Homework 1: Characterization of Potential Earthquake Sources
No late assignments will be accepted
5% of total grade; **100 pts total**

Before you get started: Draw the plots called for here on good graph paper, not on regular notebook paper. A green engineering calculation pad is very good for this type of assignment (and you will see two more like this); I highly recommend getting such a pad. I will consider neatness in my grading, so be neat.

In describing the stresses here, I will use the on-in convention described in class. Tension is positive.

Suppose that measurements of stress in the earth indicate on a vertical plane oriented north-south the horizontal normal traction is -17 MPa, and the shear traction has a magnitude of +17 MPa. On a vertical plane oriented east-west the normal traction is -17 MPa, and the shear traction has a magnitude of -17 MPa. Two vertical faults are in the region affected by this stress field. Fault A strikes 14° (i.e., N14°E), and fault B strikes 346° (i.e., N14°W). Geologists measure "strikes" relative to true north.

1   Draw a picture that _neatly_ illustrates the quantities above **(13 pts total)**
   a   Neatly draw a square box in a map view with sides 3"-4" long, with the sides trending north-south and east-west, and put a north arrow in the box (**1 pt**).
   b   Show normals to the box sides in light lines. Label the x-axis as pointing east and the y-axis as pointing north (**2 pts**).
   c   Label the "far-field" stresses on the sides of the box (**4 pts**).
   d   Inside the box draw the traces of the fault planes (i.e., the azimuth of the vertical fault planes) in fairly heavy lines (**2 pts**). Make the box big enough so that it is useful and make sure that the box is in equilibrium.
   e   Label the normal to fault A as the x'-axis and a line parallel to the fault as the y'-axis; make the x' and y ' axes be right-handed. (**2 pts**).
   f   Label the normal to fault B as the x''-axis and a line parallel as the fault be the y''-axis; make the y'' and y'' axes be right-handed (**2 pts**).

2   Fill in the following table as you go (you can't fill this out entirely at the start, but you can have it filled out completely by the end):   **(16 pts total)**

	Normal stress (MPa)	Shear stress (MPa)	Normal traction (MPa)	Shear traction (MPa)
North-south plane	σ_{xx}	σ_{xy}	τ_{xn}	τ_{xs}
East-west plane	σ_{yy}	σ_{yx}	τ_{yn}	τ_{ys}
Fault A	$\sigma_{x'x'}$	$\sigma_{x'y'}$	$\tau_{x'n}$	$\tau_{x's}$
Fault B	$\sigma_{x''x''}$	$\sigma_{x''y''}$	$\tau_{x''n}$	$\tau_{x''s}$

3   Prepare a Mohr circle diagram using the convention described in class. A positive angle is a counterclockwise angle in this part of the exercise. (30 pts total)

    a   Plot the point that depicts the tractions acting on a north-south plane, and label the point (τ_{xn}, τ_{xs}). (2 pts).

    b   Plot the point that depicts the tractions acting on an east-west plane, and label the point (τ_{yn}, τ_{ys}). (2 pts).

    c   Draw the Mohr circle that defines the state of stress in the region containing the faults (4 pts).

    d   Plot the point that depicts the normal and shear <u>tractions</u> acting on fault A by using the negative double angle between the x-axis and the x'-axis; label the point ($\tau_{x'n}, \tau_{x's}$) and the negative double angle $-2\theta_{XX'}$ (2 pts). Write the <u>stresses</u> in the table (2 pts).

    e   Plot the point that depicts the normal and shear <u>tractions</u> acting on fault B by using the negative double angle between the x-axis and the y''-axis; label the point ($\tau_{x''n}, \tau_{x''s}$) and the negative double angle $-2\theta_{XX''}$ (2 pts). Write the <u>stresses</u> in the table (2 pts).

    f   Determine the magnitude of the most tensile principal stress (σ_1) and the least tensile principal stress (σ_2) from the Mohr circle plot. Write your answers below:

       $\sigma_1 = \tau_{x'''n}$ =_____. (2 pts) $\sigma_2 = \tau_{y'''n}$ =_____. (2 pts)

    g   Determine the orientation relative to true north (i.e., find the trend) of the two principal horizontal stresses (4 pts) by using the negative double angle on the Mohr circle plot (i.e., find the orientation of σ_1 and σ_2 relative to the y-axis), and draw a new box with the sides normal to the orientations of these two stresses (2 pts). Draw faults A and B inside this box (2 pts). Neatly label the stresses acting on the box sides (e.g., $\sigma_{x'''n}$ = 55 MPa) (2 pts).

4   Determination of the sense of slip (9 pts total)

    a   From your answers above, what is the sense of slip that you would expect for fault A? By sense I mean right-lateral or left-lateral. (2   pts)

    b   What is the sense of slip that you would expect for fault B? (2 pts)

    c   If the shear strength of the fault is governed by friction (so that the shear <u>strength</u> of the fault is proportional to the compressive stress acting across the fault) and each fault has the same coefficient of friction, which fault is most likely slip? Explain below (5 pts).

5   Assume that one of the faults does slip. Geologists had collected information <u>before</u> the
    earthquake and estimated a possible rupture length of 50 km, a rupture height of 10 km
    (this is typical for the San Andreas fault), and an average amount of slip of 2.0 meters, with
    the relative displacement being purely horizontal. These turn out to precisely describe the
    fault rupture. If the shear modulus of the rock surrounding the fault is 3.0 x10^4 MPa (and
    this is a typical value) make the following calculations **(9 pts total)**:
    a   Calculate the seismic moment i<u>n Newton-mete</u>rs. **(2 pts + 1 pt)**

    b   Using the relations in the class notes, estimate the likely moment magnitude of the quake
        (2 pts + 1 pt).

    c   Using the Bikini Atoll atomic blast as a comparison (energy release of 10^{12} joules),
        how many bomb blasts would the earthquake be equivalent to? **(2 pts + 1 pt)**

6   Suppose that the geologic estimates were off, and that the actual relevant dimensions were:
    rupture length = 40 km, rupture height = 8 km, average slip = 1.6 meters **(13 pts
    total)**.
    a   Calculate the seismic moment i<u>n Newton-mete</u>rs. **(2 pts + 1 pt)**

    b   Using the relations in the class notes, estimate the likely moment magnitude of the quake
        (2 pts + 1 pt).

    c   Using the Bikini Atoll atomic blast as a comparison (energy release of 10^{12} joules),
        how many bomb blasts would the earthquake be equivalent to? **(2 pts + 1 pt)**

    d   Comment on how different the answers are for question 6 relative to those of question 5,
        and indicate whether you think the differences are likely to be significant in terms of
        engineering design considerations **(4 pts)**.

7   Neatness counts for **10 points**