References are to equations appearing in the course book.

Problem 6.1

The parameter T_2' is associated with the (relatively smooth) variation in the z-component of the external field. An estimate of the average gradient in this component can be found from a given phase variation. If the z-component changes from $B_0 + \Delta B(\vec{r}_1)$ to $B_0 + \Delta B(\vec{r}_2)$, then the average gradient of that component between the two points $\vec{r}_1$ and $\vec{r}_2$ can be defined as

$$\overline{G} = \frac{|\Delta B(\vec{r}_2) - \Delta B(\vec{r}_1)|}{|\vec{r}_2 - \vec{r}_1|} \tag{8.8}$$

Suppose two protons are situated at these points. If $|\vec{r}_2 - \vec{r}_1|$ is 2 mm, and if there is no initial phase difference between their spins, find the value of $\overline{G}$ leading to a 2π difference in phase, after a time of 5 ms, for the two proton spins.

Problem 6.2

Experiments with $\pi/2$-pulses and short T_R can be expected to have reduced signal. That is, in the limit that T_R becomes much less than T_1 (but still much larger than T_2^*), show that $M_z(nT_R^-)$ is proportional to T_R/T_1.

Hint: Recall (8.31) and the Taylor expansion of the exponential function.

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.