

# Physics 475: Electron Spin Resonance

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## Corrections/Notes for the EN-35 Instruction Manual

1. The *magnetic moment* is specifically the magnetic *dipole* moment. If you have a static magnetic moment  $\vec{\mu}$  at the origin then the magnetic vector potential  $\vec{A}$  and the magnetic field  $\vec{B}$  in SI units are

$$\vec{A}(\vec{r}) = \frac{\mu_0}{4\pi} \frac{\vec{\mu} \times \hat{r}}{r^2} \quad (1)$$

$$\vec{B}(\vec{r}) = \frac{\mu_0}{4\pi} \frac{3(\vec{\mu} \cdot \hat{r})\hat{r} - \vec{\mu}}{r^3} \quad (2)$$

(Reference: Griffiths' *Introduction to Electrodynamics* 3e, pp. 242-246.) For a loop current in a plane the magnitude of magnetic moment is the area of the loop multiplied by current. The vector direction is normal to the plane and is in the direction of the thumb if the fingers of the right hand point in the direction of the current.

2. So for an electron in a Bohr type orbit (as opposed to a wavefunction which would require some kind of operator to extract a current) the amount of current is equal to the amount of charge passing a point in any given time so  $-e/T = -e(\omega/2\pi)$ . The area of the circular orbit is  $\pi r^2$  so

$$\vec{\mu} = \pi r^2 \left( \frac{-e\omega}{2\pi} \right) \hat{\omega} = \frac{-er^2\vec{\omega}}{2} \quad (3)$$

The basic formula for angular momentum is  $\vec{\omega}$  multiplied by the moment of inertia which is simply  $m_e r^2$  so  $\vec{L} = m_e r^2 \vec{\omega}$  and

$$\vec{\mu} = -\frac{e}{2m_e} \vec{L} \quad (4)$$

The coefficient of  $\vec{L}$  in this expression is the *gyromagnetic ratio*. A charged rotating object (or revolving charged body) has both an angular momentum (which doesn't depend on charge but does depend on  $\omega$  and the details of the mass distribution and shape) and a magnetic moment (which doesn't depend on the mass but does depend on  $\omega$  and the distribution of the charge).

3. The Bohr magneton has an  $\hbar$ , not an  $h$  as shown in formula (4) and the preceding discussion.
4. In this experiment you are directly observing the transitions between the Zeeman levels.
5. The DPPH chemical structure is shown in Fig. 5. The unpaired electron means that this a *free radical*. DPPH is a little unusual in that it is a *stable* free radical; usually they quickly undergo a chemical reaction. We are making specific measurements on the nitrogen with the unpaired electron. The state of the electrons (not just one electron but taken as a group)

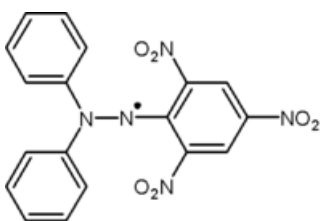


Figure 1: The chemical structure of 2,2-diphenyl-1-picrylhydrazyl. The phenyl groups are on the left. The unpaired electron is on the central nitrogen.

is  ${}^2S_{1/2}$ . The convention is that if the total spin quantum number is  $S$  then the preceding superscript is  $2S + 1$ . The total  $J$  quantum number is given as a preceding subscript and the total  $L$  quantum number is referred to with the code S, P, D, etc. So the state  ${}^2S_{1/2}$  has  $S = 1/2$ ,  $L = 0$ , and  $J = 1/2$ . In many ways this state acts as though there is one single electron but in reality it is a multielectron state.

6. Don't do the part of the lab that involves static magnetic fields. The main result is that the peaks are shifted if the new field is parallel (or anti-parallel) to the field of coils and unaffected if the new field is transverse.