Here’s a question about the book *Artemis* (from the same author who brought you *The Martian*). The author has a knack for twisting science, space, and humor into wonderful stories. In his books, you’ll read about the temporary colonization of Mars, the Moon, what happens in zero – G (or when you get stuck outside, without a pressure suit, in it)…all kinds of good stuff. It’s fiction, based in fact (very similar to the way Michael Crichton used to write).

Anywho – I was reading *Artemis*, and stumbled upon this section. In this scene, the main character, Jazz, uses a similar method to your Quiz #6 to try to see what numbers are used on a 4-digit keypad (in this case, for a hotel safe):

Time to become a safecracker. Those things aren’t exactly made to protect the crown jewels.

The contents of my now-destroyed purse lay strewn across the floor. I found the makeup compact and slapped it against my palm several times. I opened it to a mess of crumbled powder. I held it up to the safe and blew across the surface.

Brown, dusty makeup clouded the air around the safe. I stepped back and waited for it to clear up. Dust takes a long time to settle in Artemis. Atmosphere plus low gravity equals particles taking forever to fall.

Eventually the area cleared up. I took a good look at the keypad. A layer of makeup covered everything, but three of the buttons had more dust on them than the others. The 0, the 1, and the 7. Those were the ones with finger grease on them. With a hotel like the Canton, you could bet they cleaned everything in the room between guests. So those numbers had to be the digits Jin Chu chose for his combination.

According to the instructions on the safe, you set a four-digit code.

Hmm. A four-digit code with three unique numbers. I closed my eyes and did some math. There’d be...fifty-four possible combinations. According to the instructions, the safe would lock down if it got three incorrect combinations in a row. Then the hotel staff would have to open it with their master code.

1. **(10 points) (w)** Welp, Jazz made a mistake! There aren’t 54 ways to order those numbers. You job, for this first question, is to figure out how many possible 4-digit safe codes there actually are. Show me exactly what you do!

   *(and feel free to ask if you get stuck – on this, or on any of these exam questions!)*
2. Pilot Butte is the iconic Bend centerpiece of the state park of the same name in East Bend (at left, a view from the top, looking west. Sunsets are pretty rad up there). Pilot Butte’s base is 4140 feet above sea level, and the summit is at 4620 feet. There is a wonderful trail (from base to summit) that is just about 1 mile long.

a. **(5 points)** What is the average grade of the trail? Use the Excel Calculator, for sure!

b. **(5 points)** Where did you place the trail’s distance (the “1 mile”)? “Run” or “road”? Please explain why you placed it where you did!

Now, the trail around Pilot Butte winds around in such a way to make the effort of climbing manageable (see map at right – the existing Pilot Butte trail is the red spiral). Let’s suppose, for a moment, that another, silly trail heads straight uphill from trailhead to summit (marked in orange on the map).

c. **(5 points)** Estimate how long that orange trail would be.

d. **(5 points)** What would the grade of that orange trail be, to the nearest percent?

3. All right! Time to analyze part of my commute to work! I keep talking about these steep roads in Bend – let’s take a closer look! Start by watching the video here (heads up: it’s got a background music track, to keep you from getting bored): [http://youtu.be/BsctpGJ9JzA](http://youtu.be/BsctpGJ9JzA). Notice that I’ve labeled 7 “waypoints” (markers with elevations and distances) on this bike ride. We’ll be using those waypoints to calculate average grades.

a. **(5 points)** Find the average grade between waypoint 2 and waypoint 3 (to the nearest whole percent). Since I’m giving you elevations and road distances, you’ll have to figure out what goes where in the Excel Calculator!

b. **(5 points)** Find the average grade between waypoint 4 and waypoint 5 (nearest whole percent). This is the part that hurts going uphill.

c. **(5 points)** Find the average grade for the whole trip (between waypoints 1 and 7). Doesn’t seem so bad, when you look at the whole thing, huh? 😊

d. **(5 points)** *(w)* What was my average speed, in miles per hour, for the whole trip? Make sure to show/explain me how you did it!

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1 I’ve skied this is fat snow years. It’s rad!
4. You’ve heard me say, over and over again, that the grade of, say, a road calculated the “right way” will always be larger than the grade of the same road calculated the “wrong way”.

   a. (10 points) In a sentence or two, explain to me why this is always the case! You’ll want to remind yourself how “right way” and “wrong way” grades are calculated for this, for sure!

   b. (5 points) We’ve also been assuming, for most of the work we do in class, that the “right way” grades are “close enough” in value to the “wrong way” grades. For most roads, that’s true. But, in general, that’s not always the case – it’s possible to have a vast difference between a “right way” and “wrong way” grade. Mess around in the Excel calculator and find me an angle where its “right way” grade is wildly larger than its wrong way grade! We’ll define “wildly” to mean “the right way grade is a 3–digit number, while the wrong way grade is only a two–digit number.” Please give the angle, as well as the two grades.

   c. (10 points) We talked in class about the special case of “100% grade” (like a roof pitched at 12:12). But that’s a “right way” grade of 100%. Why can’t the “wrong way” ever be exactly 100%? Write one or two sentences!

5. In this last question, we’ll do another cost analysis like we’ve been doing in class. A few of my friends have been asking me (over the past couple of years) if I think it’s smart to install one of those under sink hot water heaters. You know the ones – there’s an extra little spigot on your sink that, basically, delivers on-demand boiling water:

   People that are in favor of these tell me that they're great, because you no longer have to wait for boiling water (there’s a small tank under the sink – usually a gallon or two – that’s heated constantly with a little teeny tiny water heater. It’s like our on-demand hot water heater example that we warmed up with in class).

   Of course, there are a couple of things that need to be considered here:

   - How much do these things cost?
   - How much does it cost to run them all day long to keep their water boiling?

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2 I know you might get Excel to show “100%” in the “Wrong Way” box, but that’s just rounding. If you increase the decimal, it’ll always be under.

3 Nyuck, nyuck.
Then, thinking about the benefits of not installing one, we have to ask the same questions:

- How much would it cost to not install one (and instead use, say, an electric teakettle)?
- How much does it cost to heat water to boiling with said electric teakettle?

I’ll take care of the second bullet in each of those pairs. You? You do some Googling and take care of the first!

a. **(5 points)** Do a Google Search for “Instant Hot Water Dispenser”, and settle on one that you would buy, if you had to. Include a screenshot of it as your answer to a, so I can see its cost.

b. **(5 points)** Find a decent electric kettle that you would consider purchasing online. Again, include a screenshot so I can see its price!

As for the costs associated with actually running these instant hot water dispensers, I did a bit of searching, and discovered that they have two costs associated with them:

- the “standby” energy usage, which is how much energy it takes to actually keep the water in its little tank hot (“on-time” power). This works out to an average of **0.605 Kilowatt-Hours per day** of energy usage.
- the “dispensing” energy usage, which is how much energy it takes to actually deliver the water into your cup. This is much less... **about 0.021 Kilowatt-Hours per 8 ounce cup of dispensing.**

To compare, let’s look at the costs of not using these dispensers. My family uses an electric teakettle, so I’ll use that to compare.

- To heat 8 ounces of water to boiling in our electric teakettle will take **0.04 kilowatt-hours**. In addition, every additional 8 ounces adds another 0.04 kilowatt-hours (so the usage “scales up” – it would take 0.08 kilowatt-hours for 16 ounces, 0.12 kilowatt-hours for 24, and so on).

Let’s make an assumption: the family we’re analyzing will make two individual 8-ounce cups of coffee in the morning, and one 8-ounce cup of tea in the evening. So, all told, we’ll boil 8 ounces of water three times.

c. **(5 points)** After reading all of the above, tell me why it doesn’t make sense to purchase an instant hot water dispenser to save money if your family (like mine) is only going to use it to make three 8-ounce cups of coffee a day. Make sure to reference the above energy values in your answer!

d. **(10 points)** How many 8-ounce cups of boiling water would you need to make each day until you’d spend the same amount of energy using the electric teakettle as the instant hot water dispenser? Hint: you can use the Excel Calculator’s “Linear Modeling” tab here; your “costs” won’t be measured in dollars, but rather in “cups of boiling water”. Please take a screenshot of your Excel work and include it with your answer – and make sure you add proper labels (axes names, chart title, lines) to the graph so someone looking at it understands what it means!

So, really, there’s no cost savings reason to use these to boil water to just make coffee (well, unless you’re going to make one helluva lot of coffee). There are other reasons, however, you might consider one (for example, using it to help with making pasta – instead of having to wait for a big pot of water to boil on a stove).

Like so many things in life, the answer to this one (“Should I get an instant hot water dispenser?”) is, “it depends.” 😊

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4 I’m assuming that the instant hot water dispenser you screenshot in a is less than the kettle in b.