

---

## EXERCISE 2: Ising Hamiltonian matrix for a fixed number of up-spins

```
Clear[L, upspins, downspins, dim];
L = 6;
upspins = L / 2;
downspins = L - upspins;
dim = L! / (upspins! downspins!);

(* BASIS *)
Clear[onebasisvector, basis];
onebasisvector = Flatten[{Table[1, {k, 1, upspins}], Table[0, {k, 1, downspins}]}];
basis = Permutations[onebasisvector];

(* PARAMETERS OF THE HAMILTONIAN *)
Clear[Jxy, Jz];
Jxy = 1.0;

(* ELEMENTS OF THE HAMILTONIAN *)
Clear[HH];
(* Initialization *)
Do[Do[HH[i, j] = 0., {i, 1, dim}], {j, 1, dim}];

(* Diagonal elements *)
Do[
  (* Ising interaction *)
  Do[If[basis[[i, j]] == basis[[i, j + 1]],
    HH[i, i] = HH[i, i] + Jz / 4, HH[i, i] = HH[i, i] - Jz / 4];
    , {j, 1, L - 1}];
  , {i, 1, dim}];

(* TOTAL HAMILTONIAN *)
Clear[Hamiltonian];
Hamiltonian = Table[Table[HH[i, j], {j, 1, dim}], {i, dim}];

Print[];
Print["Diagonal Elements:"];
Do[
  Print["<", basis[[i, 1]], basis[[i, 2]], basis[[i, 3]], basis[[i, 4]],
    basis[[i, 5]], basis[[i, 6]], "|H|", basis[[i, 1]], basis[[i, 2]], basis[[i, 3]],
    basis[[i, 4]], basis[[i, 5]], basis[[i, 6]], "> = ", Chop[HH[i, i]]];
  ,
  {i,
  1,
  dim}]
```

Diagonal Elements:

$$\langle 111000 | H | 111000 \rangle = \frac{3 Jz}{4}$$

$$\langle 110100 | H | 110100 \rangle = -\frac{Jz}{4}$$

$$\langle 110010 | H | 110010 \rangle = -\frac{Jz}{4}$$

$$\langle 110001 | H | 110001 \rangle = \frac{Jz}{4}$$

$$\langle 101100 | H | 101100 \rangle = -\frac{Jz}{4}$$

$$\langle 101010 | H | 101010 \rangle = -\frac{5 Jz}{4}$$

$$\langle 101001 | H | 101001 \rangle = -\frac{3 Jz}{4}$$

$$\langle 100110 | H | 100110 \rangle = -\frac{Jz}{4}$$

$$\langle 100101 | H | 100101 \rangle = -\frac{3 Jz}{4}$$

$$\langle 100011 | H | 100011 \rangle = \frac{Jz}{4}$$

$$\langle 011100 | H | 011100 \rangle = \frac{Jz}{4}$$

$$\langle 011010 | H | 011010 \rangle = -\frac{3 Jz}{4}$$

$$\langle 011001 | H | 011001 \rangle = -\frac{Jz}{4}$$

$$\langle 010110 | H | 010110 \rangle = -\frac{3 Jz}{4}$$

$$\langle 010101 | H | 010101 \rangle = -\frac{5 Jz}{4}$$

$$\langle 010011 | H | 010011 \rangle = -\frac{Jz}{4}$$

$$\langle 001110 | H | 001110 \rangle = \frac{Jz}{4}$$

$$\langle 001101 | H | 001101 \rangle = -\frac{Jz}{4}$$

$$\langle 001011 | H | 001011 \rangle = -\frac{Jz}{4}$$

$$\langle 000111 | H | 000111 \rangle = \frac{3 Jz}{4}$$