Notes:

- The torque makes ***m*** line up with ***B*** (paramagnetism).
- Just like in the electrical case: $U = -\vec{m} \cdot \vec{B}$
- ***F*** = 0 in a uniform field.
- If the field is not uniform: $\vec{F} = -\vec{\nabla} U = \nabla\left(\vec{m} \cdot \vec{B}\right)$
- One can minimize *U* by: Rotating ***m***, or by moving to larger ***B***.

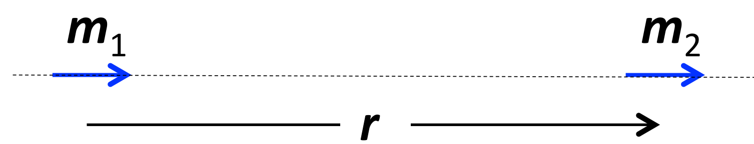
Microscopic picture of magnetic materials:

I only mention this because Griffiths (p. 258) is incorrect.
There are two origins of magnetic moment.

- Current loops (*e.g.*, electrons orbiting in atoms).
- Intrinsic magnetic moments (due to spin).
  The electron's spin and magnetic moment are not due to a spatial motion of charge. In fact (as far as we can tell), the electron is a point particle. The spin of elementary particles is a purely quantum mechanical effect and can't be understood classically.

Interacting magnetic dipoles: (G, problem 6.3)

Calculate the force between two dipoles.



The field due to a dipole is:

$$\vec{B} = \frac{\mu_0 m}{4\pi r^3}\left(2\cos\theta\,\hat{r} + \sin\theta\,\hat{\theta}\right)$$

just like an electric dipole.

In this case, θ = 0, so ***B*** points along $\hat{r}$, as does m_2.

So, $\vec{F} = \vec{\nabla}\left(\vec{m}\cdot\vec{B}\right) = -\frac{3\mu_0 m_1 m_2}{\pi r^4}\hat{r}$

You can do this in spherical or Cartesian coordinates

Diamagnetism (6.1.3)

and the adiabatic approximation .

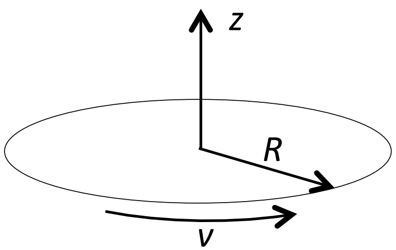
Griffiths shows the microscopic origin of diamagnetism (induced ***m*** opposes ***B***). However, his derivation has a hidden assumption, which I'll point out.

Consider an electron in a circular orbit about the nucleus.

It behaves like a current loop: $I = -e\frac{v}{2\pi R}$

So, there is a dipole moment along z: $m_z = -\frac{1}{2}evR$

The circular motion is due to the electric force: $\frac{1}{4\pi\varepsilon_0}\frac{e^2}{R^2} = m_e\frac{v^2}{R}$



Now, turn on B_z.

This is where the approximation comes in. We assume that the change of the magnetic force per period is small: $\frac{d(evB)}{dt}\left(\frac{2\pi R}{v}\right) \ll m_e\frac{v^2}{R}$. In this case the orbit remains circular (not elliptical). This is called the adiabatic approximation (slow changes).

End 10/23/13