References are to equations appearing in the course book.

Problem 4.1

The key equation (4.12) can be used to investigate general questions. If unmagnetized material is placed in a region with a finite static field at $t = 0$ ($M_z(0) = 0$):

> Find the time it takes, in units of T_1, for the longitudinal magnetization to reach 85% of M_0.

Problem 4.2

A direct derivation of the steady-state solution, when it exists, of a system of differential equations can often be found by the following procedure. Assuming that the system evolves to constant value for large times, all time derivatives can be set to zero. The problem reduces to a system that can often be solved analytically. Show that the steady-state solution of the Bloch equations (4.37)–(4.39) is

$$\begin{aligned} M_{x'}^{ss} &= M_0 \frac{\Delta\omega T_2}{D} \omega_1 T_2, \\ M_{y'}^{ss} &= M_0 \frac{1}{D} \omega_1 T_2, \\ M_z^{ss} &= M_0 \frac{1 + (\Delta\omega T_2)^2}{D}, \end{aligned}$$

where

$$D = 1 + (\Delta\omega T_2)^2 + \omega_1^2 T_1 T_2.$$

The problems are based on those in Robert W. Brown, Y.-C. Norman Cheng, E. Mark Haacke, Michael R. Thompson, Ramesh Venkatesan. *Magnetic Resonance Imaging: Physical Principles and Sequence Design*, 2nd Edition, Wiley, 2014.