Homework 6: Physics of Magnetism and Earth’s Magnetic Field

Read Lowrie 5.1, 5.2.1-5.2.4; 5.4.1-5.4.7
Due Thu. 2/18

1. The figure on the left, below shows a rectangular current loop being supplied by an electrical source. The loop is allowed to rotate and stays connected to the source by a split ring. While the loop is rotating, the split ring keeps the positive end—where current is entering the loop—always on the bottom, and the negative end—where current is leaving the loop—always on top. This is a schematic diagram of a very useful machine. What is it? Explain how it works.

2. Measurements of the magnetic field at a geomagnetic observatory gave the following results: northward component: 27,000 nT; east component -1800 nT; downward component -40,000 nT.
(a) Is the observatory in the northern or southern hemisphere?
(b) What are the local values of inclination $I$ and declination $D$?

3. Let’s examine how the Earth’s magnetic field varies with latitude. Use Matlab to calculate and plot the following on the surface of the Earth as a function of latitude $\lambda$ from the south to the north pole:

(a) The downward component $B$ ($Z$ in Fig. 5.27 or $B_z$ right).
(b) The northward component of $B$ ($X$ in Fig. 5.27 or $B_x$ right).
(c) The magnitude of $B$ ($|F|$ in Fig. 5.27 or $|B|$ right).

As always, explain why your solutions make sense.
4. Have a look at Fig. 5.33. Order \( n \) tells how many wavelengths of fluctuations occur in 360° around the Earth. Thus, \( n = 1 \) corresponds to a wavelength equal to the circumference of the Earth and \( n = 20 \) corresponds to a wavelength of fluctuation of about \( 2\pi R/20 = 2000 \) km. Fig. 5.33 shows the strength of different wavelengths as measured by the MAGSAT satellite.

(a) The book claims that the source for \( 15 < n \leq 45 \) is dominate by the Earth’s crust and that larger wavelength variations \( (n \leq 14) \) are caused primarily by the core. Like gravity, the shape of a magnetic anomaly changes with distance due to “upward continuation” as can be seen by the dependence on \( (1/r)^{n+1} \) in Eq. 5.34. Given what you understand about “upward continuation” explain why (or why not) the book’s claim makes sense.

(b) We know that seafloor magnetic lineations have much shorter wavelengths than those corresponding to \( n = 45 \). Do you expect the use of satellites is a good way to measure these shorter wavelength undulations? What would be a better way?