Lancaster University                                        Department of Physics

# PHYS421 - Michaelmas Term 2010
## Sheet 4 (total mark = 30)

THIS SHEET MUST BE ATTACHED TO YOUR ANSWERS — please insert your name at the top of this page and ensure your work is clearly legible. Do not submit your work in folders or plastic sleeves. Your answers should be placed in the appropriate IN-BOX in the Physics Foyer not later than 16:00 on Tuesday 14 December 2010. Work handed in after the above time and before the seminar on Thursday 12pm will be subject to a 10% reduction. Work handed in later than this will not count towards your continuous assessment.

I declare that this submission is my own work. I have not submitted it in substantially the same form towards the award of a degree or other qualification. It has not been written or composed by any other person and all sources have been appropriately referenced or acknowledged.

Signed:

**1. (a)** [7] Following notes, use Schroedinger equation for an electron in a magnetic to derive the spectrum of Landau levels for two-dimensional electrons in a semiconductor heterostructure. Explain meaning of the following terms: 'magnetic length' and 'filling factor'. **(b)** [4] For $B = 10$Tesla estimate the value of magnetic length for electrons and determine how many Landau levels are completely filled by electrons in a two-dimensional electron gas with electron sheet density $n_e = 10^{11}$cm$^{-2}$. **(c)** [4] Describe what is the Hall effect. Describe the quantum Hall effect phenomenon from the point of view of empirical observations and explain how one can use it in metrology.

**2.** [15] **Open-ended team-work assignment.** Describe the principle of operation of scanning tunneling microscope. Using internet (Google search for *'scanning tunneling microscope', STM*), find one example demonstrating how STM was used, and, as part of a team, participate in the preparation of a presentation on the results of your search. Write a report (about 2 pages) describing what observations have been made and how these observations have been interpreted in the example you found. Supplement your report with a printout of the discussed STM scan(s). In your report, state what role did you play in the team. Presentations will take place during the class on Monday, 13 December, 2010.