- 1. In regard to the Maxwell speed distribution, you might wonder why all the molecules in a gas in thermal equilibrium don't have exactly the same speed. After all, when two molecules collide, doesn't the faster one always lose energy and the slower one always gain energy? And if so, wouldn't repeated collisions eventually bring all the molecules to some common speed? Describe an example of an elastic billiard ball collision in two dimensions in which this is not the case: the faster ball gains energy and the slower ball loses energy. Include numbers and be sure that your collision conserves both energy and momentum.
- 2. (a) Derive the Maxwell speed distributions in two and one dimensions.
  - (b) What is most likely speed in each case?
  - (c) What is average speed in each case?
  - (d) What is root-mean-square speed in each case?
- 3. A thick coin has equal probability of landing on its head (H), its tail (T), or its side (S). If three distinguishable thick coins are flipped,
  - (a) How many microstates are there? Show them explicitly.
  - (b) How many macrostates are there? Show them explicitly.
  - (c) What are the formulæ for the number of microstates and macrostates if N coins are flipped and each coin has S sides? (I guess eventually you would call them dice instead of coins, but whatever.)
- 4. On episode 196 of MythBusters, Kari, Grant, and Tory test "tastes like chicken". There are 11 plates of fried chicken (C) and 9 plates of fried non-chicken (N) like snake, turtle, etc. numbered from 1 to 20 which are sampled one at a time by blindfolded tasters. An arrangement is an ordered set e.g. CCNNCNNNCNCC...; NCNCNCNCCCCC...; etc.

A) What is the probability of randomly guessing the correct arrangement if the blind tasters know that there are 11 Cs and 9 Ns?

B) With the same knowledge, what is the probability of getting exactly one plate wrong?

C) What is the probability of randomly guessing the correct arrangement if the blind tasters do not know how many of the plates are chicken?

D) With the same knowledge, what is the probability of getting exactly one plate wrong?

- 5. You are given a well-shuffled deck of 52 playing cards faces down.
  - (a) What is the probability of drawing 7, 10,  $3\heartsuit$ ,  $K\diamondsuit$ , and  $7\heartsuit$ , in that order?
  - (b) Does it matter if you take the first five cards off the top of the deck or pull cards from random places in the deck?
  - (c) What is the probability of drawing  $7\spadesuit$ ,  $10\spadesuit$ ,  $3\heartsuit$ ,  $K\diamondsuit$ , and  $7\heartsuit$ , in any order?

- (d) How many microstates contain 5 clubs? In other words, what is the multiplicity of the macrostate with 5 clubs?
- (e) What is the probability of drawing a royal flush?
- (f) What is the probability that Jamy Ian Swiss (Google if necessary) can draw a spade royal flush from the deck?

## Bonus

1. Find  $(\partial V/\partial T)_{Pn}$  for the van der Waals gas, whose equation of state is

$$\left(P + \frac{an^2}{V^2}\right)(V - nb) = nRT,$$

where n is the number of moles.