MSE 102, Fall 2012 Midterm #1

Write your name here: ______________________________

Instructions:

- Answer all questions to the best of your abilities. Be sure to write legibly and state your answers clearly.
- The point values for each question are indicated.
- You are not allowed to use notes, friends, phones, consultants, employees, etc.
- There are a total of 105 points. 100 points will be considered a perfect score for grading purposes. Points above 100 will count as extra credit for the midterm contribution to your grade.
- Feel free to ask questions, but only for clarification purposes.

Good luck. I sincerely hope you all do really well.

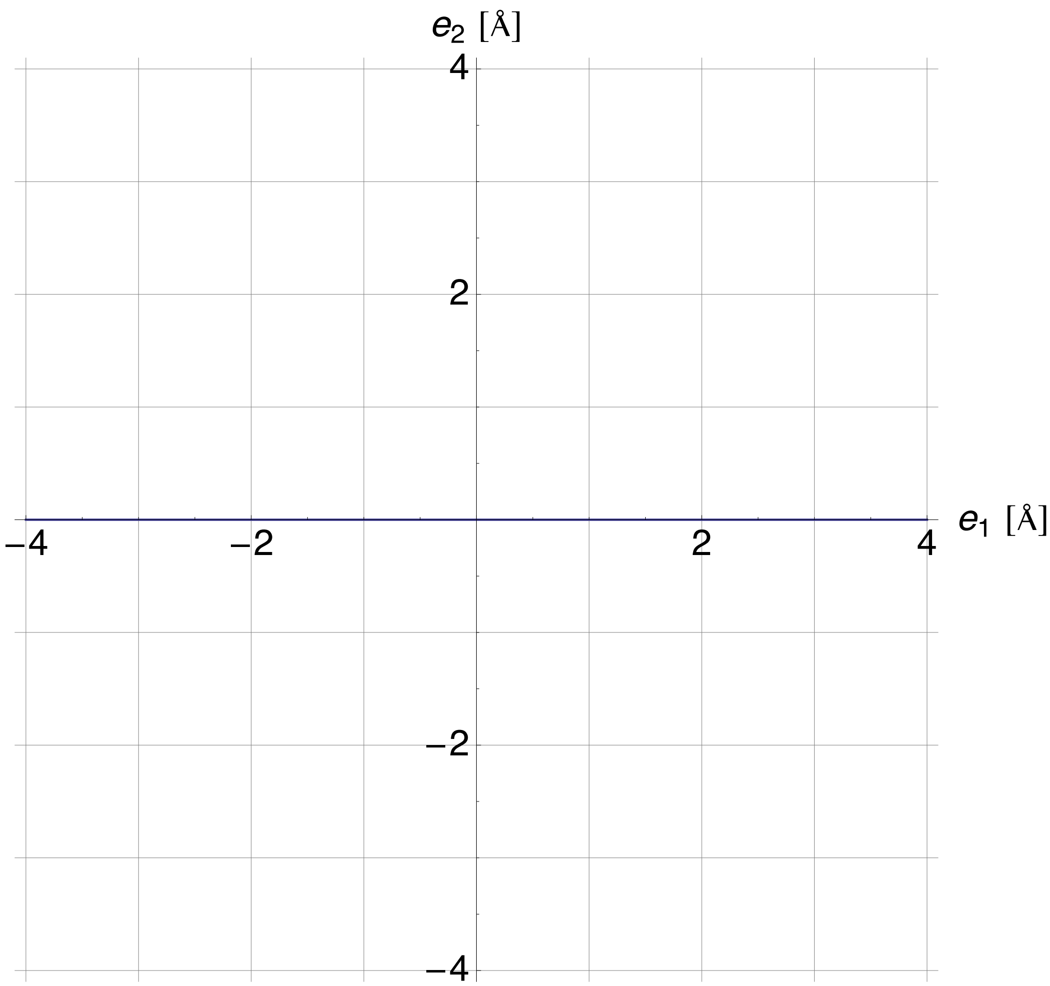
-Prof. Chrzan

Problem 1. **[40 points total]** A 2-D crystal has an atomic scale structure described by the symmetry group *c2mm* (see the attached entry from the International Tables for Crystallography). The length of the vector $\mathbf{a}$ is 2 Å, and the length of lattice vector $\mathbf{b}$ is 4 Å. There are Si atoms at Wyckoff position(s) *c*, and there are O atoms at positions *f* with $x = 1/8$ and $y = 1/8$.

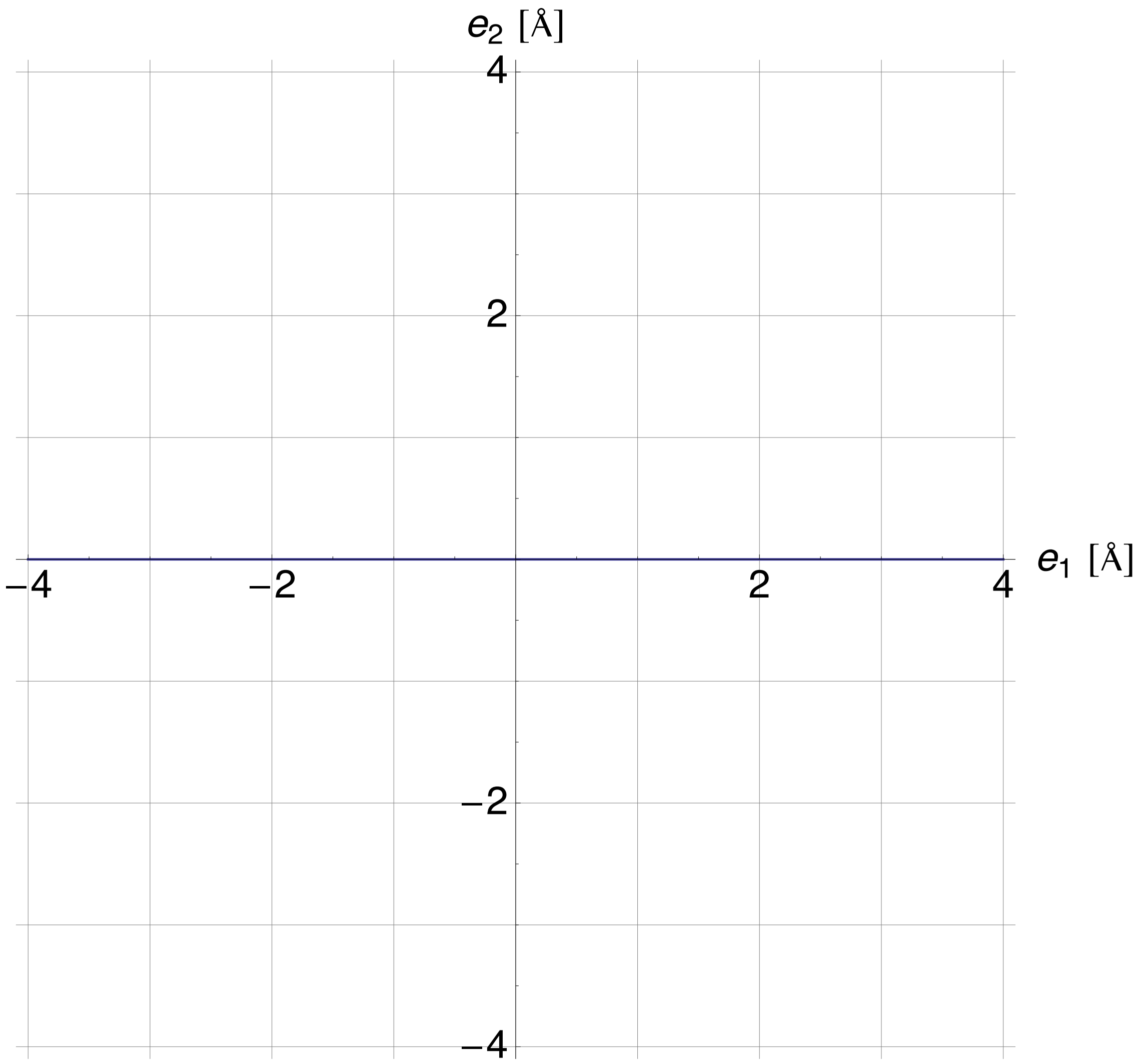
Based on this information:

1. (5 points) On the attached graph, plot the positions of the lattice points with an ×. Plot all of the lattice points that appear in the range of the plot. (5 points) Indicate the positions of the Si atoms with a **O**.

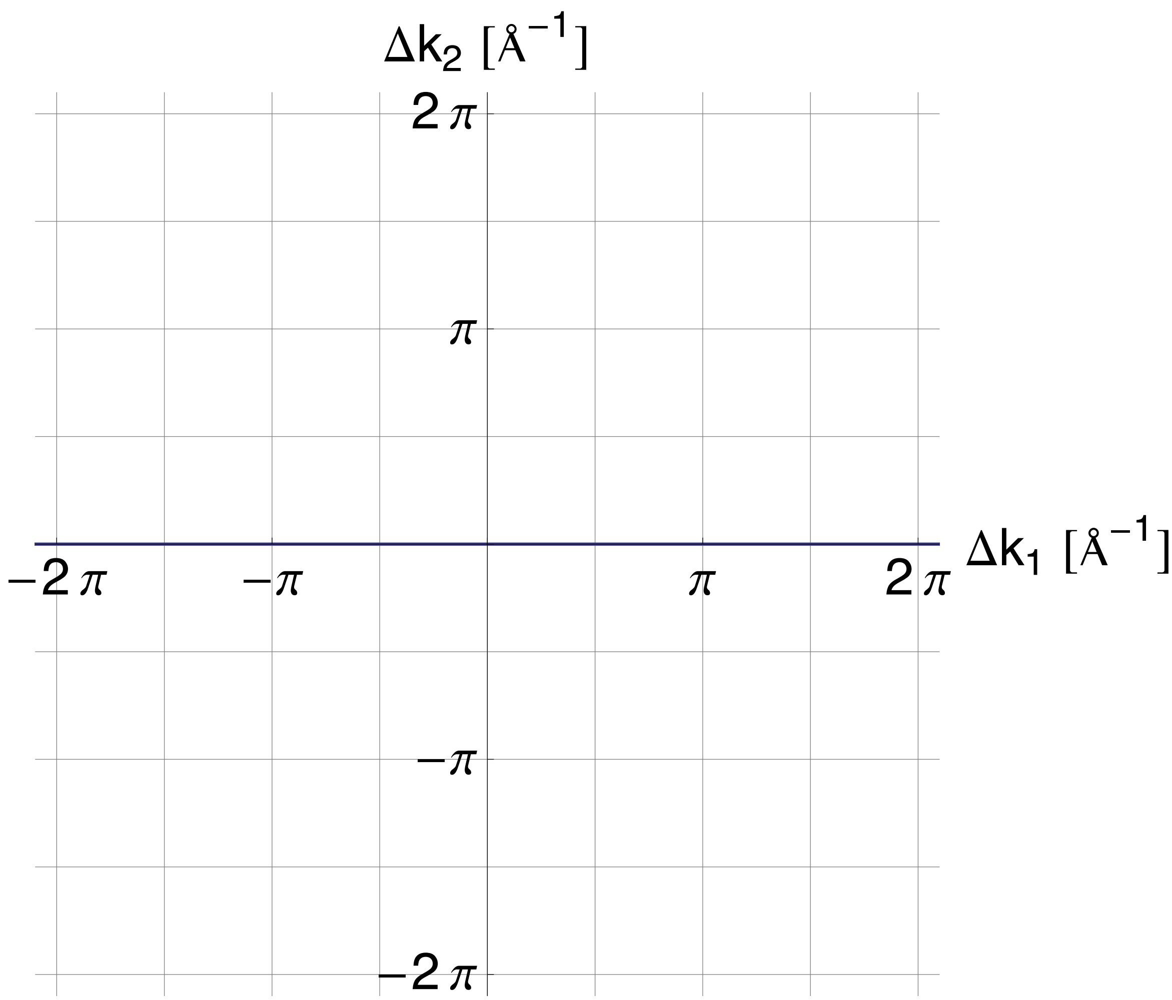
2. (5 points) Identify a set of *primitive* lattice vectors for the crystal. Write their coordinates here (in terms of $\mathbf{e}_1$ and $\mathbf{e}_2$) and draw them on your plot of the lattice.



3. (5 points) Identify the Wigner-Seitz cell for this crystal on the plot below. Use a straight edge and construct the plot as carefully as you can. (5 points) How many Si atoms are there per primitive unit cell? (5 points) How many O atoms are there per unit cell described in the plane group table entry?

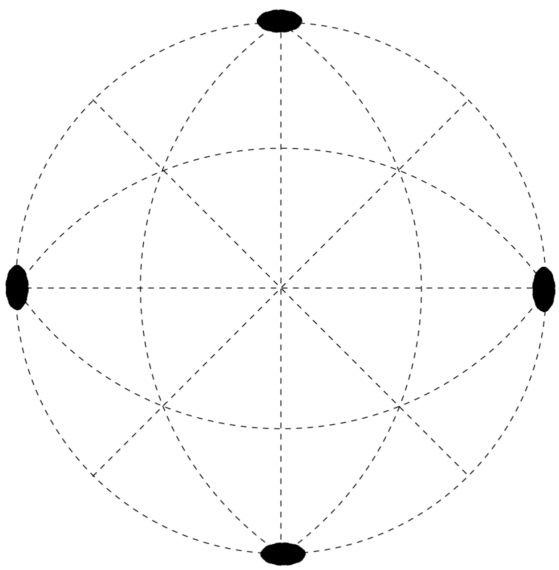


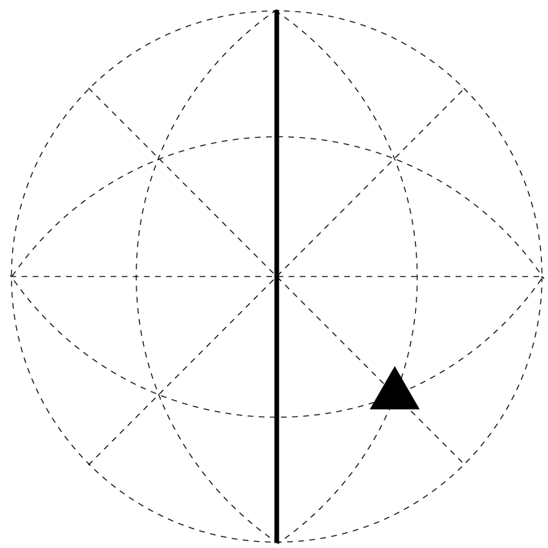
4. (5 points) Construct the primitive reciprocal lattice vectors corresponding to the primitive lattice vectors you found in part (2) of this problem and write them in terms of $\mathbf{e}_1$ and $\mathbf{e}_2$. On the graph below sketch the vectors and plot the positions of the reciprocal lattice points generated by your primitive reciprocal lattice vectors by marking them with an $\times$. Indicate the positions of all reciprocal lattice vectors in the range of the plot.

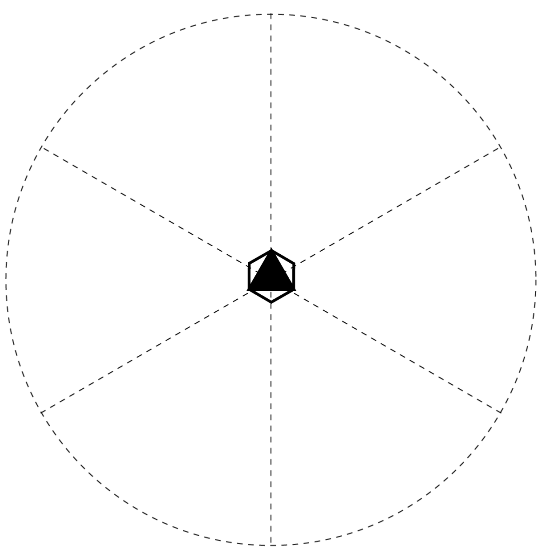


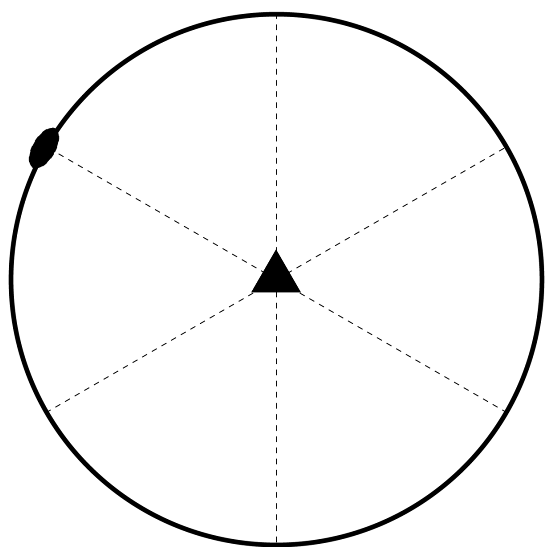
5. (5 points) On the same plot, indicate with a **O** the points at which you expect to see diffraction peaks with contributions from the O atoms based on the conditions given in the Plane Group table entry. (That is, don't worry about additional effects associated with the fact that x and y may have specific values.) (5 points) Is your plot consistent with the reflection conditions given in the plane group table? Why or why not?

Problem 2. **[20 points total]** (5 points each) Complete the following stereograms. Indicate all symmetry elements on the stereogram (no need to list them explicitly), and which directions are equivalent by symmetry. Be sure to pick a direction that does *not* lie on a symmetry element. [You will lose one point per incorrect (either missed or erroneously present) symmetry operation and equivalent direction (up to the maximum value of each stereogram).]

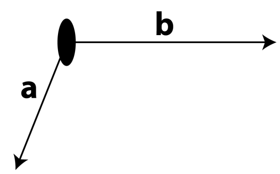








Problem 3. **[10 points total]** A crystal structure contains the 2 lattice translations and the two-fold rotation axis shown in the figure. All of the symmetry of the crystal is implied by the depicted operations. (5 points) Sketch the unit cell with all of its symmetry operations. (5 points) Provide a detailed (though it can be brief) justification for each symmetry operation that you sketched.



Problem 4. **[15 points total]** The primitive lattice vectors of a 3D crystal are given by:

$$\mathbf{a} = -2\mathbf{e}_1 - 1\mathbf{e}_2$$
$$\mathbf{b} = 1\mathbf{e}_1$$
$$\mathbf{c} = 2\mathbf{e}_3$$

(5 points) Find the primitive reciprocal lattice vectors for this lattice. Express them in terms of $\mathbf{e}_1$, $\mathbf{e}_2$ and $\mathbf{e}_3$. (5 points) Give vector normal to the (312) plane for this crystal. (5 points) What is the distance between (111) planes for this crystal?

Problem 5. **[20 points total]** The image on the next page is an atomic scale sketch of a portion of a known 2-D crystal. The atoms are shown as blue dots.

(a) (5 points) Identify a set of lattice points in the sketch. Mark them with an $\times$. (You only need to identify enough of the points to prove that you have identified the lattice.)

(b) (5 points) Identify a primitive unit cell. How many atoms are in a primitive unit cell? Sketch the basis vector for each atom in the primitive unit cell.

(c) (5 points) Give the name of the plane group describing the symmetry of this crystal. At what positions do the displayed atoms sit?

(d) (5 points) Within your primitive unit cell, sketch the asymmetric unit for your crystal.