1. Below in Fig. 1, the heat flow in a system is described. Determine the temperature T at the given point as the temperature on the other side of the system changes from T_1 to T_2 using an equivalent electrical circuit.

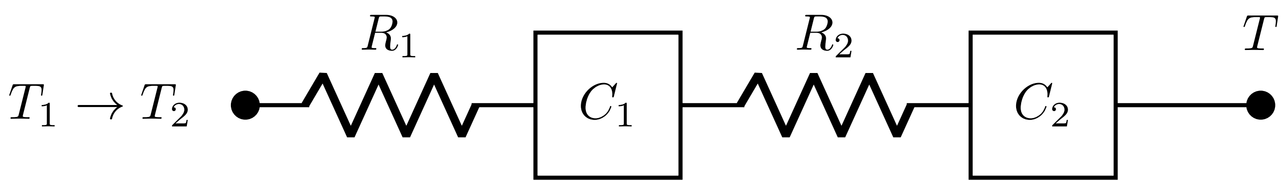

Figure 1: Schematic of a heat flow in a system.

2. A Pomeranchuk cooling chamber is cooled down to 2.2 mK and that temperature is held constant for 24 hours. The heat leak is 4×10^{-7} J/min and let us assume that the chamber was precooled to 20 mK. Approximate how much Helium-3 is required to perform this type of a process.

   The entropies of solid and liquid 3He on the melting curve are

$$\frac{S_s}{R} = \ln 2 - \frac{3}{2}\left(\frac{J}{kT}\right)^2; \quad T \geq 2\,\mathrm{mK}, \quad \frac{J}{k} = -0.72\,\mathrm{mK} \tag{1a}$$

$$\frac{S_l}{R} = 4.6\frac{T}{K}; \quad T \leq 20\,\mathrm{mK}. \tag{1b}$$

3. Enthalpies and pressures of Helium-3 liquid and vapor are presented below in Table 1. Describe how enthalpy is related to evaporation cooling. Derive an expression for the supplied heat flow $\dot{Q}$ in an idealized evaporation scheme where $\dot{n}$ moles of 3He are removed from the liquid per second at constant pressure in a reversible way.

4. On the lecture, we discussed competition of potential and kinetic energy and its influence on the solidification of helium at low temperatures. Now, instead of short-range attractive potential, let us consider liquid/solid phase transition under the influence of long-range, repulsive Coulomb interaction. Show that in an electron system with quadratic dispersion relation the stable phase at small densities n is a solid, i.e. $E_{\mathrm{kin}} \ll E_{\mathrm{pot}}$ at small n (so called Wigner solid). What happens in the case of linear dispersion relation (graphene)?

$T(K)$	P (millitoor)	$H_1(J/mol)$	$H_v(J/mol)$
0.20	0.012	0.34	24.73
0.25	0.239	0.48	25.78
0.30	1.877	0.62	26.82
0.35	8.619	0.77	27.86
0.40	28.12	0.93	28.90
0.45	72.69	1.09	29.94
0.50	159.2	1.25	30.97
0.55	308.5	1.42	32.00
0.60	544.5	1.59	33.01
0.65	893.1	1.77	34.01
0.70	1381	1.95	35.00
0.75	2039	2.13	35.97
0.80	2892	2.32	36.93
0.85	3972	2.51	37.87
0.90	5304	2.71	38.81
0.95	6919	2.92	39.73
1.00	8842	3.12	40.63

Table 1: Pressures and enthalpies of Helium-3 at $T < 1\,\mathrm{K}$.