Wavelength and Resolution

Background:
Objects are seen when light reflects off the object. Resolution is the ability to distinguish between two separate objects very close together. The human eye has a resolution of about 0.10 mm (Raven and Johnson), which means that two points must be at least 0.10 mm apart to be distinguished as two separate points, and an object needs to be at least 0.10 mm in diameter for it to be detected by the human eye. Magnifying lenses allow us to see objects that are closer together than 0.10 mm by artificially spreading them apart. But if the object is very much smaller than the wavelength of light, then the light wave can pass right around it without being affected. Therefore, the resolution of objects by light magnification is still limited to the wavelength of visible light. The visible spectrum of electromagnetic radiation falls between 400 and 700 nm. It has been demonstrated that objects smaller than approximately ½ the wavelength of light cannot be detected. As a result, resolution from visible light is limited to objects larger than or farther apart than 250 nanometers.

To “see” objects on a nano-scale, better resolution is necessary. Electron microscopes work by reflecting high energy off of objects. These electrons have wavelengths over 100,000 times shorter than visible light. They are “focused” using electrostatic or electromagnetic fields so that objects on the order of 0.20 nm can be detected (Raven and Johnson). As electrons are passed through very thin samples (transmission electron microscope) or bounced off the surface of whole samples (scanning electron microscope), they are detected by a cathode ray tube (TV screen). The object is “seen” only indirectly as the results of the deflected electrons are interpreted as images or “pictures” of the object.

Purpose:
The purpose of this activity is to demonstrate the limits of our ability to “see” objects and the details of objects at the nano scale using indirect methods such as electron microscopes or scanning-tunneling microscopes, and to illustrate the importance of resolution to detect detail.

Materials:
4 Demonstration boxes with differently sized and spaced holes and dowel rod “detectors”
2 sample objects with differing properties, such as a roll of tape, a rubber ball, a calculator, or any solid object that will fit in the box.

Procedure:
1. Place the object in the box and place the dowel rods vertically through the holes so that they are all around and on top of the object. Note the length of dowel rod above the box using the marks on the side. For example, if the dowel rod hits the bottom of

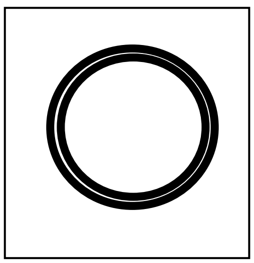
the box, the lowest visible line above the lid will be 0. Since the rods are of uniform length, a rod that is 3mm higher than the bottom of the box will have its 0 line 3mm above the lid.

2. Make a simple sketch of the object in the space provided on the left on the data page, and show the relative placement of the dowel rods on the grid provided on the right. Write the number indicating the elevation of each dowel rod in the corresponding spot on the grid. Then interpret the grid in the third box.

3. Repeat steps #1 and #2 using the other three lids with differently spaced holes and differently sized dowel rods. The smaller dowel rods and the closer spacing represent higher energy electron beams with smaller wavelengths and therefore greater resolution. For each box, write the number indicating the elevation of the dowel rod in the corresponding spot on the grid.

Sample Data:
The following data might be expected for a small rubber ball inside each box.

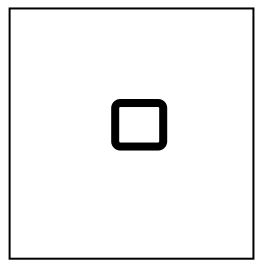
Sketch of actual object



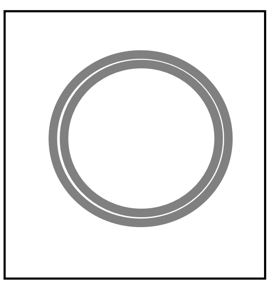
Grid data Box #1

0		0		0
0		4		0
0		0		0

Image of object from grid data



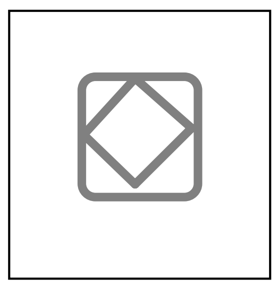
Sketch of actual object



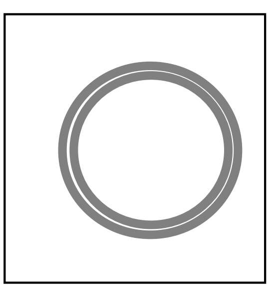
Grid data Box #2

0	0	0	0	0
0	3	2	3	0
0	2	2	2	0
0	3	2	3	0
0	0	0	0	0

Image of object from grid data



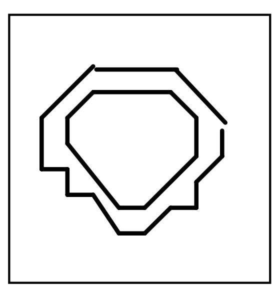
Sketch of actual object



Grid data Box #4

	0	0	0	0	0	0	0	0	
	0	0	3	3	3	3	0	0	
	0	3	2	2	2	2	3	0	
	3	2	2	2	2	2	2	3	
	3	2	2	2	2	2	2	3	
	3	3	2	2	2	2	3	0	
	0	3	3	2	2	3	3	0	
	0	0	0	3	3	0	0	0	

Image of object from grid data



Name ________________________ **Section**_________________

Date ___________________

Data Page

Sketch of actual object | Grid using Box #1 | Sketch of object from grid

Sketch of actual object | Grid using Box #2 | Sketch of object from grid

Sketch of actual object | Grid using Box #3 | Sketch of object from grid

Sketch of actual object | Grid using Box #4 | Sketch of object from grid

Questions:

1. How well did the “detectors” from the box with the lowest “resolution” represent the actual object?

2. How well did the “detectors” from the box with the highest “resolution” represent the actual object?

3. What properties of an object might be missed when using indirect measurement such as was used in this activity?

4. What is necessary to improve the resolution?

Insight: ____

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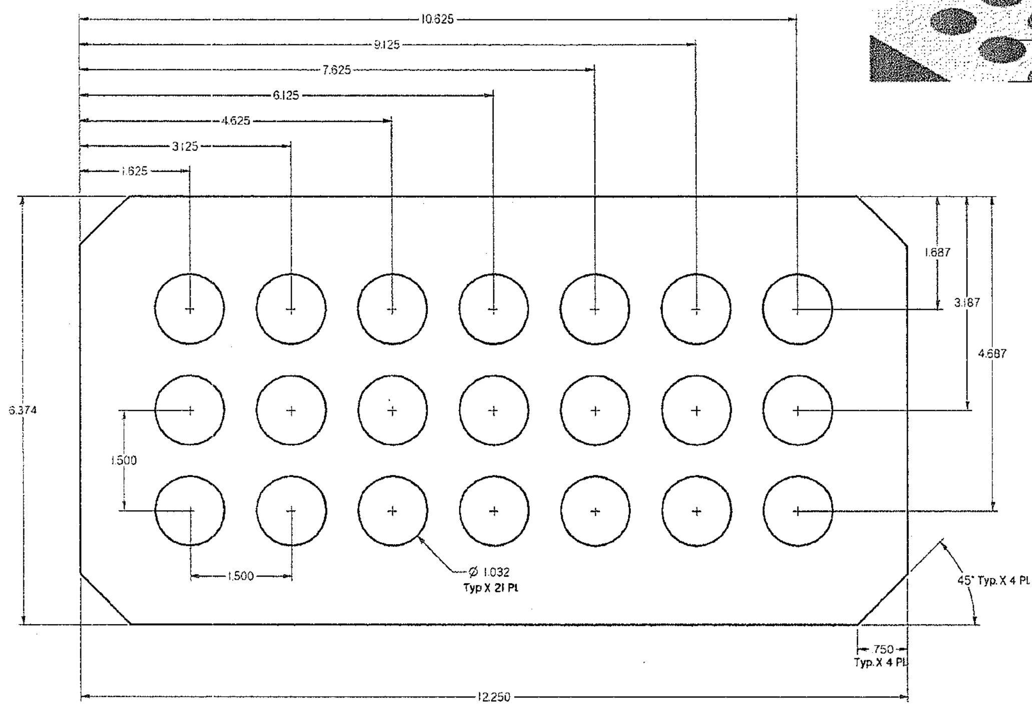
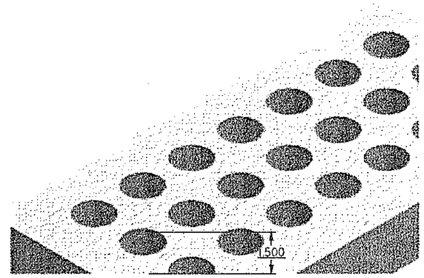
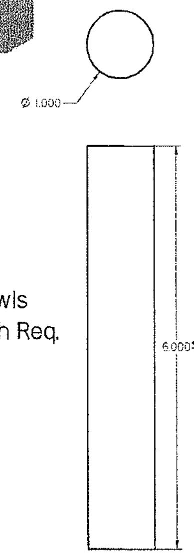


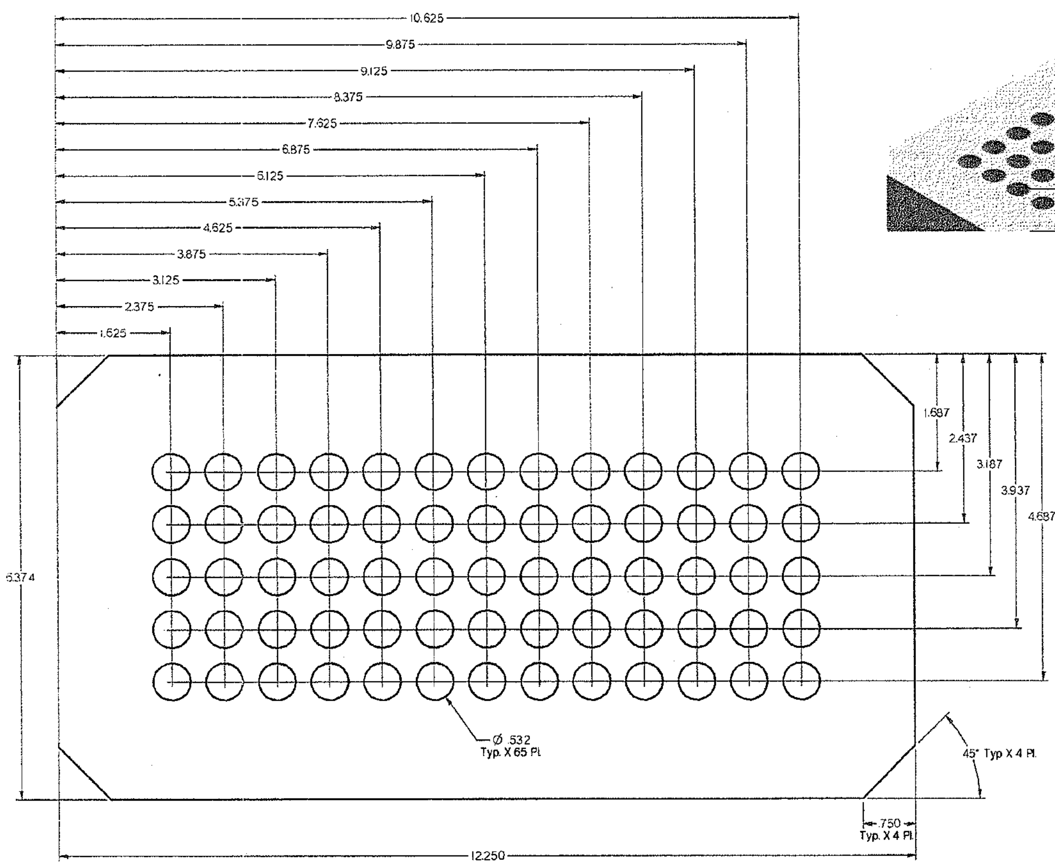


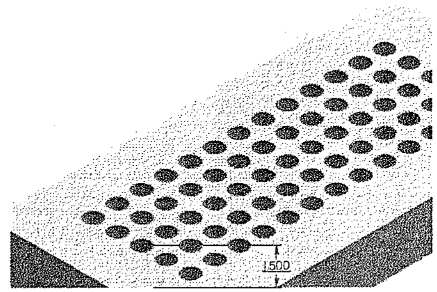


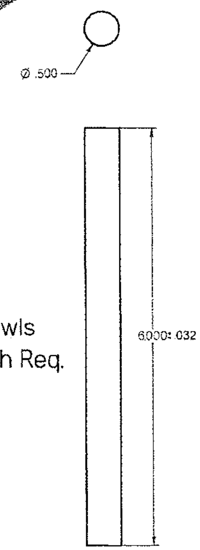
1" Dowls
21 Each Req.

fits Sterilite storage box #1952

MATERIAL	Wood 12" X 8" board	Machine Laboratory Chemical & Biomolecular Engineering	
DRAWN	Paul Green 02/28/07		
ADVISOR	David Tomasko		
STUDENT		Group: School Science Project	
The Ohio State University			
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES ANGLES ±10° FRACTIONS ±1/64 2 PL ±.001 3 PL ±.0005		SIZE A2	PART Name: Peg Board	REV
		FILE NAME: Science Project 1 Inch Holes.dft	
		SCALE: NONE	WEIGHT:	SHEET 3 OF 1



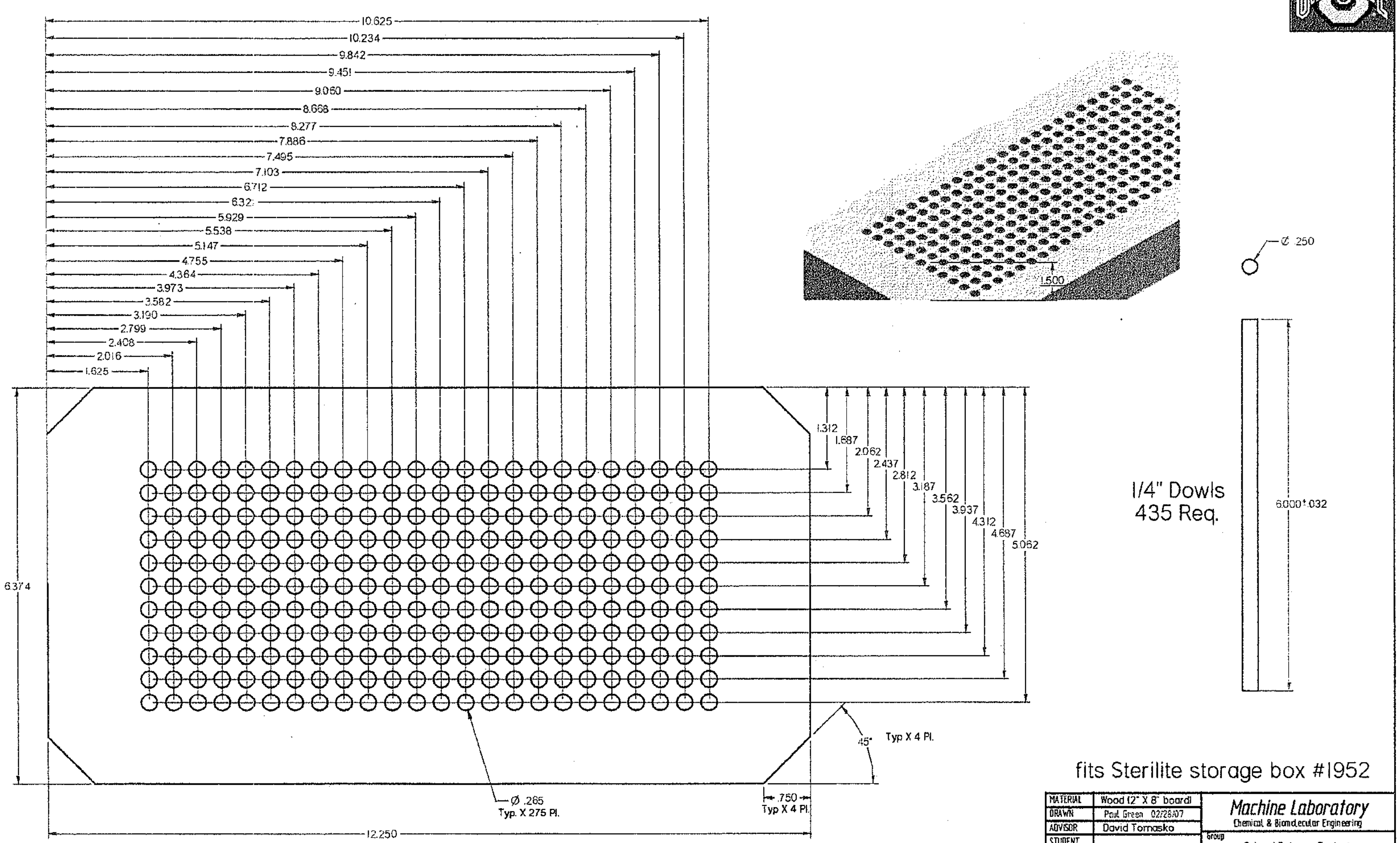




1/2" Dowls
105 Each Req.

fits Sterilite storage box #1952

MATERIAL	Wood (2" X 8" board)	*Machine Laboratory* Chemical & Biomolecular Engineering	
DRAWN	Paul Green 02/28/07		
ADVISOR	David Tomasko	Group: School Science Project	
STUDENT			
The Ohio State University		SIZE A2 | PART Name: Peg Board	REV
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES ANGLES ±10° FRACTIONS ±1/64 2 PL ±0.01 3 PL ±0.005		FILE NAME: Science Project .5 Inch Holes.dft	
		SCALE: NONE | WEIGHT:	SHEET 3 OF 1



fits Sterilite storage box #1952

MATERIAL	Wood 12" X 8" board	Machine Laboratory Chemical & Biomolecular Engineering	
DRAWN	Paul Green 02/26/07		
ADVISOR	David Tomasko	Group: School Science Project	
STUDENT			
The Ohio State University		SIZE A2	PART name: Peg Board / REV
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES ANGLES ±10° FRACTIONS ±1/64 2 PL ±0.01 3 PL ±0.005		FILE NAME: Science Project .25 Inch Holes.dft	
		SCALE: NONE	WEIGHT / SHEET 3 OF 1