Congratulations! You passed!

Next Item

1 / 1 points

1. If $\Delta E = -3$, then:

- [x] $P(s=1)$ increases when T increases.

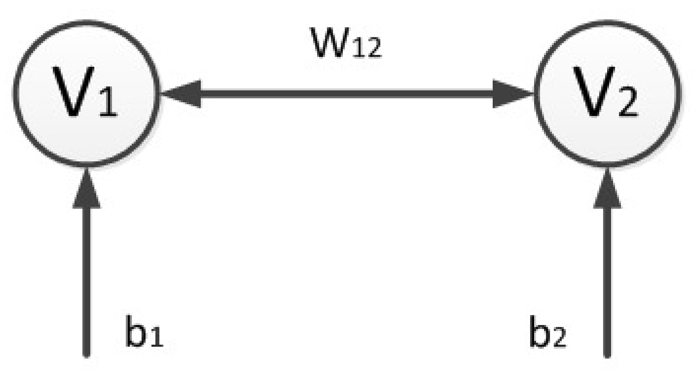
  Correct
  At $T=1$, $P(s=1)$ is 0.05, i.e. fairly close to 0. Increasing the temperature brings that probability closer to 0.5, i.e. it increases it.

- [ ] $P(s=1)$ decreases when T increases.

---

1 / 1 points

2. The Hopfield network shown below has two visible units: V_1 and V_2. It has a connection between the two units, and each unit has a bias.



Let $W_{12} = -10$, $b_1 = 1$, and $b_2 = 1$ and the initial states of $V_1 = 0$ and $V_2 = 0$.

If the network always updates both units simultaneously, then what is the lowest energy value that it will encounter (given those initial states)?

If the network always updates the units one at a time, i.e. it alternates between updating V_1 and updating V_2, then what is the lowest energy value that it will encounter (given those initial states)?

Write those two numbers with a comma between them. For example, if you think that the answer to that first question is 4, and that the answer to the second question is -7, then write this: **4, -7**

Please use a space after the comma in your response to be read/graded properly in the Coursera platform.

0, -1

Correct Response
From the initial state, both units will want to turn on.

If we update both of them at the same time, then both will turn on, leading to a configuration with energy 8. Next, both units will want to turn off,

bringing us back to the initial state, which has energy 0. We'll only ever alternate between those two states, so the lowest energy we'll see is

0.

If we update one unit, say V_1, first, then it will turn on. Now we're in a state with energy -1. From that state, neither unit will want to

change its state, so we'll stay in that state forever.

---

0 / 1 points

3. This question is about Boltzmann Machines, a.k.a. a stochastic Hopfield networks. Recall from the lecture that when we pick a new state s_i for unit i, we do so in a stochastic way: $p(s_i = 1) = \frac{1}{1+exp(-\Delta E/T)}$, and $p(s_i = 0) = 1 - p(s_i = 1)$. Here, ΔE is the *energy gap*, i.e. the energy when the unit is off, minus the energy when the unit is on. T is the *temperature*. We can run our system with any temperature that we like, but the most commonly used temperatures are 0 and 1.

When we want to explore the configurations of a Boltzmann Machine, we initialize it in some starting configuration, and then repeatedly choose a unit at random, and pick a new state for it, using the probability formula described above.

Consider two small Boltzmann Machines with 10 units, with the same weights, but with different temperatures. One, the "cold" one, has temperature 0. The other, the "warm" one, has temperature 1. We run both of them for 1000 iterations (updates), as described above, and then we look at the configuration that we end up with after those 1000 updates.

Which of the following statements are true? (Note that an "energy minimum" is what could also reasonably be called a "local energy minimum")

- [x] For the warm one, $P(s_i = 1)$ can be any value between 0 and 1, depending on the weights.

  Correct
  For every value between 0 and 1, we can sep up the weights and the states in such a way that we get that value.

- [ ] The cold one is more likely to end in an energy minimum than the warm one.

  This should be selected

- [x] The warm one could end up in a configuration that's not an energy minimum.

  Correct
  The warm one could end up anywhere, because it's truly stochastic.

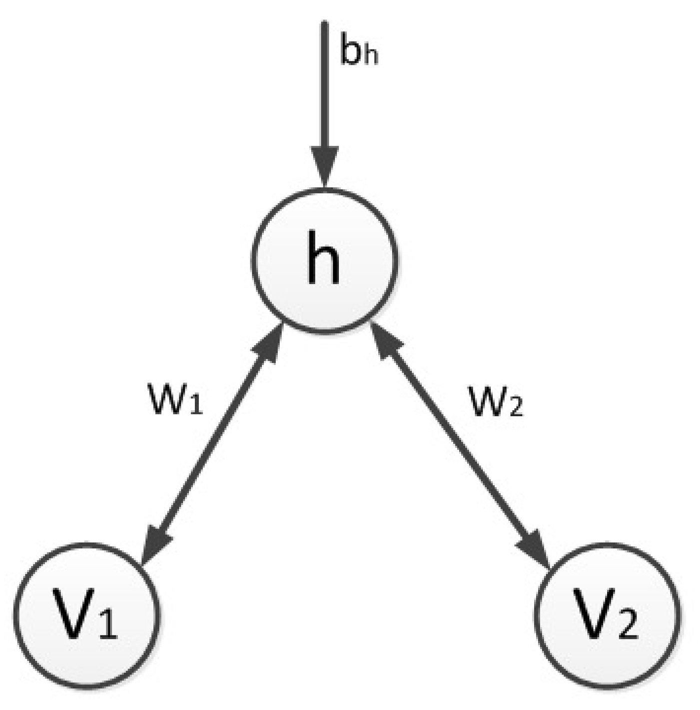
- [x] For the cold one, $P(s_i = 1)$ can be any value between 0 and 1, depending on the weights.

  This should not be selected
  For the cold one, $P(s_i = 1)$ is always either 0 or 1 (or one might say it could be 0.5 when the energy gap is 0). It can never be something like $1/3$.

---

1 / 1 points

4. The Boltzmann Machine shown below has two visible units V_1 and V_2, and one hidden unit h.



Let $W_1 = 3$, $W_2 = -1$, and $b_h = -2$.

What is $P(V_1 = 1, V_2 = 0)$? Write your answer with at least three digits after the decimal point.

Hint: if you feel confused about the purpose of a hidden unit, revisit the lecture videos.

0.4705

Correct Response
This Boltzmann Machine has eight configurations. Each has an energy, and from the energies you can calculate the probabilities. To get the requested

probability, we add up two probabilities:
$P(V_1 = 1, V_2 = 0) = P(h = 0, V_1 = 1, V_2 = 0) + P(h = 1, V_1 = 1, V_2 = 0)$
.

In detail, it's as follows.

$E(h = 0, V_1 = 0, V_2 = 0) = 0$

$E(h = 0, V_1 = 0, V_2 = 1) = 0$

$E(h = 0, V_1 = 1, V_2 = 0) = 0$

$E(h = 0, V_1 = 1, V_2 = 1) = 0$

$E(h = 1, V_1 = 0, V_2 = 0) = 2$

$E(h = 1, V_1 = 0, V_2 = 1) = 2 + 1$

$E(h = 1, V_1 = 1, V_2 = 0) = 2 + -3$

$E(h = 1, V_1 = 1, V_2 = 1) = 2 + -3 + 1$

Thus,
$\sum_s exp(-E(s)) = exp(0) + exp(0) + exp(0) + exp(0) + exp(-2) + exp(-3) + exp(1) + exp(0) \approx 7.903404$
. Now we can convert the

energies into probabilities. We're only interested in two probabilities, as mentioned above.

$P(h = 0, V_1 = 1, V_2 = 0) \approx \frac{exp(0)}{7.903404} \approx 0.1265$

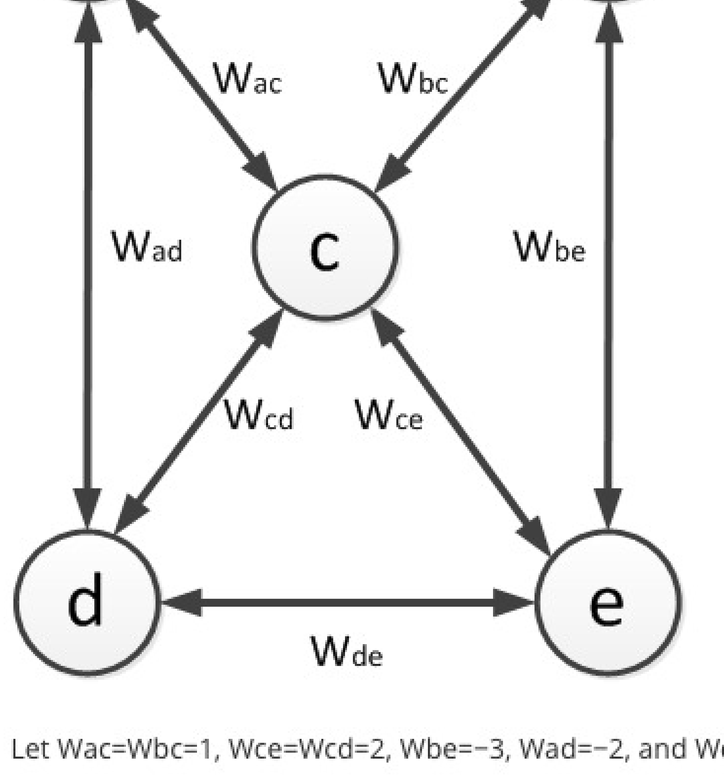
$P(h = 1, V_1 = 1, V_2 = 0) \approx \frac{exp(1)}{7.903404} \approx 0.3440$

That makes for a total of about 0.4705.

---

1 / 1 points

5. The figure below shows a Hopfield network with five binary threshold units: a, b, c, d, and e. The network has many connections, but no biases.



Let Wac=Wbc=1, Wce=Wcd=2, Wbe=−3, Wad=−2, and Wde=3.

What is the configuration that has the lowest energy? What is the configuration that has the second lowest energy (considering all configurations, not just those that are energy minima)?

A configuration consists of a state for each unit. Write "1" for a unit that's on, and "0" for a unit that's off. To describe a configuration, first write the state of unit a, then the state of unit b, etc. For example, if you want to describe the configuration where units a and d are on and the other units are off, then write 10010. For this question you have to describe two configurations, and write them with a comma in between. For example, if you think that the lowest energy configuration is the one where only units a and d are on, and that the second lowest energy configuration is the one where only units b, d, and e are on, then you should write this: **10010, 01011**

00111, 10111

Correct Response