**Level 3 Condensed Matter Physics- Part II**
**Weekly problem 4 solutions**

(1) The change in the current ($\Delta I$) cannot be larger than the precision of the measurement and therefore $\Delta I = I(t) - I_o = -0.001 I_o$, where $I_o$ is the current at $t = 0$ [1 mark].

Using $I(t) = I_o \exp(-t/\tau)$:

$$\Delta I = I_o \left[\exp\left(-\frac{t}{\tau}\right) - 1\right] = -0.001 I_o$$

Substituting $t$ = 1 year gives $\tau$ = 999 years. This is a lower limit for the average scattering time. [2 marks]

(2) For a Type I superconductor:

$$B_c(T) = B_c(0)\left[1 - \left(\frac{T}{T_c}\right)^2\right]$$

[1 mark]

Substituting $T$ = 4.2 K, $T_c$ = 7.2 K and $B_c(0)$ = 0.080 T gives $B_c(T = 4.2\ \text{K})$ = 0.053 T. [1 mark]

The maximum current is:

$$I_{max} = \frac{2\pi R B_c(T)}{\mu_o} = \frac{2\pi \times (0.5\ \times 10^{-3}\ \text{m}) \times 0.053\text{T}}{4\pi \times 10^{-7}\ \text{H/m}} = 132.5\ \text{A}$$

[2 marks]

(3) The superconducting phase (beyond the London penetration depth) is a perfect diamagnet and has susceptibility -1. [1 mark]

If the volume fraction of superconducting and normal phase is $V_{sc}$ and $V_n$ respectively, with $V_{sc} + V_n = 1$, then:

$$\chi = -V_{sc} + (2 \times 10^{-5})V_n = -0.7$$

Solving for $V_n$ gives $V_n$ = 0.3 (30%) and hence $V_{sc}$ = 0.7 (70%). [2 marks]