Key: Yellow highlight = required component

Shifting Molecules in 3 dimensions

Subject Area(s) : Problem solving, Chemistry, Physics, Trigonometry

Associated Unit : Introduction to methods, and problem solving.

Lesson Title : Problem solving and spatial reasoning.

Grade Level : 9th-12th

Time Required : One (1) 50-minute class period.

Summary **Students will be using MOF unit cell representations of non-orthogonal shapes to practice spatial reasoning and problem solving when having to duplicate one of these shapes using trigonometric functions.**

Engineering Connection

1. Engineering Category = Relating science and/or math concept(s) to engineering

Keywords

MOFs, Spatial reasoning, vectors

Educational Standards (List 2-4)

State STEM Standard (required) N/A

ITEEA Standard N/A

NGSS Standard (strongly recommended) SC.68.CS-CS.1.4

Interact with content-specific models and simulations to support learning, research and problem solving (e.g., immigration, international trade, invasive species).

CCSS Standard - CCSS.Math.Content.HSG.SRT.D.11

(+) Understand and apply the Law of Sines and the Law of Cosines to find unknown measurements in right and non-right triangles (e.g., surveying problems, resultant forces).

Pre-Requisite Knowledge

Sine and Cosine functions.
Vectors
Shifting transformations
Angles

Learning Objectives

After this lesson, students should be able to:

- **Shift a non-orthogonal object properly in order to duplicate the object in all directions.**
- **Use trigonometric functions to calculate shifts in each direction.**

Introduction / Motivation (5E – Engage)

The students will be introduced to Metal Organic Frameworks, and be shown an example of MOF-5, as well as MOF 5 as a supercell when it is duplicated into the x, y, and z, directions. These

supercells give us a much better look at the interactions and shapes inside of MOFs. Students will then be shown MOF-505 which is a non orthogonal MOF, these shapes have angles that are not simply 90 degrees. Students will be told about the potential uses of MOF-505, and be asked to create the supercell of MOF-505 when given the lattice parameters for MOF-505.

Lesson Background & Concepts for Teachers (5E – Explain)

MOFs – Metal organic frameworks, Metal cations attached to organic linkers that form repeating polymeric shapes. Have extremely high amounts of free space and surface area which gives them the capabilities to hold large amounts of gasses. This is the primary interest in MOFs in research.

Vocabulary / Definitions

Word	Definition
Nonorthogonal	When two lines or axis are at an angle other than 90 degrees.

Associated Activities (5E – Explore)

Practice similar steps with different MOFs that have different angles and sizes.

Lesson Closure

Leading the students into activities with different vector practices, and tying this lesson into your appropriate next lesson.

Assessment (5E – Evaluate)

Lesson Summary Assessment
Descriptive Title: MOF-505 and MOF-1 comparison

Homework
Descriptive Title: Vector and Triangle practice

Contributors

Nicholas Hutchinson

Supporting Program

NSF RET program at the University of South Florida.

Classroom Testing Information

N/a