PH2202 Thermal Physics
Fall Semester - 2024
Indian Institute of Science Education and Research, Kolkata
Instructor: Koushik Dutta

Homework: 6 Submission Date: 09/04/2024

The hand written solutions must be submitted at the start of the tutorial.

1. For this problem, let us agree with the following convention: If heat is exchanged from several reservoir and some total work is being done by an engine in a cyclic process, we will use $Q_1 + Q_2 + Q_3 + Q_4 .. = W$ instead of $Q_1 - Q_2 - Q_3 + Q_4 + .. = W$ with the understanding if heat goes inside the engine, it is positive, and if heat goes out of the engine, it is negative.

   (a) Consider a heat engine that is interacting with only one reservoir at temperature. From Clausius inequality, prove the Kelvin-Planck statement of the 2nd Law.

   (b) Consider a heat engine that is connected with two reservoirs at temperature T_1 ad T_2 with $T_1 > T_2$ with no work source. From Clausius inequality, prove the Clausius statement of the 2nd Law.

   (c) From Clausius inequality, prove the Carnot's theorem, i.e for a two reservoir system $\eta \leq 1 - \frac{T_2}{T_1}$.

   In fact, the most general result is the following:
   The efficiency of any engine (other than a Carnot engine) running in an arbitrary cycle is always less than that of a Carnot engine running between reservoirs at the maximum and minimum temperatures attained during the cycle, i.e

$$\eta \leq 1 - \frac{T_{\min}}{T_{\max}} \ . \tag{1}$$

2. Find the equation of state of a system for which Gibbs free energy $G = 0$.

3. Find out the Gibbs free energy for black body radiation. Using the results of the above problem it shows that pressure depends only on the temperature.

4. The density of iodine at the boiling point (458.3 K) is 3.71 g/c.c. and latent heat of vaporisation is 40.9 cal/g. If the boiling point changes by 1 degree C for a change of pressure of 17 mm of Hg, find the specific volume of vapour.

5. The vapur-exit tube of a pressure cooker has a radius of 2 mm and is closed by a mass of 140 g fitted at its mouth. What is the boiling point of water inside the cooker? Latent heat of vaporisation of water = 540 cal and specific volume of water vapour is 1674 c.c.

6. Show that for an ideal gas chemical potential $\mu = \mu_0(T) + RTln(p/p_0)$ where μ_0 is the chemical potential at pressure p_0.

7. Show that for a van der Waals gas, $C_p - C_V \simeq R(1 + \frac{2a}{RTV})$ with necessary justifiable approximations.