Homework day 4

Problem 1

E. Todesco, (Unit 5 and Unit 6)

2 points

Among the four equations

$$E = mc^2 \qquad E_0 = mc^2 \qquad E_0 = m_0c^2 \qquad E = m_0c^2$$

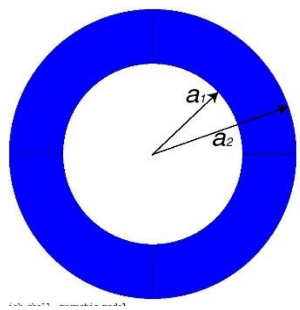
discuss which equation can be considered correct and which is wrong, according to the meaning given to E, E_0, m and m_0. *(2 points)*

Problem 2

P. Ferracin, (Unit 9-12)

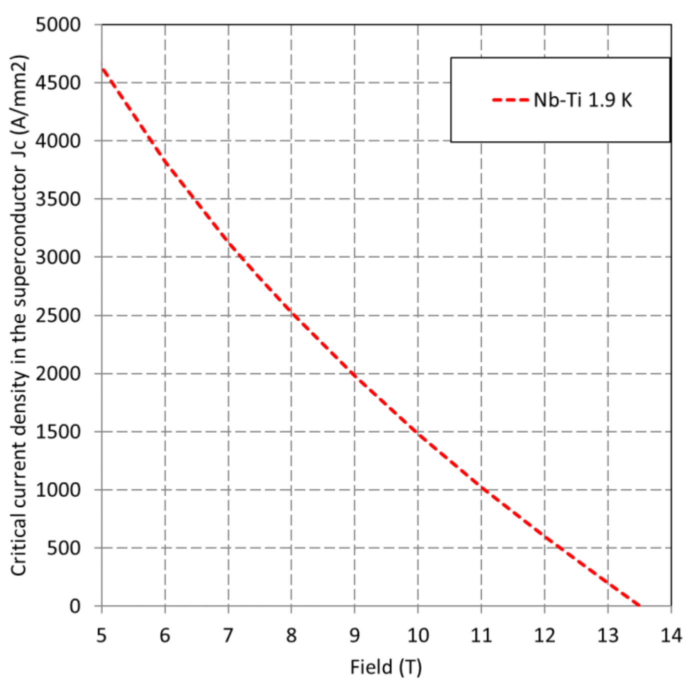
5 points

Let's consider a perfect $cos\theta$ dipole magnet with the main parameters of the LHC main dipole coil (see Appendix II, thick shell approximation, unit 9-12).



The inner radius a_1 is 28 mm and the outer radius a_2 is 59.3 mm.

The critical curve J_{sc} vs. B for Nb-Ti at 1.9 K is given below (same as exercise set 5).



Assuming for the entire coil the cable of the LHC main dipole inner layer and no iron surrounding the coil, compute

- The short sample conditions
    - Short sample field B_{ss} (for a perfect $cos\theta$ dipole the coil peak field is equal to the bore field)
    - Short sample current density in the superconductor J_{sc}
    - Short sample overall current density J_o
- F_x
- F_y

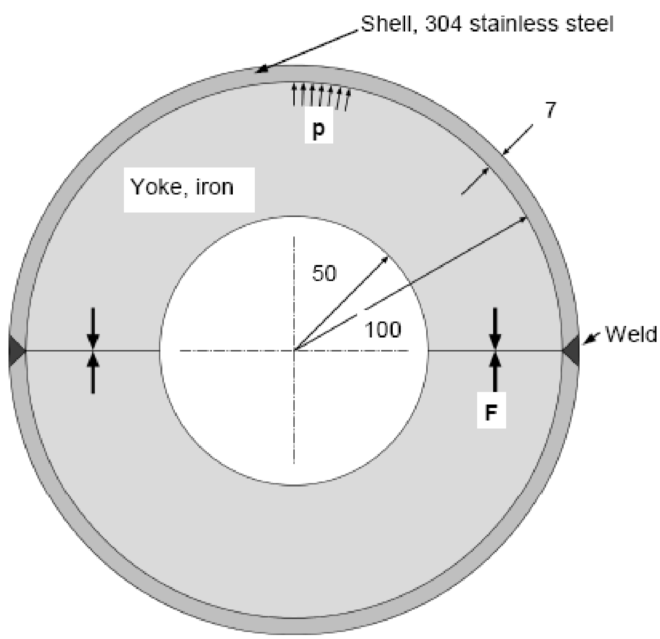
and plot the azimuthal stress on the mid-plane (assuming no shear within the coil).

Problem 3

P. Ferracin, (Unit 13-14)

5 points

The figure below shows a yoke enclosed in a helium containment shell. The shell has been pressed against the yoke and welded. At the end of the welding operation, the strain in the shell was measured and found to be 0.000700 (700 microstrain) from the shrinkage of the weld zones.



1. What is the normal pressure *p* between the shell and yoke the end of the welding operation?
    a. Assume an elastic modulus E for the shell of 200000 MPa.
2. If the assembly is cooled to 4.2 K, what is the force (F) per mm between the upper and lower yoke halves?
    a. Assume the iron yoke infinitely rigid.
    b. The iron integrated thermal contraction from 293 K to 4.2 K $\alpha_{ir} = 2 \times 10^{-3}$
    c. The stainless steel integrated thermal contraction from 293 K to 4.2 K $\alpha_{ss} = 3 \times 10^{-3}$.

Problem 4

P. Ferracin, (Unit 20-21)

5 points

A NbTi strand is carrying a transport so that current density in the superconductor j_{sc} is 2000 A/mm^2 at 1.9 K. Let's assume a transition to the normal state, with all the NbTi filaments alone in free space (no stabilizer), in adiabatic conditions. Compute how long it takes to the filaments to heat up to 1000 K. Assume the following properties for NbTi:

- Normal state resistivity $\rho_{sc} = 6 \times 10^{-7}$ Ωm
- Density γ = 6550 Kg/m^3
- Specific heat c_p (at 300 K) = 426 J/(Kg K)

Now, assume that the filaments are embedded in a matrix of pure copper with a copper-to-superconductor ratio of 1.5. When the superconductor transitions to the normal state, all the current is expelled to the copper stabilizer. Compute how long it takes to the copper to heat up to 300 K. Assume the following properties for copper:

- Resistivity $\rho_{sc} = 3.4 \times 10^{-10}$ Ωm
- Density γ = 8960 Kg/m^3
- Specific heat c_p (at 100 K) = 240 J/(Kg K)