“The nation that controls magnetism will control the universe” – Dick Tracy (1935)

1) Jackson 5.27 [10 points]

2) Jackson 5.33 [10 points] (a)–5, (b)–5.

3) Jackson 5.34 [20 points] (a)–3: Use the formula given in Problem 5.10b as the start. (b)–7; (c)–7; (d)–3: No discussion of Prob. 5.18 is needed.

4) Jackson 6.8 [20 points]

   Text for 2018: Intermediate steps: It’s easiest to argue that $\vec{P}$ always follows $\vec{E}$, so $\vec{P}$ points along $\hat{x}$. The surface current is $\vec{K} = \sigma_p \vec{v}$ where $\sigma_p$ is the surface polarization charge density, and $\vec{v} = \vec{\omega} \times \vec{r}$. $\vec{K} = \vec{M} \times \hat{n}$ so $\vec{M} = k\omega P x$ where $P$ is the magnitude of the polarization vector. Use the surface pole density $\vec{M} \cdot \hat{n}$ as the source for $\Phi_M$. Looking at the microscopic charges gets quite confusing, the obvious answer is off by a sign.

   Text for later years: The hard part of this problem is the start. $\vec{P}$ always follows $\vec{E}$, so $\vec{P}$ points along $\hat{x}$. You need the surface magnetic pole density $\sigma_M = \vec{M} \cdot \hat{n}$ to source $\Phi_M$.

   There are (at least) three ways to begin. First, you could use the surface current density $\vec{K}_M$ and surface magnetization $\vec{M}$, $\vec{K}_M = \vec{M} \times \hat{n}$ where $\hat{n}$ is an outward normal to the surface. The surface current density comes from the surface polarization density $\vec{K} = \sigma_p \vec{v}$ where $\sigma_p$ is the surface polarization charge density, and $\vec{v} = \vec{\omega} \times \vec{r}$. $\vec{K} = \vec{M} \times \hat{n}$ so $\vec{M} = k\omega P_0 x$ where $P_0$ is the magnitude of the polarization vector.

   Second, you could look at the volume magnetization $M$ and find the volume current $\vec{J}_M = \nabla \times \vec{M}$. You imagine a little dipole whose head and tail are separated by a small difference, so $\vec{J} = Nq(\vec{v}_+ - \vec{v}_-)$. This is nice, but wrong by a sign – the dipole remains oriented along $\hat{x}$, so the charge hops from dipole to dipole in the opposite direction to what you have found. You can find $\vec{M}$ from $\vec{J}_M = \nabla \times \vec{M}$, you discover $\nabla \cdot \vec{M} = 0$ and construct $\sigma_M$.

   The third way is to look around Jackson Eq. 6.100: a material in bulk motion acquires an effective magnetization $\vec{M}_{eff} = \vec{P} \times \vec{v}$. The derivation is awful.