HOMEWORK #4, DUE MARCH 12

1) Assume tradition scaling and you want to increase the areal density by a factor of 10. How much do the following parameters change?
a) The write head current.
b) The write head current density
c) The write field.
d) The media thickness
e) The grain volume.
f) The fly height

2) In magnetic recording what is the magnetic 'trilemma'? Why may this be a general problem for any magnetic information technology?

3) In longitudinal recording the grains near the transition are the least stable while for perpendicular recording the grains in the center of the bit are least stable. Why?

4) Assume you have a write field sufficient to write media with a coercive field of 5 kOe. Further assume the media has to be no more than 10-nm in thickness and you need 10 grains per bit for signal to noise.
a) Assuming independent grains (and a 1-nm spacing between grains) calculate the expected areal density you can achieve and have the data stable for 10 years.
b) How does this compare to current hard drives.
c) Assume you have patterned media (with equal bit size to spacing) what density can you achieve?
d) Assume you use heat assisted magnetic recording and can write media with 40 kOe coercive field what density can you achieve?

5) The uncertainty in the position of the transition in magnetic recording (known as the jitter) can be estimated by the equation: $\sigma = \frac{\pi^2}{4}\, a \sqrt{\frac{s}{3W}}$ where a is the width of the transition, s is the cross-track correlation length (the distance over which the magnetic transition fluctuates across the width of the track) and W is the track width. For an uniform, magnetically de-coupled grains the media the transition width is half the grain diameter ($D/2$) and $s = D$.
(a) Assuming a grain diameter of D=8 nm and a track width of 60 nm estimate σ and from that estimate the bit size assuming σ must be 10% of the bit length.
(b) Assume you can write a track that is 30 nm wide (W= 30 nm) for the same media. Will the areal density increase and by how much?
(c) Does this suggest that the number of grains/bit is not the best estimate for areal density?
(d) From this can you explain why the bits are becoming squarer over the last 10 year (*i.e.* the bit width is decreasing faster than the bit length)?

6) Assuming a magnetic bit is thermally stable, what is the height of the barrier in Joules? How does this energy compare to write a flash cell?

7) Assuming you have an STT-MRAM cell which is 30 nm in diameter, perpendicular anisotropy and is thermally stable ($K_UV=50k_BT$). If the tunnel process has an effective spin polarization of 80% what is the minimum current and current density to switch the bit?