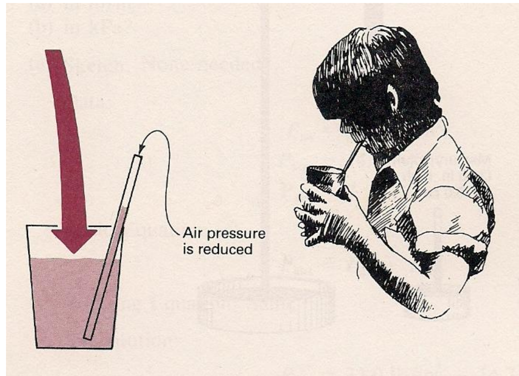
Willy Wonka and the Chocolate Factory



1. Mr. Willy Wonka, the eccentric owner of the greatest chocolate factory in the world, has decided to open the doors of his factory to a group of lucky children and their parents. In order to choose who will enter the factory, Mr. Wonka devises a plan to hide several golden tickets beneath the wrappers of his famous chocolate. How many children and golden tickets will Mr. Wonka allow?
2. The search for these golden tickets is fast and furious. Augustus Gloop, a corpulent child whose only hobby is ________________, unwraps the first ticket, for which his town throws him a parade.
3. Veruca Salt, an insufferable brat, receives the next ticket from her father, who had employed his entire factory of ____________________ to unwrap choclolate bars until they found a ticket.
4. Violet Beauregarde discovers the third ticket while taking a break from setting a world record in ___________________________.
5. The fourth ticket goes to Mike Teavee, who, as his name implies, cares only about _________________________.
6. Charlie Bucket, the unsuspecting hero of the movie, defies all odds in claiming the fifth and final ticket. A poor but virtuous boy, Charlie lives in a tiny house with his parents, Mr. and Mrs. Bucket, and all four of his grandparents. His grandparents share the only bed in the house, located in the only bedroom. Where do Charlie and his parents sleep?
7. Charlie gets three sparse meals a day, which is hardly enough to nourish a growing boy. As a result, he is almost sickly thin. What present does Charlie get on his birthday?
8. A tremendous stroke of luck befalls Charlie when he spots a silver dollar in the gutter. He decides to use a little of the money to buy himself some chocolate before turning the rest over to his mother. After inhaling the first bar of chocolate, Charlie

decides to buy just one more and within the wrapping finds the fifth golden ticket. Where does Charlie go after he finds the golden ticket?

9. Charlie asks his grandpa to accompany him to the chocolate factory. Magically, Charlie's most beloved grandparent, Grandpa Joe, springs out of bed for the first time in ________________________. Charlie's lucky find has transformed him into an energetic and almost childlike being. Grandpa and Charlie set out on their adventure.
10. In the factory, Charlie and Grandpa Joe marvel at the unbelievable sights, sounds, smells and especially tastes of the factory. Whereas they are grateful toward and respectful of Mr. Wonka and his factory, how did the other four children and parents behave? Did the other four children leave the factory peacefully or painfully?

11. Augustus Gloop falls into a hot chocolate river because he leans over too far while taking a long drink. The chocolate flows into a pipe that rises above the level of the river.
    a) What must be true about the pressure inside the pipe in order for the chocolate to rise above the level of the river? (Hint: How does a straw in your mouth suck up the refreshing drink to your mouth).

    b) What is the maximum possible height to which the chocolate can rise? (Remember the pressure in a fluid is the same everywhere at the same depth, so the pressure inside the pipe at river level must be equal to the pressure at the surface of the river. Assume chocolate has the same density as water).

    c) Augustus tries to yell something while he is trapped in the pipe. However, it should have been impossible to hear him. Why? (Hint: Sound does not transmit in outer space).
    d) Wonka says the pressure in the pipe is building up underneath Augustus, and eventually Augustus is explosively dislodged. Is it possible for the pressure to build up this way if the river is exposed to the air? Why or why not?

12. Violet Beauregarde's passion is chewing gum, which she prefers to candy. The next scene seems like her dream come true when Wonka introduces the guests to a gum extracted from real food that can exactly duplicate the experience of eating a three coarse meal. However, he has not perfected the gum yet, and despite his very specific admonition not to touch the gum, Violet pops a piece into her mouth and starts chewing. At first everything seems fine as Violet enjoys her first two courses of tomato soup and roast beef, but when she arrives at the blueberry pie, something unfortunate happens: Violet turns a shade of deep violet and swells up into a large sphere. Mr. Wonka tells us that she is filled with fluid (which fortunately means it's mostly water weight!), and his servants, the little Oomp-Loompas, roll her away, to be pressed and de-juiced. Our task will be to determine some of the properties of this amazing gum. Particularly, how dense must the gum be to provide enough juice to turn Violet into a giant blueberry……? (Don't answer yet)

a) After the incident, what is the volume, in m^3, of Violet if she is a perfect sphere with a diameter almost equal to her height, which is around 1.4 meters?

   [Use $V = \frac{4}{3}\pi r^3$]

b) What would be Violet's total mass in Kg? [Note: Because human bodies and blueberries are comprised mostly of water; we can assume that Violet's density will be about equal to the density of water, which is 1000 kg/m^3.} {Use M = DV}

c) What is her weight in lbs? (Note 2.2 lbs = 1 kg)

d) What is the gum volume, in m^3, before Violet eats it? [Note: The size of the gum looks to be approximately the same as a piece of Bazooka gum, so we'll estimate it's dimensions to be 2.5 cm long by 1.8 cm wide by 0.50 cm thick} Use: V = lwt and remember that 1,000,000 cm^3 = 1 m^3

e) Assuming Violet started with a mass of 50 kg before she ate the gum, what would be the mass of the gum? Note M = (mass of violet) + (mass of gum) = Total mass calculated in #12 b.

f) What is the density of the gum, before Violet eats it? [Use D = M/V]

g) How many more times is the gum density greater than water?
h) Do you think Violet would have been able to lift it to eat it?

13. Charlie is a model little boy, but in the next couple of scenes, he makes an unfortunate transgression, mostly due to the ill-advised prodding of Grandpa Joe. In this scene, he and Joe drink some of the forbidden experimental "fizzy lifting drink". At first they have a grand time as they float about in a bubble filled room, but after a while they realize that they are headed straight up towards a giant whirling fan at the top of the ceiling. If they don't stop their ascent they are going to be chopped to pieces. Fortunately they realize at the last minute to solve the problem. How did they solve the problem of rising into the fan?
14. We can reasonably assume that the incredible buoyancy Charlie and Joe have is due to the volume of gas that they ingest. Let's find out what the volume that would need to be to get them off of the ground. We know that the minimum buoyant force acting on each of them must be at least equal to their weight. We also know from Archimedes' principle that the buoyant force acting on a submerged object is equal to the weight of the volume of fluid that is displaced by the object. In this case the object is Grandpa Joe, and the fluid displaced is air. (Density of Air)(Volume of Air)g = (Mass of Joe) g ; Since Weight = m g;

a) Calculate the volume of fluid that is displaced by the expanded Joe: [Use the formula Mass of Joe = (Density of Air)(Volume of fluid Displaced)] {Note: Assume Grandpa Joe has a mass of 70 kg and the density of air is 1.3 kg/m^3}

b) Let's assume that this expanding gas caused Grandpa Joe to expand into a sphere like Violet. What would be his radius? [Use $V = \frac{4}{3}\pi r^3$] Solve for r:

c) What would be his diameter?
d) How does this diameter compare with Violet's diameter in #12 (a)?
e) At this size, would Joe and Charlie even fit into the room?)
f) We know the gas will expand until it equalizes with the external pressure (as long as the container is able to expand), which in this case is one atmosphere or 101,000 Pascals. Use the ideal gas law to calculate the number of moles of gas needed to achieve the volume in #14 (a). [Use the formula: P V = n R T] where V = answer from #14 (a);
P = 101,000 Pa; R = Ideal Gas Constant = 8.31 J/mol K; T = Room Temperature = 293 K
Solve for n:

g) Stomachs can't expand this much. Therefore, the fizzy lifting drink is probably just going to cause a lot of discomfort rather than increase buoyancy. Because the stomach volume can't increase much, the pressure is going to go up. If we account for just a little bit of expansion and approximate the average distended stomach to be a sphere with a radius of about 0.08 m, what is this volume? Use $V = \frac{4}{3}\pi r^3$

h) Use the gas law again to determine the amount of gas pressure in Grandpa Joe's stomach if he can't balloon out: Use P V = n R T; where V = answer from #14 (g); R = 8.31 J/mol K; T = 293 K; and n = answer from #14 (f). Solve for P:

i) How many times greater is this pressure with atmospheric pressure?

j) Do you think this is enough pressure to explode Grandpa Joe?

k) Let's assume for the moment that Grandpa Joe is able to expand easily to the final volume calculated in #14 (a). If he expands without any energy (heat) exchange between his stomach and his surroundings, this would be an adiabatic process. The gas inside Joe's stomach would be doing work on the surroundings, thus losing energy and dropping temperature. We can actually calculate how much the temperature in his stomach would drop. For an adiabatic process the following equation relate V, and T at some initial point in the process to some later point. Pressure is constant since Grandpa Joe is allowed to expand. Calculate the new temperature, (T_2): Use the Charles Law formula: $V_1/T_1 = V_2/T_2$; where V_1 = answer from #14 (g); T_1 = 293 K; and V_2 = answer from #14 (a); Solve for T_2:

l) Since Temperature in Celsius = Temperature in Kelvin + 273; what is the temperature of Grandpa's Stomach in Celsius? Would this freeze Grandpa's stomach?

m) Willy Wonka wouldn't design a candy drink capable of freezing people to death. Perhaps the gas in the drink is highly exothermic when it reacts with stomach acid, and it generates heat, which prevents energy loss that would occur in the adiabatic case. So what if the expansion is isobaric instead? We'll need to assume that the pressure in

Grandpa Joe's stomach is the pressure we calculated in #14 (h) and we maintain that pressure by adding energy to the system as Joe's stomach expands. Because the volume is expanding the temperature must go up in order to maintain pressure. Because pressure is caused by collisions of the gas particles with the container walls, if the container gets bigger, the gas particles must hit with higher energy to maintain the same average pressure. This is the essence of isobaric pressure. Therefore, we'll need to use the First Law of Thermodynamics: $\Delta U = Q - P\Delta V$; (Note: The negative sign means the gas is doing work on the surroundings), However we can substitute $Q = n\ c\ \Delta T$; and $\Delta U = 3/2\ n\ R\ \Delta T$; which gives us the formula:

$$3/2\ n\ R\ \Delta T = m\ c\ \Delta T - P\ \Delta V$$

Where n = answer for #14 (f); R = 8.31 J/mol K; P = answer from #14 (h);
ΔV = answer from #14 (a); and c = specific heat for fizzy drink = 28 J/mol K
{We will assume a specific heat of the fizzy lifting gas to be similar to that of the atmosphere (around 28 J/mole K).}
Solve for ΔT:

n) The temperature of the Sun is 1,600,000 K. How does your calculation in #14 (m) compare with this?

o) Would you say that Grandpa Joe would vaporize in a nuclear fusion reaction during the isobaric process?

p) Would you say that Wonka was right when he said his drink wasn't perfected yet?

15. With the hope of being on the beloved television, Mike Teavee shrinks himself, and his mother has to carry him out in her purse. Willy Wonka explains his Wonkavision: "People send pictures through the air in a million pieces every day, so why couldn't I do it with chocolate?"

    a. We know form relativity that matter is just a form of energy. We should be able to measure the state of the energy of every piece of the chocolate bar and note it down somehow, just like we sample a picture with a camera. If we had a complete description of the state of energy of the chocolate bar, we could transmit that description (through the air in a million pieces, in an email through the tubes, or whatever). At the other end, say we have a large source of energy (huge). We take that energy, and change it's state to match the chocolate bar. We should then have a chocolate bar. Is there another name for this science fiction process? What is it?

    b. Of course, this also implies something more disturbing---that matter isn't much more than a bunch of information about energy. If instead of making a chocolate bar with the energy description you receive, what if you store it on your hard drive? Is this copy a chocolate bar? Chocolate bars are different than pictures, because you can feel them, taste them. But what are you tasting? You are tasting various chemicals, which themselves are just an arrangement of energy. The taste is just a way to interpret the information about the energy contained in the chocolate bar. Same with touch/smell. You are interpreting information about the arrangement of energy in the chocolate bar. What if, instead of chocolate, we did it with a person. A person named Mike Teavee. Consider that when we assemble the duplicate, we don't delete the original. Which one is the Mike? How would you know if Mike were the copy or the original? How would you know how many copies of Mike existed? What if we stored a Mike on a hard drive, or carried him around on a USB stick? If the last copy of Mike was on a USB stick and his mother accidently destroyed the data, would it be murder?

c. Bitmaps are data. Information. Are pictures anything more than information? Certainly, they contain information, but are they themselves anything more than information? We can agree that a poster is an object. But, it would still be a poster if it was blank. A poster is some form of paper----usually with a picture on it, but it doesn't need the picture to be what it is. It seems that a picture has to be interpreted in order to exist. A bunch of bits on the hard drive is just data until you display it and recognize it as a picture. A bunch of colors on a poster could just be a bunch of colors unless you see the picture the colors make. This seems to suggest pictures are just a form of information. What about Mike Teavee? Was he just a form of information? Explain.

16. During each child's fiasco, Mr. Wonka alienates the parents with his nonchalant reaction to the child's seeming demise. He remains steadfast in his belief that everything will work out in the end. After each child's trial, the Oompa-Loompas beat drums and sing a moralizing song about the downfalls of greedy, spoiled children. When only Charlie remains, Willy Wonka turns to him and congratulates him for winning. The entire day has been another contest, the prize for which is the entire chocolate factory, which Charlie has just won. Charlie, Grandpa Joe, and Mr. Wonka enter the great glass elevator, which explodes through the roof of the factory and crashes. Where do they end up?