Problem 1 (10 points)

a. Using a constitutive model for an isotropic elastic solid that relates strains to applied effective stresses corrected by Biot's coefficient, assume you have a sample in subsurface subjected to overburden, and that confinement in both horizontal principal directions is so large that the horizontal strains are nearly zero. Derive elastic equations for horizontal stresses (use the variables x and y for horizontal directions) in terms of vertical loading as a function of depth (in z direction).

b. Assume you are at depth of 4 km and the pore pressure at that depth is hydrostatic. Using the equations derived in a) above, Biot's parameter of $\alpha = 0.7$, and a Poisson's ratio $\nu = 0.2$, estimate the horizontal stress magnitudes $S_{hmin} = S_{Hmax}$ at that depth.

Problem 2 (30 points)

Bernabe and Brace (1990) in their article "Deformation and fracture of Berea Sandstone" reported a number of triaxial test measurements for Berea sandstone, and some of them are given in the table below (all data in MPa).

S_3 (confining pressure)	P_p (pore pressure)	$S_1 - S_3$ (differential stress)
10	0	116
50	0	227
20	8	119
45	8	183
60	8	206
75	8	228
50	37	120
50	32	141
90	64	161
90	55	187
130	96	186
130	84	207

Fit this data to Mohr-Coulomb criterion to compute unconfined compressive strength C_0 and internal friction coefficient μ_i for Berea sandstone.

Problem 3 (20 points)

Given:

- $S_{Hmax} = 90$ MPa
- $S_{hmin} = 51.5$ MPa
- $P_p = P_w = 31.5$ MPa

Recreate Figure 6.2 in Zoback, also shown here.