(1) A patterned magnetic device with $[Co/Cu]_4$ multilayer structure and proper Co and Cu sub-layer thickness shows a giant magnetoresistive behavior. Assume the testing is done using a current-perpendicular-to-plane (CPP) mode. Explain the giant magnetoresitive (GMR) effect using a two-channel (also named as two-resistor) model. (1.2 point)

(2) Today's available CPP GMR device for a read sensor application uses a tri-layer structure, also called a spin valve structure. Using Co as both the free layer and pinned layer and Cu as the spacer layer, schematically show a read sensor that can work linearly (resistance vs magnetic field). We want to pin the fixed layer with an antiferromagnetic layer. Give two reasons why the system is usually post-annealed. You need to provide the relative magnetization configuration between the fixed and free layer to enable a linear working range; (0.5 point);

(3) In phase diagram, Cobalt (Co) can have two crystalline structures: hexagonal closely packed (hcp) phase and face center cubic (fcc) phase. Which Co phase will you choose for the free layer in your above designed read sensor? Provide the justification for your choice. (0.5 point)

(4) If the above CPP GMR device has a large size in a square shape (500 nm in length) and thin Co free layer (5 nm in thickness), will the magnetization of the free layer be uniform or not? Assume there is no magnetic dipole field from the pinned layer. Plot a possible domain configuration without external magnetic field for this large square Co free layer. Assume there are no magnetic domain pinning sites (e.g defects) in Co free layer. (1.0 point)

(5) If the above CPP GMR device has a small size in a rectangular shape (20 nm in length and 10 nm in width) and a thin Co free layer (2 nm in thickness) for sensing future bit patterned media, what is the necessary magnetic anisotropy constant for this Co free layer to be thermally stable at room temperature? Assume the required thermal stability factor is 40.

Boltzmann constant is 1.38×10^{-16} erg K^{-1}. (0.8 point)