University of California Santa Cruz — Physics Department

Statistical Physics 219 SQ 2018

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Midterm Exam
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1. One of the methods of obtaining very low temperatures is based on the dependence of the thermodynamic properties of certain materials (paramagnetic salts) on the magnetic field. The free energy of such a material is given by $F = F_0 - \frac{\alpha}{T}B^2$, where B is he magnetic induction, T is the temperature and F_0 is the free energy in the absence of the magnetic field. Compute the amount of heat this system absorbs when demagnetised isothermally at temperature T.

2. Compute the total kinetic energy of the molecules of a monoatomic gas which hit a unit area of a wall per time.

(a) Derive first the expression for this energy in the case of a generic isotropic distribution with the distribution function $f(v)$. The concentration of the molecules is n.

(b) Compute it for the Maxwell distribution.

3. Estimate the maximum power one may get from a cyclic thermal machine which uses an ocean current whose velocity is $u \approx 0.1m/s$. The surface layer of the ocean is $h \approx 1km$ and has an excess temperature of $\Delta T \approx 20K$. The width of the plant in the direction perpendicular to the current is $L \approx 1km$.

4. The free energy of equilibrium radiation (photon gas) in a cavity of volume V is given by $F = -AVT^4$, where $A = \frac{\pi^2 k_B^2}{45\hbar^3 c^3} = 2.52 \cdot 10^{-15} \frac{g}{cm \cdot s^2 \cdot K^4}$. Compute the heat capacity C_V of a photon gas whose pressure is $P = 1\text{atm}$ and the volume is $V = 1\text{litre}$. Compare it with the heat capacity of an ideal gas which has the same temperature, volume and pressure.

5. A rocket, which has the shape of an L-long cylinder, is filled with a gas of molecules and moves with the acceleration a. The temperature of the gas is T; the mass of each molecule is m. The engine is then switched off and the gas inside equilibrates. Compute the shift of the centre of mass of the gas in the rocket. If you wish, you may assume that $maL \ll T$.