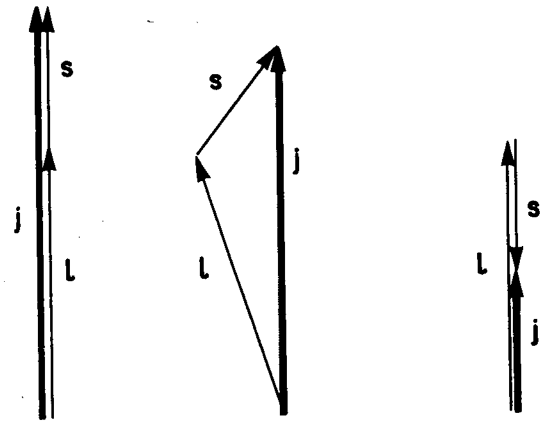

Fig. 9.7. Classically if two angular momentum vectors **l** and **s** are added together to form a resultant **j** the magnitude of the resultant must lie between $|l - s|$ and $l + s$.

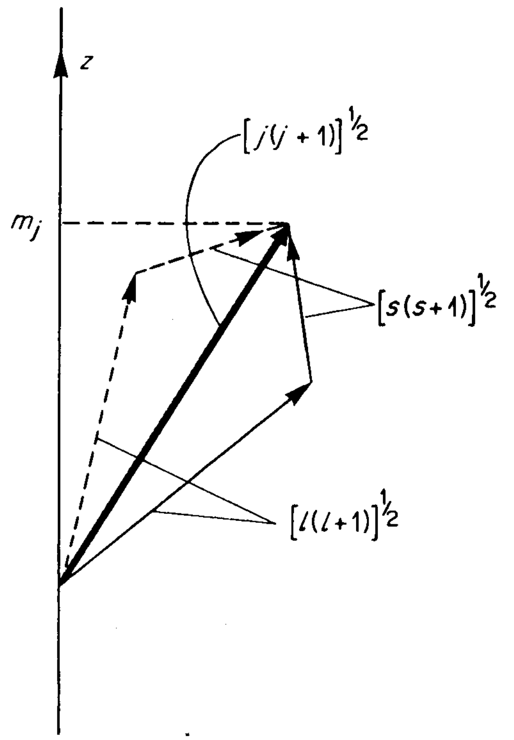

Fig. 9.8. If quantum angular momentum vectors of magnitude $\hbar[l(l+1)]^{1/2}$ and $\hbar[s(s+1)]^{1/2}$ are added to form a vector of magnitude $\hbar[j(j+1)]^{1/2}$ then j can only take the values $|l - s|$, $|l - s| + 1$, etc. in integral steps up to $(l + s)$. If $s = \frac{1}{2}$ this means $j = l + \frac{1}{2}$ or $l - \frac{1}{2}$. The z-component of j, denoted by m_j, is well defined but not the components m_l and m_s.

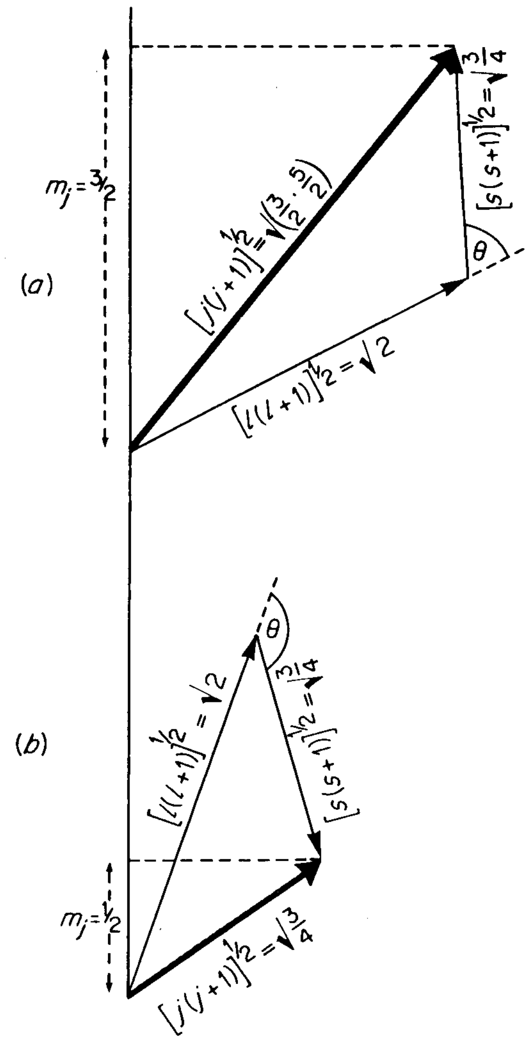

Fig. 9.9. The relative orientations between the spin, orbital and total angular momentum for the cases (*a*) $l = 1$, $s = \frac{1}{2}$, $j = \frac{3}{2}$ and (*b*) $l = 1$, $s = \frac{1}{2}$, $j = \frac{1}{2}$. Note the considerable difference in the value of θ, the angle between the orbital and spin vectors in the two cases.

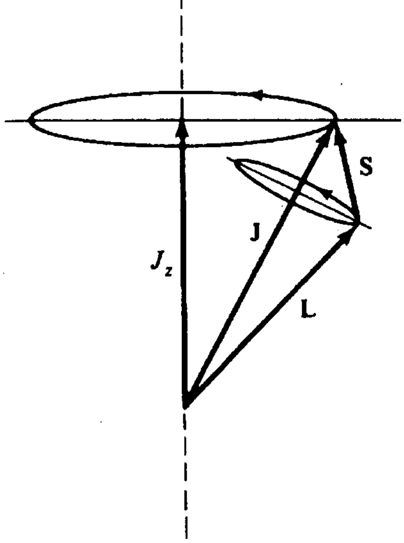

FIGURE 12.1 Schematic vector representation of the L-S scheme of angular momentum addition. J^2 and J_z are fixed, as are L^2 and S^2.

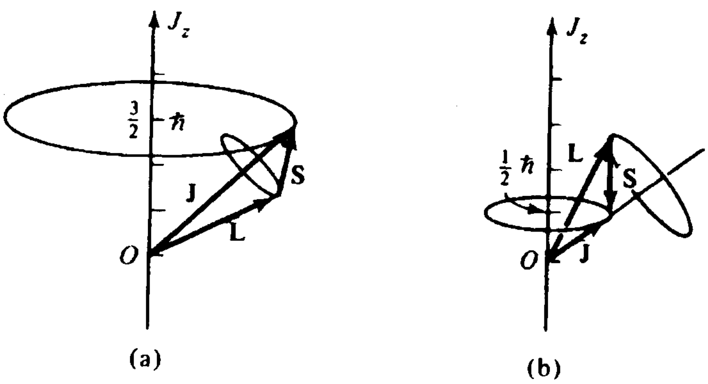

FIGURE 12.2 Diagrams depicting coupling of the L and S vectors of a single *p* electron, in the L-S scheme. The doublet contains two values of *j*.

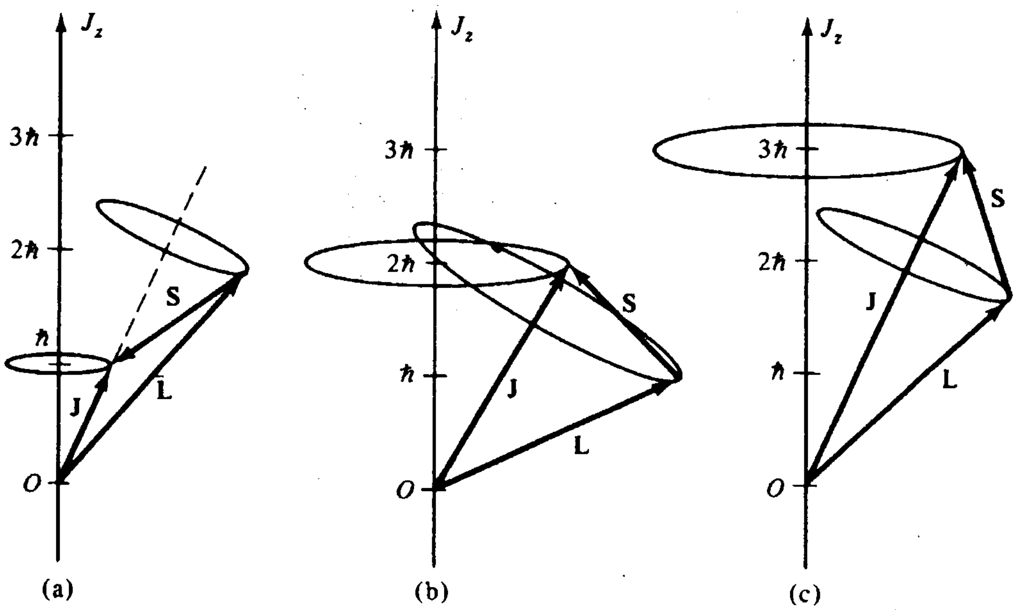

FIGURE 12.3 Diagrams depicting coupling of L and S vectors for two electrons in an orbital *D* state and a spin-1 state. The resultant triplet of *j* values is

$$j = 1, 2, 3$$

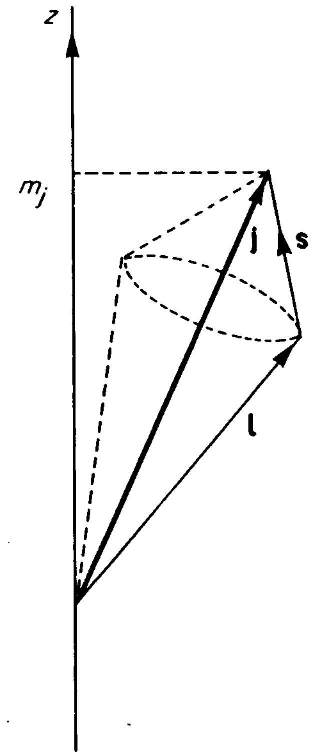

Fig. 9.11. If **l** and s precess round their resultant **j**, the components of **l** and s along z are not well defined. Quantum mechanically m_l and m_s are not good quantum numbers.

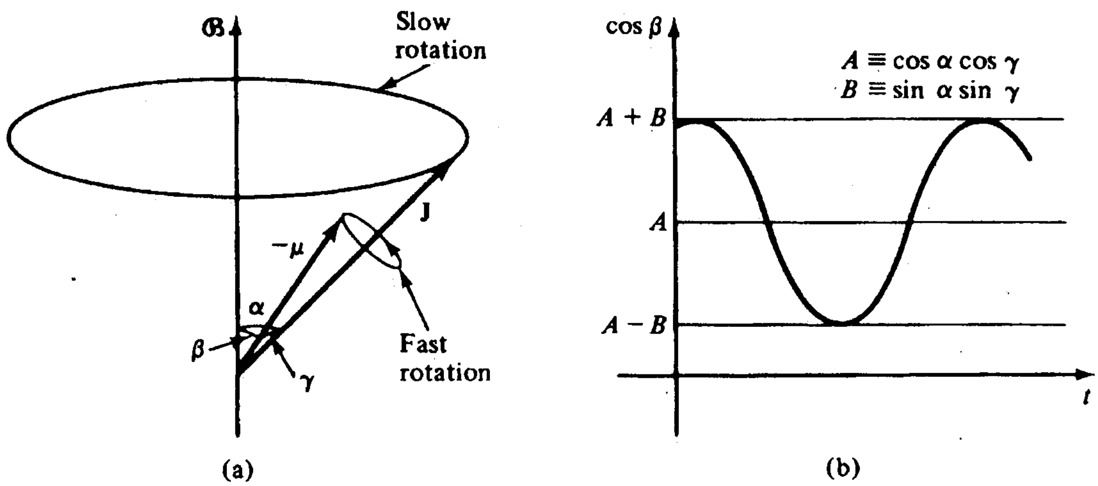

FIGURE 12.8 (a) In the presence of a weak $\mathcal{B}$ field, the precession of J about $\mathcal{B}$ is slow compared to that of μ about J. (See Problem 12.16.) (b) Variation of $\cos\beta$.

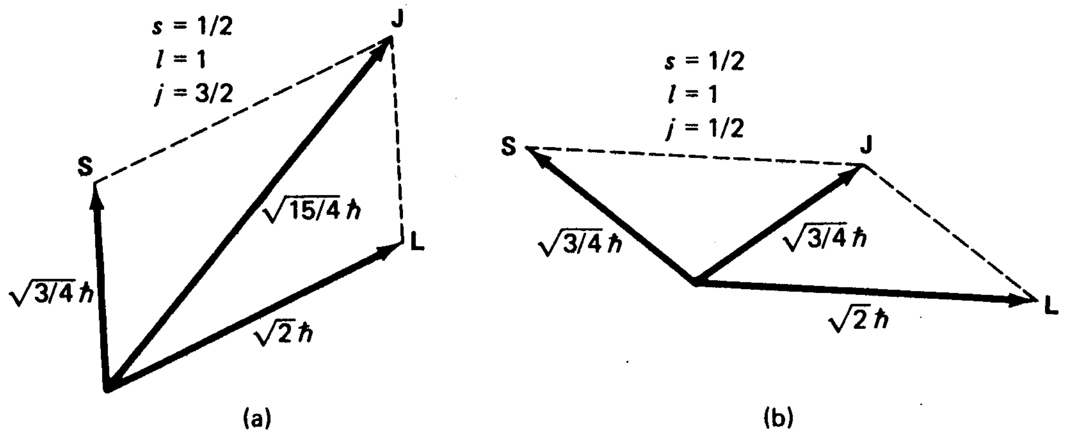

Fig. 9.1 Graphical representation of the addition of spin and orbital angular momenta ($s = \frac{1}{2}$ and $l = 1$) according to the vector model. (a) If the spin and angular momentum vectors are as nearly parallel as possible, the result is a state with $j = \frac{3}{2}$. (b) If the spin and angular momentum vectors are as nearly antiparallel as possible, the result is a state with $j = \frac{1}{2}$.

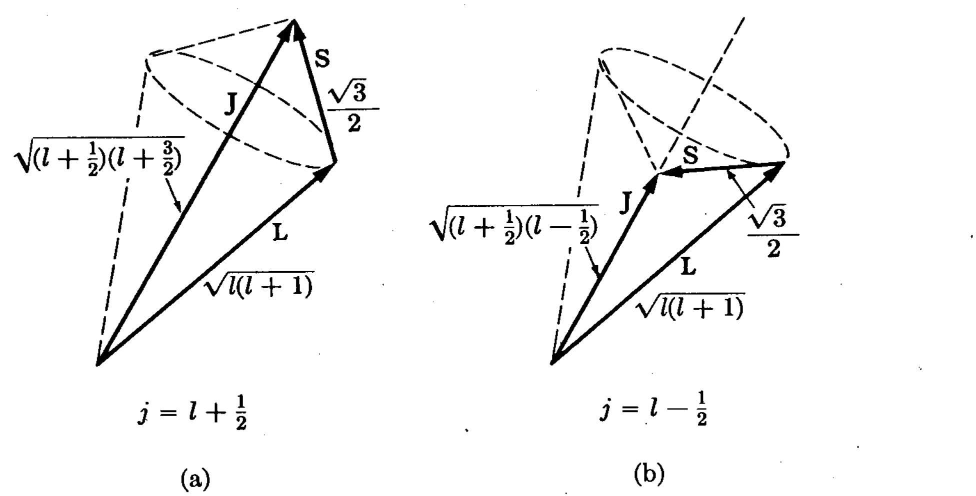

FIG. 9–2. Graphical representation of the addition of an orbital angular momentum $\boldsymbol{L}$ to a spin angular momentum $\boldsymbol{S}$ to give a total angular momentum $\boldsymbol{J}$, for the case $s = \frac{1}{2}, l \neq 0$. The two cases of $\boldsymbol{S}$ (a) "parallel" to $\boldsymbol{L}$ and (b) "antiparallel" to $\boldsymbol{L}$ are shown.

The three states ζ_{1+1}, ζ_{10}, and ζ_{1-1} are the states with total spin unity and the three orientations that are possible for any $j = 1$ state, and are called triplet states. The state ζ_{00} has total spin zero, the only possibility is $m = 0$ as for any $j = 0$ state, and it is called a singlet state. The words *triplet* for $S_T = 1$ and *singlet* for $S_T = 0$ are used in discussions of all systems of two spin $\frac{1}{2}$ particles, such as the two electrons in helium, a neutron and a proton scattering each other, and "charmonium."

Figure 9.1-1 may help to clarify the nature of the four eigenfunctions. The states ζ_{1+1} and ζ_{1-1} simply show that if the two spins both point up, or both point down, then the resultant is an angular momentum $j = 1$ that points up or down. For the $j = 0$ state ζ_{00}, the spins cancel to give zero. The state ζ_{10} causes the greatest discomfort at first glance. How can a spin that points up plus a spin that points down give a resultant with $j = 1$? As Figure 9.1-1 shows, the answer is that the spins are not fixed vectors, but lie in cones, and can therefore be given a relative phase that produces a horizontal resultant.

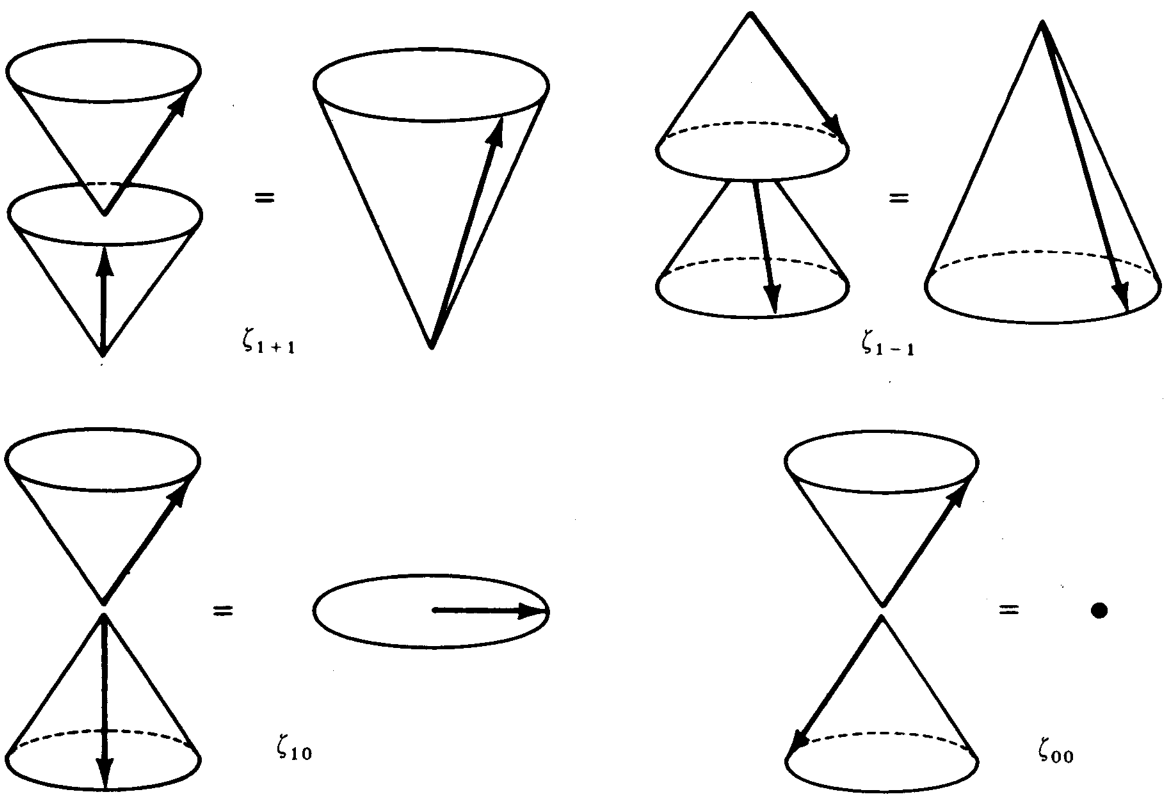

Fig. 9.1-1. The geometric interpretation of the four angular momentum eigenfunctions for two spin $\frac{1}{2}$ particles. Note particularly how a χ_+ and a χ_-, depending on their relative phase, can combine to give either ζ_{10} or ζ_{00}.