

**Royal Holloway**

**UNIVERSITY OF LONDON**

**MSci EXAMINATION**

**NANOTECHNOLOGY**

**CP4505A**

**SUMMER 1998**

Time Allowed: **TWO HOURS**

Answer **TWO** questions only. No credit will be given for attempting a further question.

Each question carries 20 marks. The mark *provisionally allocated* to each section is indicated in the margin.

**TURN OVER WHEN INSTRUCTED**

1. (a) Define and explain the physical meaning of the *phase breaking* length,  $L_\phi$ , of the conduction electrons in a disordered conductor. What is the *effective dimensionality* of such a conductor with respect to the weak localisation effect? [4]
- (b) Show that the weak localisation contribution to the conductance is proportional to the phase breaking length in the 1D case and to the logarithm of the phase breaking length in the 2D case. [7]
- (c) A metal film has the following characteristics:  
elastic scattering rate for the conduction electrons,  $\tau^{-1} = 10^{13} \text{ s}^{-1}$ ;  
phase breaking rate,  $\tau_\phi^{-1} = 10^{10} \text{ s}^{-1}$ ;  
Fermi velocity,  $v_F = 10^6 \text{ m s}^{-1}$ .  
Calculate the largest diameter of a ring in a chain of rings made from such material in which Aharonov-Bohm oscillations could be observed. [5]
- (d) Describe the negative process for the fabrication of mesoscopic rings. [4]
2. (a) Describe the principle of operation of the Scanning Tunnelling Microscope in the Constant Current (CCI) Mode and in the Constant Height (CHI) mode. What are the practical limitations of CCI which can be overcome using CHI? [5]
- (b) Describe the Independent Electrode Approximation ( Tersoff-Hamann) model of STM imaging. How would an STM tip move according to the TM model if the sample density of states at the Fermi level, evaluated at the centre of the tip, has nodes? [7]
- (c) What is the *reciprocity principle* in STM? [4]
- (d) Give three examples of nanotechnology techniques based on the use of a scanning probe. [4]
3. (a) Explain the physics of a Single Electron Transistor (SET). [6]
- (b) Describe the *Dolan bridge* technique for the fabrication of sub-micron tunnel junctions. [4]
- (c) What is the physical meaning of the sensitivity and the contrast of a positive e-beam resist? What if the contrast is zero? [5]
- (d) Explain the physical limitations on the resolution of photo-lithography, X-ray lithography and electron-beam lithography. How does the resolution depend on the contrast of the resist in each case? [5]

END