

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

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

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  $\bar{G}$  leading to a  $2\pi$  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.