg^{-1} K^{-1}.

8. A solid metal block of mass 4.0 kg is heated for 8 minutes exactly by an electric heater. A p.d. of 14 V is applied across the heater, and the current flowing through the heater is recorded as 2.5 A. If the temperature of the block rises by 17 K, calculate the specific heat capacity of the metal.

9. Determine the change in temperature of water flowing down a 25 m high waterfall if the kinetic energy of the water at the bottom is entirely converted into internal energy.

10. 45 g of water at 13 °C is placed in a metallic calorimeter which weighs 0.12 kg. An electrical heater is immersed in the water. With 7.5 V across the heater producing a current of 1.1 A for exactly 5.5 minutes, a final temperature of 25 °C was achieved. Determine an experimental value for the specific heat capacity of water.

11. A car of mass 1350 kg moving at 25 m/s is slowed down to rest 3 times. If 65% of the car's kinetic energy is retained by the car's brake discs, what is their rise in temperature if each of the four brake discs has a mass of 2 kg? The specific heat capacity of the brake disc metal is 435 J kg^{-1} K^{-1}.

12. In an experiment to measure the specific heat capacity of water, a student used an electrical heater to heat some water. Calculate a value for the specific heat capacity of water given that his results were:

- mass of beaker: 150 g;
- mass of beaker and water: 672 g;
- current in the heater: 3.9 A;
- p.d. across the heater: 11.4 V;
- initial temperature: 18.5 °C;
- final temperature: 30.2 °C;
- time taken: 13.0 minutes.

13*. A length of wire of heat capacity 15 J/K has a p.d. of 6.0 V applied between its ends, so that a current of 0.25 A flows. Compute the temperature increase of the wire produced in 2 minutes.

14*. A hot drinks machine has a water tank of capacity 8 litres. The manufacturer claims that the machine can produce 50 cups of boiling water at any one time. Determine:

i) the volume of a cup;

ii) the power rating of the machine's heater if 190 cups can be produced in one hour, if the water initially enters the tank at 20 °C.

15*. A power plant expels waste energy at a rate of 750 MW by heating a river which flows past it. The river is 25 m wide, 4 m deep and flows at an average speed of 0.9 m/s. By how much does the river's temperature increase due to the power plant's waste energy?

16*. An electric kettle has a heating element with a heat capacity of 500 J/K and power rating of 2.5 kW. Determine the rise in temperature per minute when the kettle is heating 1.2 kg of water.

17*. A lump of metal of mass 100 g is left in boiling water for a long time. It is then transferred to a can, of mass 25g made from the same metal, containing 120 g of water at 20.0 °C. The can is well-insulated and the final temperature of it and its contents settles at 28.0 °C. Find:

i) the heat gained by the water;

ii) in terms of c, the specific heat capacity of the metal, the heat gained by the can;

iii) in terms of c, the specific heat capacity of the metal, the heat lost by the lump of metal;

iv) the specific heat capacity of the metal.

18*. Determine the final temperature when 250 g of water at 50 °C is mixed with 100 g of water at 10°C.

19*. 22 g of liquid at 65 °C is mixed into 120 g of water at 10 °C. Given that the specific heat capacity of the liquid and the water are 4000 J kg^{-1} K^{-1} and 4200 J kg^{-1} K^{-1} respectively, determine the temperature of the liquid-water mix when thermal equilibrium is reached.

20*. A small engine is cooled by water flowing through it. Water enters the engine internal water galleries at 20 °C and leaves it at 22 °C, removing heat at a rate of 70 W. At what rate does water flow through the engine?

21**. m_1 kg of a first liquid at T_1 K is mixed with m_2 kg of a second liquid at T_2 K, where $T_1 > T_2$. The specific heat capacities of the first and second liquids are c_1 J kg^{-1} K^{-1} and c_2 J kg^{-1} K^{-1} respectively. Determine, in terms of the parameters of the liquids, the temperature of the mix when thermal equilibrium is reached. What key assumption has been made in order to determine this final temperature?

Answers - Heat and Thermodynamics Supplementary Questions

Part 1

1. 1.38×10^5 J
2. 4.18×10^4 J
3. 0.0150 kg
4. 1.10×10^8 J
5. 7880 W
6. 722 s
7. i) 3 kg m/s ii) 15 J iii) 0.160 K
8. 247 J kg^{-1} K^{-1}
9. 0.0584 K
10. 5040 J kg^{-1} K^{-1}
11. 236 K
12. 5680 J kg^{-1} K^{-1}
13*. 12 K
14*. i) 1.6×10^{-3} m^3 ii) 2.84 kW
15*. 1.98 K
16*. 27.1 K/min
17*. i) 4032 J ii) 0.2c iii) 7.2c iv) 576 J kg^{-1} K^{-1}
18*. 38.6 °C
19*. 18.2 °C
20*. 0.00833 kg/s
21**. $T = \dfrac{m_1c_1T_1 + m_2c_2T_2}{m_1c_1 + m_2c_2}$