

# Exercise: Programming



# Session Outline

- Introduce where to find the code and how to open it
- Exercise: program the set partitioning and max cut QUBOs
- Review the solution (tomorrow)

## Session Goals

1. Practice programming a QUBO onto Advantage



# Material



# Exercises

If you have access to Leap

1. Log in to Leap
2. In a new tab open up [https://github.com/dwave-training/cdl\\_2021\\_python](https://github.com/dwave-training/cdl_2021_python)
  - a) This is where the exercises and instructions are. Note that both the set partitioning and max cut exercises are here
3. To open up the code in the Leap IDE, type <https://ide.dwavesys.io/#> in front of the github URL.
  - a) Alternatively open [https://ide.dwavesys.io/#https://github.com/dwave-training/cdl\\_2021\\_python](https://ide.dwavesys.io/#https://github.com/dwave-training/cdl_2021_python)
  - b) You may complete the exercise in the Leap IDE

# Exercises

If you DO NOT have access to Leap

1. Install Ocean locally if you haven't already  
<https://docs.ocean.dwavesys.com/en/latest/overview/install.html>
2. Open and clone or copy the code in the exercises folder here:  
[https://github.com/dwave-training/cdl\\_2021\\_python](https://github.com/dwave-training/cdl_2021_python)
  - a) This is where the exercises and instructions are. Note that both the set partitioning and max cut exercises are here
3. Instead of using the *DWaveSampler* and *EmbeddingComposite*, use *SimulatedAnnealing* instead. Replace the sampling code in the files with this:

```
from neal import SimulatedAnnealingSampler

sampler = SimulatedAnnealingSampler()
Sampleset = sampler.sample(bqm)
```

SimulatedAnnealingSampler documentation:

[https://docs.ocean.dwavesys.com/en/latest/docs\\_neal/sdk\\_index.html](https://docs.ocean.dwavesys.com/en/latest/docs_neal/sdk_index.html)



# Reminders



# Example: Set Partitioning

## Problem

Partition the numbers in  $[-5, 9, 4]$  into two sets such that the sum of each set is equal

$$E_{qubo} = 260x_0 + 36x_1 - 64x_2 - 360x_0x_1 + 288x_1x_2 - 160x_0x_2$$

$x_0$	$x_1$	$x_2$	E
0	0	0	0
0	0	1	-64
0	1	0	36
0	1	1	260
1	0	0	260
1	0	1	36
1	1	0	-64
1	1	1	0

# Example: Maximum Cut

## Problem

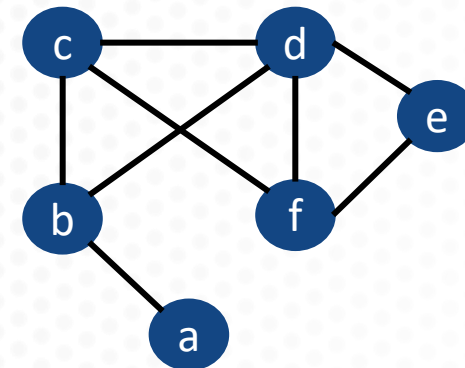
Partition the set so that the partition cuts through a maximum number of edges

**Step 5.** Combine objectives and constraints

$$E_{qubo} = \sum_{(i,j) \in E} -x_i - x_j + 2x_i x_j$$

Let's expand this for our problem:

$$E_{qubo} = \begin{matrix} & \begin{matrix} a & b & c & d & e & f \end{matrix} \\ \begin{matrix} a \\ b \\ c \\ d \\ e \\ f \end{matrix} & \begin{pmatrix} -1 & 2 & 0 & 0 & 0 & 0 \\ & -3 & 2 & 2 & 0 & 0 \\ & & -3 & 2 & 0 & 2 \\ & & & -4 & 2 & 2 \\ & & & & -2 & 2 \\ & & & & & -3 \end{pmatrix} \end{matrix}$$





# Challenge

How would you rewrite the maximum cut code so that it can run on any graph (like what we did with the antennas example).

The QUBO for the maximum cut problem is:

$$E_{qubo} = \sum_{(i,j) \in E} -x_i - x_j + 2x_i x_j$$