Problem 1

(2 points each) Circle the best answer:

(i) Which of the following conditions is true in a *triaxial extension* test for principle stresses, S_1, S_2, S_3

(a) $S_1 > S_2 = S_3$

(b) $S_1 < S_2 = S_3$

(c) $S_1 = S_2 = S_3$

(ii) Which of the following *is not* a standard assumption of poroelasticity.

(a) There is an interconnected pore system uniformly saturated with fluid.

(b) The pore pressure, the total stress acting on the rock externally, and the stresses acting on the grains are statistically defined.

(c) The total volume of the pore system is large compared to the volume of the rock.

(iii) True or False? The elastic behavior of an *isotropic* solid is fully characterized by three independent constants.

(a) True

(b) False

(iv) The Mohr-failure envelope for a rock as a distinct parabolic curve, which failure model would provide the best capability to predict the failure of the rock.

(a) Hoek-Brown

(b) von Mises

(c) Mohr-Coulomb

(v) True or False? A typical range for Poisson ratio in rocks is between $0.2 < \nu < 0.6$

(a) True

(b) False

(vi) So-called *cap failure models* provide the ability to model

(a) inelastic effects occurring for increasing hydrostatic pressure.

(b) failure in pure shear.

(c) inelastic effects due to slip on crystallographic planes.

(vii) In a vertical wellbore, we expect breakouts to occur along the direction of

(a) S_v.

(b) S_{Hmax}.

(c) S_{hmin}.

(viii) True or False? A *stable wellbore* is defined as one that is absent from any breakouts.

(a) True

(b) False

Problem 1 continued on next page...

(ix) In a vertical wellbore, we expect drilling induced tensile fractures to occur along the direction of

(a) S_v.

(b) S_{Hmax}.

(c) S_{hmin}.

(x) True or False? In a lower hemispherical projection plot associated with drilling deviated wells, the outermost concentric ring, i.e. the edge of the plot, represents a vertical well.

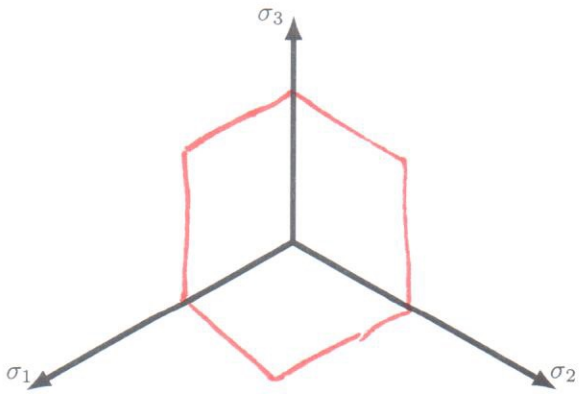
(a) True

(b) False

Problem 2

(5 points each) Short answer:

(i) Sketch a Mohr-Coulomb failure surface in the π-plane on the figure.

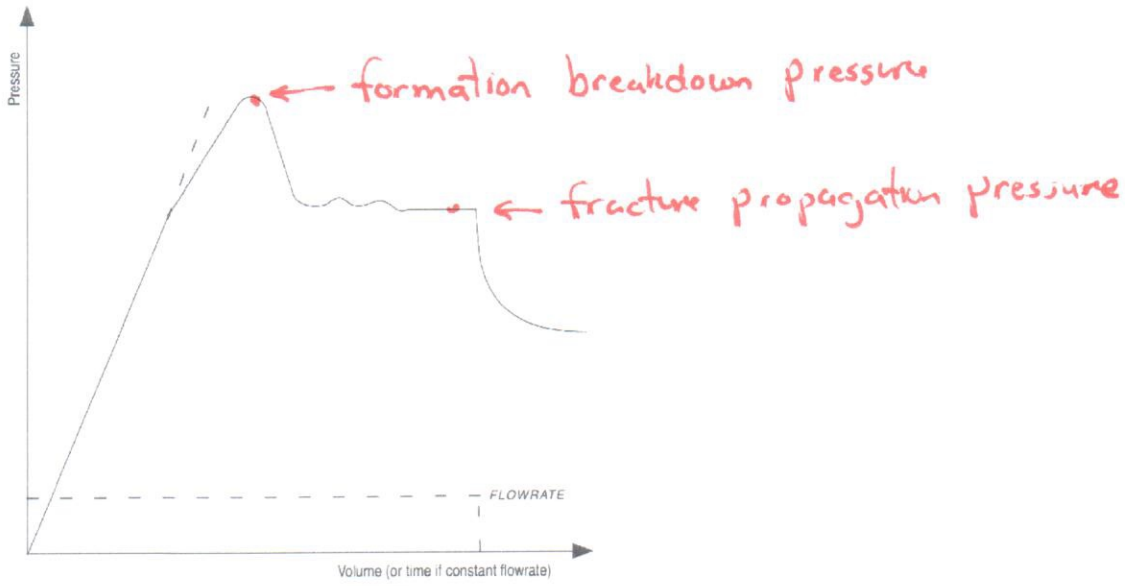


(ii) List two reasons why tensile strength is relatively unimportant in reservoir geomechanics.

1. Entire crust of the Earth is under compressive stress.

2. Rocks have negligible tensile strength.

(iii) On the figure below that schematically represents an extended leakoff-test

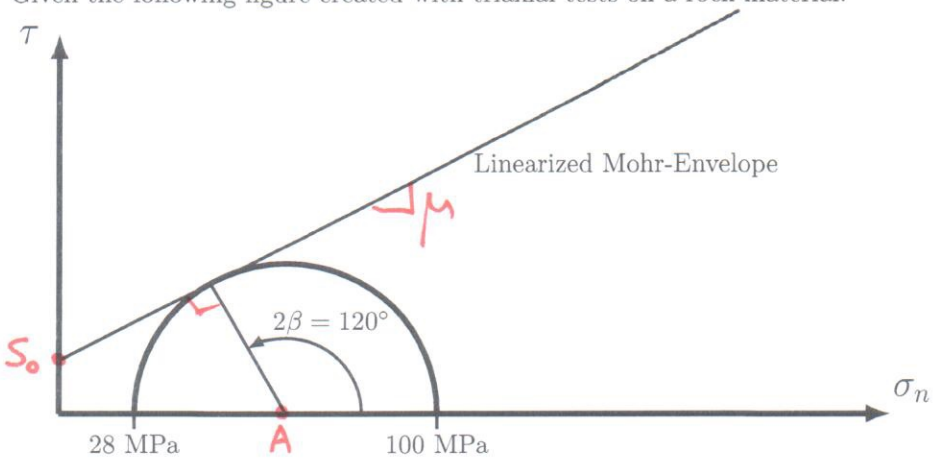


Label the **formation breakdown pressure** and the **fracture propagation pressure**.

Problem 3

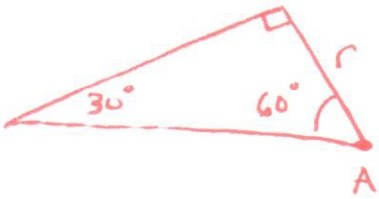
(20 points)

Given the following figure created with triaxial tests on a rock material:



Give the unconfined compressive strength of the material.

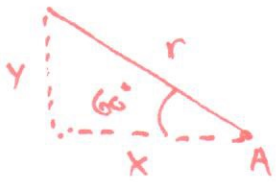
From problem geometry:



$$\mu = \tan 30^\circ = \frac{1}{\sqrt{3}}$$

$$A = \frac{100 + 28}{2} = 64$$

$$r = \frac{100 - 28}{2} = 36$$



$$x = r\cos(60^\circ) = 18$$

$$\tau = y = r\sin(60^\circ) = 18\sqrt{3}$$

$$\sigma_n = A - x = 46$$

$$S_0 = \tau - \sigma_n \mu = 18\sqrt{3} - 46/\sqrt{3} = 8\sqrt{3}$$

$$C_0 = 2S_0\left(\sqrt{\mu^2+1} + \mu\right) = \boxed{16 \text{ MPa}}$$

Problem 4

(20 points) Lab strength tests on *dry rock samples*, i.e. no pore fluid, with peak shear strength values have been fit to the linear relationship $S_1 = 22.8$ MPa $+ 4.12$ MPa S_3. What is the unconfined compressive strength C_0 and internal friction coefficient μ_I for this rock.

$C_0 = 22.8$ MPa

$n = 4.12$

$$\mu = \frac{n-1}{2\sqrt{n}} = 0.769$$

Problem 5

(**25 points**) Given the geographical stress,

$$\mathbf{S}_G = \begin{bmatrix} 47.5 & -12.5 & 0 \\ -12.5 & 47.5 & 0 \\ 0 & 0 & 40 \end{bmatrix} \text{ MPa}$$

For a wellbore deviated 30° from vertical along an azimuth oriented directly to the north, find the wellbore stress tensor, $\mathbf{S}_B$.

$\phi = 30°$ $\delta = 0°$

Use Matlab script

$$S_b = R_b S_g R_b^T$$

$$S_b = \begin{bmatrix} 45.625 & -10.825 & 3.248 \\ -10.825 & 47.5 & -6.25 \\ 3.248 & -6.25 & 41.875 \end{bmatrix}$$