Problem Set for Chapter 8 “The Structure and Evolution of the Three-Dimensional Solar Wind” in the book “Evolving Solar Activity and the Climates of Space and Earth”.

1. It is the Sun’s magnetic field that constrains the solar wind expansion. The strength of the Sun’s dipole magnetic field is strongest at the magnetic poles. Explain why the solar wind expansion most easily opens up the Sun’s polar fields.

2. Magnetic reconnection commonly occurs both close to the Sun and well out into the heliosphere. With regard to the overall magnetic flux budget of the heliosphere, explain why it matters if reconnection occurs inside or outside the point (the so-called Alfvén point) where the solar wind flow becomes super-Alfvénic.

3. Explain why, fundamentally, solar wind stream steepening typically produces a forward-reverse shock pair rather than just a single forward shock.

4. A shock accelerates plasma in the direction in which it propagates. Reverse shocks propagate sunward in the solar wind rest frame. Explain why a spacecraft observes an increase in radial (from the Sun) flow speed when it encounters a reverse shock in the solar wind.

5. Assume a spherically symmetric, adiabatically expanding solar wind with a speed of 400 km/s at 0.14 AU and a terminal wind speed of 480 km/s. Assume that a sudden and persistent step increase in speed from 400 to 700 km/s occurs at all longitudes and latitudes at 0.14 AU while the density and thermal pressure remain constant there. Describe qualitatively what the resulting speed and pressure disturbance would look like when it reaches 1 AU and then later at 3 AU. Use something like the type of cross-hatch format in Figure 8.9 to identify the last 30-hr interval of initially slow wind at 0.14 AU.

6. Assume a spherically symmetric, adiabatically expanding solar wind with a speed of 700 km/s at 0.14 AU and a terminal wind speed of 750 km/s. Assume that a sudden and persistent step decrease in speed from 700 to 400 km/s occurs at all longitudes and latitudes at 0.14 AU while the density and thermal pressure remain constant there. Describe qualitatively what the resulting speed and pressure disturbance would look like when it reaches 1 AU and then later at 3 AU. Use something like the type of cross-hatch format in Figure 8.9 to identify the first 30-hr interval of initially slow wind at 0.14 AU.

7. Assume a spherically symmetric solar wind with a speed of 700 km/s at 0.14 AU and a terminal wind speed of 750 km/s. Assume a square wave decrease in speed to 400 km/s at all latitudes and longitudes at 0.14 AU that persists for 30 hours, after which the speed there returns to 700 km/s. Assume that the density and thermal pressure remain constant at 0.14 AU. Describe qualitatively what the resulting speed and pressure disturbance would look like when it reaches 1 AU and then later

at 3 AU. Use something like the type of cross-hatch format in Figure 8.9 to identify the 30-hr interval of initially slow wind at 0.14 AU.

8. The kinematic sketch shown in Figure 8.13 in Book 3 ignores dynamic effects associated with compressions and rarefactions. Explain qualitatively how dynamic effects would be expected to alter the radial field segment(s) in Figure 8.13 obtained from consideration of kinematic effects only.