NORTHERN ILLINOIS UNIVERSITY

PHYSICS DEPARTMENT

Physics 283 – Modern Physics Spring 2026

Problem Set #10

Problem Set Due: Thurs., Feb. 23, 2026
Read Krane: Chapter 11

1. **OpenStax University Physics Vol. 3: Section 2.4:** Problem 61
2. **OpenStax University Physics Vol. 3: Section 2.4:** Problem 63

3. In class we calculated the density of states for a 1 and 3-dimensional particle in a box (see Lecture notes (L#3) on the Physics 283 Website [www.niu.edu/brown]). Using a similar method, calculate the density of states for a 2-dimensional particle in a box. You should find that the density of states is independent of energy. (I give Krane's solution on Blackboard—note: he gives the density of states per unit area)

4. **Krane: Problem 1** **page 384** (explain all your answers—just don't give a number & show figure)

5. **Krane: Problem 3** **page 384** (show calculation)

6. Starting from Equation 10.61, derive Equations 10.62 and 10.63 (make certain to show all your work and derivatives in detail illustrating steps that were skipped in the textbook). *Note: these equations are in* ***Chapter 10****.*

7. **Krane: Problem 11** **page 384** (show calculation)

8. **Krane: Problem 20** **page 385** (show calculation)

9. **Krane: Problem 22** **page 385** (show calculation)
   Part (b) which one is obviously the better conductor?

Problem # 10 is on the next page

10. This is Example 10.7 (page 317) in Krane, but worded differently:

Consider a substance whose constituent atoms contain only one unpaired electron (with zero orbital angular momentum). Such atoms have spin ½ [i.e., $M_S = \frac{1}{2}$ and their spin angular momentum is $S_z = M_S \hbar$], and consequently possess an intrinsic magnetic moment: $\vec{\boldsymbol{\mu}}_{\boldsymbol{S}} = -\dfrac{g_S \mu_B \vec{\boldsymbol{S}}}{\hbar}$. The term g_S is called the *g*-factor and is required because the classical calculation for the magnetic moment (see Table 7.2, page 226) is an approximation for what happens for an electron in a multielectron atom.

When $S = \frac{1}{2}$ and $L = 0$ for a multielectron atom: $g_S \approx 2.00232$

The potential energy of a magnetic moment in a magnetic field is given by:

$$U = -\vec{\boldsymbol{\mu}}_{\boldsymbol{S}} \cdot \vec{\boldsymbol{B}} = g_S \mu_B M_S B_z \,.$$

A collection of such atoms cooled to $T = 20.28\,^{\circ}\text{K}$ (the temperature of liquid hydrogen) is placed in a magnetic field of strength $B = 7\,\text{T}$.

(a) What is the ratio, of the number of $N_\uparrow$ spin-up atoms $\left(M_S = +\frac{1}{2}\right)$ to $N_\downarrow$ spin-down atoms $\left(M_S = -\frac{1}{2}\right)$?

(b) What percentage of the total atoms are $N_\uparrow$ spin-up atoms?

Note: the total number of atoms is: $N = N_\uparrow + N_\downarrow$

(c) What percentage of the total atoms are $N_\downarrow$ spin-down atoms?

(d) For each spin-up atom, is the magnetic moment aligned parallel or antiparallel to the direction of the magnetic field?

(e) Does your answer for Part (d) agree with Krane's answer in Example 10.7?