Figure 3.6: Potential energy functions for dipole-dipole interactions. Dipoles that are arranged side by side in parallel and anti-parallel directions have dipole moments that are perpendicular to the distance vector \( \mathbf{r} \). The potential energy of the head-to-tail and head-to-head alignments of dipoles, however, must be evaluated using the more general re-arrangement in Eq. 3.13.

\[
V_{\text{dd}} = -\frac{2\mu_1 \cdot \mu_2}{|\mathbf{r}|^3} \\
V_{\text{dd}} = \frac{4\mu_1 \cdot \mu_2}{|\mathbf{r}|^3} \\
V_{\text{dd}} = -\frac{2\mu_1 \cdot \mu_2}{|\mathbf{r}|^3}
\]