Name:

Entry No.

MAJOR
PHL -726

03/05/2008

Total Marks:50

Attempt all questions. The marks for questions are given on the right margin. In multiple choice questions, marks will be given only if all the choices are correctly marked. (Total Marks:50)

1. Tick the correct statement/s (1)
   - (i) Multilayers like $Ni_{80}Fe_{20}/Cu/Co/Cu$ with double coercivity show GMR effect
   - (ii) Antiferromagnetically coupled multilayers show GMR effect
   - (iii) Spin valves show GMR effect in low fields of few tens of Oe.
   - (iv) Li is a paramagnet, multilayers of Fe/Li/Fe/Li show GMR effect

2. Properties that are required in magnetic materials used in data storage are- (1)
   - (i) large permeability
   - (ii) large remanence
   - (iii) large coercivity
   - (iv) large magnetostriction
   - (v) large magnetocrystalline anisotropy

3. Let us consider N bilayers of two ferromagnetic layers (F) of thickness b separated by a nonmagnetic layer (NM) of thickness a where the Z of the NM is smaller than the Z of the F. The sample thickness $t = N.L$ where $L=a+b$. The energy of electrons in such a sample are (1)
   - *(i)* independent of N
   - (ii) dependent on N
   - (iii) independent of b
   - (iv) dependent on b

5. The dimensional units of magnetization **M** and field-strength **H** are ___________ (same/ different), if same it is ____________ and if different they are ___________ & ___________ (1)

6. Direction of easy-axis in a single domain particle is decided by its ____________ & ____________________ anisotropy (1)

7. When nanomagnetic particles are considered at higher temperatures, k_BT becomes >> ____________energy, given by ________.This phenomena is known as ____________. $(1^{1/2})$

8. The most striking feature observed in 2D magnetic semiconductors is the ___________________________ near band-edge. (1/2)

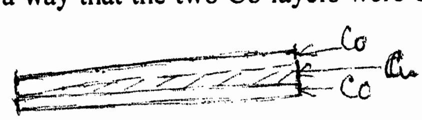
9. When compared, the thinner magnetic sample will have ______________ domains (less / more). The reason for this is _________________________. (1)

10.(a) In multilayer of Fe/Cr, Fe layers were ~ 30 A^0 and Cr layer thickness were varied between 9 A^0 to 60 A^0. The R / R_H was found to be ____________ (largest / smallest) for Cr 9 A^0. In this configuration, the strength of AF coupling would be ______________ (maximum / minimum) (1)

(b) In comparison, in a spin-valve system there are ___________ ____________ layers separated by ___________ ________________. The above mentioned layers are ______________ (uncoupled / coupled/ weakly coupled). (2)

11. What are the requirements placed on magnetism by Maxwell's equations? What is the physical meaning conveyed by them? (2)

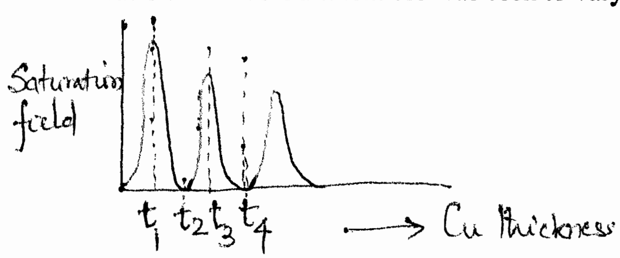
12. On a Co crystal, Cu layer was deposited in a way such that the Cu thickness increased from 0 A^0 to t_4 A^0 and on top another Co layer was capped (see figure) in such a way that the two Co layers were exchange-coupled via Cu layer (5)



(a) Explain the role of Cu layer.

(b) Resistance ratio (R_H/R_0) of this sample was then measured with increasing field. Plot qualitatively the R_H/R_0 Vs H

© The saturation field Vs Cu thickness was seen to vary as below. Explain the coupling behaviors at t_1, t_2, t_3 and t_4.



13. Plot qualitatively the ***M*** Vs ***H*** plots for the following: (5)

(i) paramagnet

(ii) ferromagnet

(iii) diamagnet

(iv) ferromagnet coated with a thin antiferromagnetic layer

(v) nanomagnetic film of Ni with domains oriented along easy-axis and field applied parallel to easy axis

(vi) case above (v) with field applied perpendicular to easy-axis direction

14. In a MOSFET structure a thin layer of p-type Si is provided with metallic contacts and its surface is insulated from gate by SiO_2 layer. The concentration of mobile electrons at the interface of Si / SiO_2 is known to be $N = 10^{15}$/cc. The electrons have velocity $v \ll c$. Estimate the temperature one needs to work at, for this electron gas to behave as a quasi-2D e-gas showing quantum effects? (4)

15. For a 3-D free electron gas $N(E) = (V/8\pi^3) \int (dS_W) / |\nabla_k E|$; where $\int dS_W = 4\pi k^2$ and $E = h^2k^2/8\pi^2m$. These lead to $N(E) \propto E^{1/2}$. On similar lines derive the expressions for density of states N(E) for 2-D gas. Plot N(E) Vs E for 2-D , 3-D electron gas, showing labels clearly. (4)

16. The CNT is energetically stable because ____.
The structure of nanotube can be specified by vector (n,m); this can be produced by rolling up atom labeled ________________ superimposed on ______________. For all zig-zag tubes ______________ and for arm-chair tubes __________________.

17. A GaAs quantum well is being designed in the lab. Assume that the barrier due to neighboring confining layers is effectively infinite and that relative effective mass of GaAs heavy holes and light holes is given by $m_{HH}=0.35$ and $m_{LH} = 0.082$ respectively. Answer the following:

(a) At the top of the valence band the effective mass of the electron is positive OR negative? (1)

(b) Draw neatly the E-k diagram, clearly showing the 2-D sub-bands (both conduction and valence bands) in x-y plane. (2)

(c) if it is desired that the highest HH confined state is separated by at least 40 meV from the highest LH confined state, what should be the maximum width of this quantum well? (4)

(d) Depict the contribution of each sub-band (in both conduction band and valence band) in N(E) Vs E plot; clearly labeling all relevant points (using m_{HH}, m_{LH}, m^*, E_g, $E_{g\,(effective)}$). You can use the results from any of the above problems for correct labeling. (3)

18. In an attractive potential, absorption of electron across the band-gap will give rise to ____________. These give rise to lines ______________________________________ in absorption spectra. (2)

19. What is Quantum confinement in nanophotonics? If the bandgap change of GaAs is changing with diameter (in nm) of quantum dot as $E_g = E_g^{bulk} + \frac{2.4}{d^2}$, to obtain Blue emission (400nm) from GaAs what should be the radius of quantum dot? (bulk band gap of GaAs=1.43eV)

$h^2/4\pi^2 m = 7.62$ eVÅ^2 $k_B = 1.38 \times 10^{-23}$ J/K $= 8.6 \times 10^{-5}$ eV/K $m_e = 9.1 \times 10^{-31}$ Kg
$h^2/2m = 150.26$ eVÅ^2