Changing Internal Energy: Consider a thermal system of water vapor where the only ways to change the internal energy are by heating or doing work:

$$\text{change in internal energy} = \text{heat into or out of system} + \text{work done on or by system}$$

For very small changes in internal energy, the above energy conservation statement turns into:

$$\begin{aligned} \text{small change of internal energy} &= \text{small amount of heating} + \text{small amount of work done} \\ d\,\text{internal energy} &= (\text{temperature})\, d\,\text{entropy} - (\text{pressure})\, d\,\text{volume} \\ dU &= T\,dS - p\,dV \end{aligned}$$

where "d quantity" indicates a very small change in a quantity.

Examine Your Intuition: For each of the three scenarios below, how would you expect the internal energy of the water vapor to change (increase, decrease, or stay the same)? Explain your reasoning.

1. You have a lidded metal pot filled water vapor and put it on a hot stove.
2. You have an insulated piston (so that no heat enters or leaves) filled with water vapor and you push down on the lid.
3. You have an uninsulated piston with a heavy top (which fixes the pressure) filled with water vapor and you put it on a hot stove.

Interpret the Surface: The plastic surface model is a graph of the internal energy of water vapor as a function of volume and entropy. The arrows in the base of the surface indicate the direction of increase for each of these quantities. The height of the surface represents the value of the internal energy.

For each of the scenarios described above, imagine that the water vapor starts with values of volume and entropy that correspond to the blue dot. For each scenario:

1. What does the surface tell you about the change in internal energy? Is this consistent with your intuition?
2. Describe in words how you determined this information from the surface.
3. Would the change in internal energy be different if you started somewhere other than the blue dot?