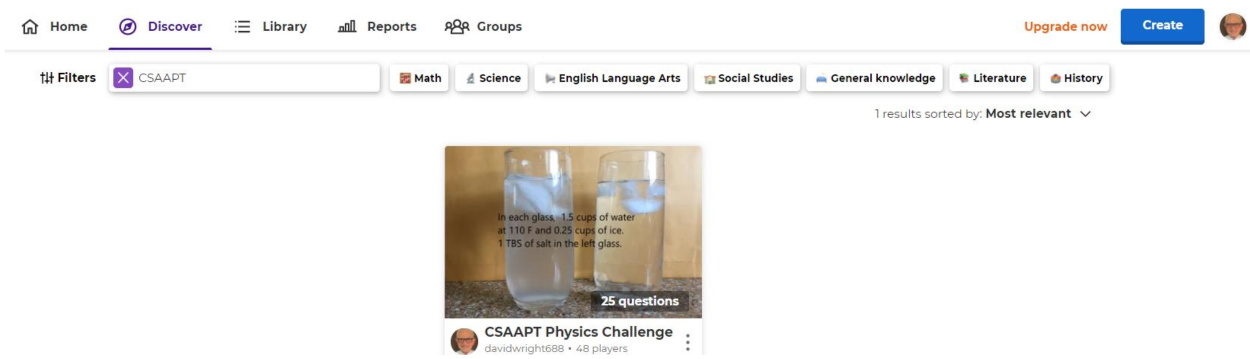
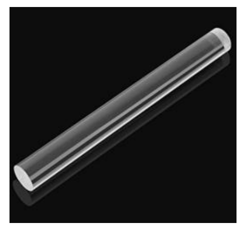
CSAAPT PHYSICS CHALLENGE- NOTES

You can search on Kahoot for “CSAAPT” to find this.



*** Indicates a demonstration that you can do

1. *****WITH THIS CYLINDRICAL LENS, WHY IS <u>UNUSUAL</u> FLIPPED OVER AND <u>DIOXIDE</u> IS NOT**? ACTUALLY BOTH WORDS ARE FLIPPED OVER.
   The red letters in “OXIDE” are vertically symmetric. They can be flipped over and still look the same. The rod is acrylic, but any transparent rod should produce the same results.
   This is what I ordered from Amazon: Acrylic Clay Roller for $6.

2. **WHAT ARE THE AFRICAN ELEPHANT’S EARS SO LARGE?** HEAT DISSAPATION.
   www.colombuszoo.org/animalareas/pacderm/elepfact.html
   African elephant ears are three times the size of Asian elephant ears. Ears are used to regulate body temperature in both species.” Also, “Elephants use their ears as signaling devices and as protective devices to ward off threats.”
   https://www.livescience.com/32893-elephant-species-differences.html
   “African elephants have large ears, shaped much like the continent of Africa itself. The larger surface area of their ears helps to keep African elephants cool in the blazing African sun. Asian elephants have less to worry about heat-wise, as they tend to live in cool jungle areas, so their ears are smaller.”
3. *****TWO IDENTICAL STEEL CYLINDERS WILL GO DOWN AN INCLINED PLANE. ONE WILL ROLL, THE VERTICAL ONE WILL SLIDE FRICTIONLESS**. THE VERTICAL ONE GETS TO THE BOTTOM FIRST.
   This demonstration is as variation of the hoop and the disk rolling down an incline. Dr. Richard Berg, at the University of Maryland included it in one his “Physics IQ test” demonstration lectures. His vertical cylinder had built in ball bearings. I used a dynamics cart to make it “frictionless”. You may have to prove to your students, that the cart with and without the cylinder will have the same acceleration down the incline. The rolling cylinder takes longer because part of the initial potential energy gets tied up in rotational kinetic energy

4. **HOW MUCH LONGER DOES THE ROLLING CYLINDER TAKE TO GET TO THE BOTTOM OF THE INCLINE**? $\sqrt{\frac{3}{2}}$ TIMES AS LONG.

The moment of inertia of a solid cylinder rolling about is axis is $I=1/2MR^2$. Use the conservation of energy (**eq 1**) $MGH=1/2\ MV^2 + I/2\ I\omega^2$, because the cylinder has both rotational and translational KE. Substituting values for moment of inertia (I) and $v=r\omega$, produces the following:

$MGH=1/2\ MV^2 + ¼\ MV^2$. Solving for v, gives (**eq 2**) $v= \sqrt{((4/3)GH)}$. The height of the incline is given by **(eq 3)** $h=L\sin\Theta$, where L is the length of the incline plane.

Using kinematics with the object starting from rest, **(eq 4)** $v^2=2aL$ (where L is the length of the inclined plane, which in this situation is the distance traveled). Substituting eq 2 and eq 3 into eq 4 and solving for "a" produces $a=2/3G\sin\Theta$.

Using $d=1/2\ at^2$, solve for t. With the sliding cylinder, $a=G\sin\Theta$, and $t=\sqrt{(2d/G\sin\Theta)}$. For the rolling cylinder, $t=\sqrt{(2d/(2/3G\sin\Theta))}$

Comparing these two times, the Rolling cylinder time is $\sqrt{(3/2)}$ times the sliding cylinders time. (Obviously 20 seconds isn't enough time to derive this result) In my experimental trials, with a 2600 gram iron cylinder of d=5.1 cm and height of about 14 cm, the time down the 1.5 degree incline was 4.84 seconds (average of 5 trials), and the frictionless vertical cylinder's time over 5 trials was 4.03 seconds. The ratio of these two times was 1.20, whereas the $\sqrt{(3/2)}$ is 1.22. Isn't Physics wonderful!!

5. **TWO HOT ALUMINUM BALLS OF THE SAME TEMPERATURE BUT DIFFERENT DIAMETERS ARE COOLING OFF. THE RATE OF COOLING IS…**

INVERSELY PROPORTIONAL TO THEIR DIAMETER.

The cooling rate of spheres is covered in an article in the February 2020 issue of the Physics Teacher, entitled "Animal Size and Heat Transfer" by Kurt Vandervoort. In the article, animals are approximated as being spheres. Newton's Law of Cooling, indicates that the Rate of heat transfer (dT/dt), is equal to a proportionality constant α times the Difference between T_s, the surrounding temperature, and the temperature of the object. $dT/d\tau= -\alpha\ (T-Ts)$ (τ is the time) This relationship is expressed by Kurt as $T-Ts=(To-Ts)e^{-\alpha\tau}$. Kurt then explains that the "proportionality constant is a function of the heat transfer coefficient(both due to convection and radiation) h, the objects surface area A, and its heat capacity at constant pressure Cp (Note: Heat capacity is equal to the m times the specific heat, and the m is the product of the density and the volume of the object.) For a sphere the proportionality constant becomes:

$$\alpha=hA/C_p = h(4\pi R^2)/\rho(4/3pR3)c_p=3h/\rho Rc_p$$

Everything in the equation is a constant other than R. Therefore the cooling rate is inversely proportional to the Radius of the sphere. Experimental measurements in Kurt's study verify this relationship.

This makes sense, since the surface area varies as the square of the Radius, and the Volume increases as the cube of the radius. The surface area to volume ratio decreases as the size (radius) of the animal increases. If a sphere has a surface area to volume ratio of 1, and you double the radius, then the surface area increases by a factor of 4 and the volume increases by a factor of 8, so the S/V ratio is cut in half. Animals generate heat internally in proportion to their volume. Animals (and metal spheres) lose heat externally in proportion to their surface area. To survive a warm blooded animal must produce as much heat as it loses to the environment. So a small sea animal in cold water would have a tough time generating enough heat to survive. Similarly Polar Bears are very suited for a cold environment, because they are so large. Babies chill before their mothers for the same reason.

If we compare aluminum spheres, with a radius ratio of 2 and the same temperature, the larger sphere will have 8 times the heat capacity, but with only 4 times the surface area. It will decrease in temperature at half the rate of the smaller sphere.

Another example would be block of ice, this time it is energy flowing into the ice. A block of ice of 1m x 1m x 1m, has a volume of $1m^3$, and a surface area of $6\ m^2$. Surface area to volume ratio of 6. If I cut the block into 8 pieces, each piece has a volume of $1/8\ m^3$, and has a surface area of $1.5\ m^2$. The surface area to volume ratio would be 12. The larger the ratio, the faster it would melt. Keep cutting the ice into smaller and smaller pieces, and the whole block of ice would melt in a matter of minutes instead of many hours.

6. **LEAD BAR IN FLOATING BOAT. YOU ARE IN A FLOATING BOAT IN A SWIMMING POOL. THERE IS A LARGE LEAD BAR ALSO IN THE BOAT. IF YOU THROW THE LEAD BAR INTO THE POOL, WHAT HAPPENS TO THE WATER LEVEL OF THE POOL?** IT GOES DOWN.

   When the lead bar is in the boat, it is displacing its own weight. If the lead bar has a mass of 110 grams is placed in the boat, the boat would need to displace an additional 110 cm^3 of fresh water in order for to stay in equilibrium. But since the density of lead is about 11 g/cm^3, then that piece of lead would only have a volume of 10 cm3, and thus would only displace 10 cm^3 of water when it is thrown from the boat. Thus, the water level in the pool would drop.

7. **WHAT IS THE ANSWER?** ANY ANSWER IS COUNTED AS CORRECT.

   This is a way of asking questions on the fly. I checked off every answer, because I don't know in advance which one will be correct. You must check off at least one, and so checking off everyone means that it will "appear" that they are correct no matter what they pick. With the basic version of Kahoot, you aren't allowed to have multiple answers to the same question. This can also be used to just poll the class on an issue for which there isn't a correct answer.

8. *****WHY DOES IT TAKE ALMOST 20 SECONDS FOR THE HOURGLASS TO BEGIN TO RISE?** IT HAS TO DO WITH FRICTION

   This device is made from the following

   a)a cheap hourglass – I bought these 1 minute timers on Amazon. It was about $7 for six of them. There are a lot of this size hourglass available, and they fit perfectly in the 1" Tubing. I had to cut off the plastic cylinder that contained the glass hourglass.

   You will need some thin solder to wind around the middle of the hourglass to get it very close to

sinking. It will take some practice to get just the right amount of solder. If you have it just a little light, then it will rise immediately after inverting the tube. You will fill the tube with fresh water.

b)You will need to buy a 3 ft section of 1" outer diameter, rigid thin walled aquarium tubing. Cut the tubing into 1 ft segments. You can buy this at a local pet shop or online. It should be about $7.
C)Two furniture end caps. You will want the rubber ones that fit tightly over the 1" tubing.

When the sand is mostly up top, the hour glass leans to the side, and the friction between the hour glass and the tubing keeps it down. I enhance this effect by putting rubber o-rings at the top and bottom of the hour glass where it will touch the tubing. When enough sand has accumulated at the bottom of the hour glass, it will be more upright, thus lessening the friction and allowing the hour glass to rise to the top.

9. *****WILL THE ICE MELT QUICKER IN THE GLASS WITH THE FRESH WATE OR THE SALT WATER?** FRESH WATER

   This experiment really surprised me. I used 1 ½ cups of 110 F water, with ¼ cup of ice, and 1 TBS of salt in one glass. The ice melted in the fresh water cup in about 4 minutes, but it didn't melt in the salt water until almost an hour. In the fresh water, when the ice melts, the dense cold water produced by the melting of the ice sinks to the bottom of the glass. In the salt water, the cold water from the melted ice is less dense than the salt water, so it doesn't not sink, and the 0 degree ice now is floating in near 0 degree water. The fresh water from the melted ice doesn't easily mix with the salt water below. Without a large temperature gradient, the melting is very slow. Of course, in both cases energy is also absorbed from the air, but air is a poor conductor of heat. See slide 11 (floating egg) for more information.

10. *****THIN METAL AND 1" THICK WOOD AT ROOM TEMPERATURE. CRUSHED ICE ON METAL MELTS IN 2.5 MNUTES.ICE ON WOOD MELTS IN.** 40 MINUTES. The piece of metal in the picture was purchased online as a "Miracle Thaw". In reality most any piece of metal, such as a frying pan will work. The principle is the thermal heat conductive properties of metal. I put about 1 TBS of crushed ice on both the metal and the pine wood. The ice on the metal melted in 2 ½ minutes, but on the wood it took 40 minutes. The metal was noticeably colder after the ice melted because energy in the metal was easily transferred from the plate to the ice. With the wood, only the energy in the wood very near the ice could reach the ice. Both the metal and wood were at room temperature in the beginning. Students may also notice that the metal will feel colder in the beginning, because our sensation of cold is more how rapidly the energy is leaving our hand, as opposed to just the temperature of what our hand is touching. Note: the Miracle Thaw works great on thin cuts of meat, but wouldn't be useful at all for a roast. It's melting of ice is impressive.

11. ***WHY DOES THE EGG FLOAT HALFWAY DOWN**? (Have you done or seen this one)
The floating egg is deceptive. This actually takes advantage of the fact that salt water and fresh water don't easily mix. Fill up the cup about half way with very salt water. Make sure that the egg will float in the salty water. Now carefully pour down the side of a glass (I poured it onto a spoon in contact with the side of the glass) fresh water. Pour in the fresh water, until the egg appears noticeably below the surface. The deception is, that if you let the salt water sit for a while, it appears clear, and the students will think that the cup is just regular water. It also surprised me that the egg will stay "floating in the middle" for days. If you stir the water up with a spoon, the two fluids will mix. You may have to experiment to see exactly the ratio of salt water to fresh water in the glass.

12. **A TIGER'S ROAR CAN BE HEARD FURTHER AWAY IN A FOREST IF IT IS A…**
LOWER FREQUENCY
https://www.clevelandzoosociety.org/z/2021/02/23/truth-or-tail-a-lions-roar-can-be-heard-5-miles-away

"Male lions will use their roar to scare off intruders and warn the pride of potential danger. It's also a show of power among other males.
Lion roars can be heard for up to 5 miles away. That means when the Zoo's male lion, Doc, roars, everyone notices!"
The Flying Circus of Physics-Jearl Walker page 150

The distance sound carries in a forest, the habitat of tigers, depends on the wavelength: Sounds with longer wavelengths are absorbed and scattered less by the trees, brush, leaves and grass than sounds with shorter wavelengths. So, to call out for a mate or as a warning to other tigers, a tiger can send the signal farther with a low frequency roaring than with higher frequency roaring. Besides, it's just scarier.

13. **JEARL WALKER WOULD DO A DEMO WHERE HE PLUNGED HIS WET FINGERS INTO MOLTEN LEAD. WHAT PREVENTED INJURY?**
WATER VAPOR CONDUCTS HEAT POORLY
The Flying Circus of Physics-Jearl Walker page 150
"When I dip wet finders into molten lead, some or all of the water flashes to vapor and my fingers are then momentarily protected by a glove of vapor. Again, the vapor slows the transfer of hat. If the lead touched my skin, the heat transfer would be so rapid that even the briefest touch would result in a burn." Caution: 1. Pot could tip over 2. Cold water could solidify the lead 3. Too much water could evaporate the water too quickly, hurling liquid lead around.

14. **THE PRIMARY REASON THAT SPRAYING WATER ON ORANGE TREES IN FLORIDA, THREATENED BY A HARD FREEZE HELPS IS THAT…** WATER GIVES UP ENERGY AS IT FREEZES

The Flying Circus of Physics-Jearl Walker page 183
"Spraying water on oranges, threatened by a hard freeze, forms a thick layer of ice on them. Is that what saves the oranges? The protection is not due to the ice layer that forms on the plants-it does not insulate the plants from the cold air. The projection comes from what happens to the water after it lands on the plants. There the water cools to the freezing points and then freezes; both processes require that the water release thermal energy to the plants so the water molecules can first slow in their thermal motion and then become locked up in the crystal arrangement of ice. The energy transferred to the plants and then to the air can keep the temperature of the orchard between -2 and 0 C which allows the plants to survive. In order to work, the water must spread onto the plants before it freezes, forming a layer of clear ice. Growers watch for this clear ice."

15. **GREENHOUSES ARE WARMED PRIMARILY BECAUSE**…
THE STRUCTURE PREVENTS HEAT LOSSES BY CONVECTION.
The Flying Circus of Physics –Jearl Walker pg 214
"The primary reason that a greenhouse is warm is that the enclosure cuts off or severely limits air circulation. Thus, warm air is not allowed to rise out of the greenhouse to be replaced by cooler air flowing along the ground; also breezes are not allowed to displace the internal warm air." There is of course also some IR light that can't get through the glass of the green house

16. **WHAT IS THE REASON THAT NASCAR TIRES DON'T HAVE TREADS?**
HEAT DISSIPATION
The Physics of Nascar by Diandra Leslie-Pelecky pg 151
"Heat dissipation is the reason racing tires don't have tread patterns like passenger-car tire. The flat surface of a racing tire (called a slick) helps dissipate heat better. The thinner tread on a racing tire-about 1/8" compared to 3/8" on a new passenger car tire-also improves heat dissipation. The grooved treads on passenger-car tires are primarily to prevent hydroplaning, which happens when water gets between the tire and the road…Deep grooves in the tire give water an escape path so that more of the tire maintains contact with the road. NASCAR doesn't race when it is wet, so hydroplaning isn't a concern."

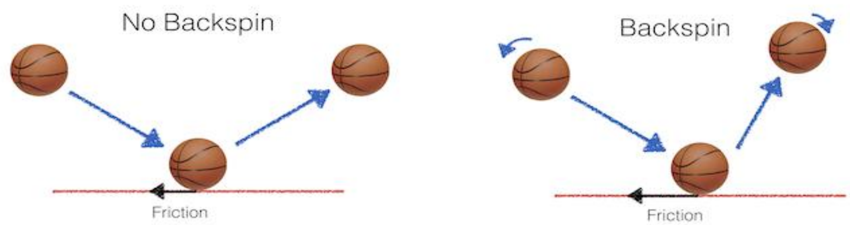
17. **EVERYTHING ELSE BEING THE SAME, WHICH OF THE FOLLOWING CLIMATES WILL ALLOW A HIT BASEBALL TO TRAVEL FURTHER?** HOT AND HUMID
https://www.exploratorium.edu/baseball/features/how-far-can-you-hit-one.html "The density of air changes with variations in temperature, pressure, and humidity. As the temperature increases, the air density decreases. For instance, air is 12 percent less dense at 95 degrees Fahrenheit than it is at 30 degrees Fahrenheit, resulting in markedly less drag.

Density also decreases with a drop in air pressure. As you move to higher altitudes, air pressure decreases significantly -- about 3 percent for every 1000 feet of elevation. So a moving baseball experiences about 16 percent less drag at the 5,000 foot elevation of Denver's Coors Field than at a sea-level stadium like Boston's Fenway Park.

Humidity is a measure of the percentage of water vapor in the air. An increase in humidity has a surprising effect on air density: As humidity increases, air density decreases. In damp air, the large, heavy oxygen and nitrogen molecules are replaced by lighter water molecules, resulting in less density -- in essence, *lighter air*. Physicist Paul Doherty explains it this way: "We think of humidity as something that's added to the air on a hot, muggy day. So you might think that a ball would go farther on a dry day than on a humid day. But for every water molecule that we add to the air, we displace a heavier nitrogen or oxygen molecule. Since the addition of humidity actually makes the air less dense, a ball will go farther on a humid day than it will on a dry day." The changes in air density related to humidity are not large: Compared to dry air at the same temperature and pressure, there's only about a 1 percent reduction in density for a humidity of 80 percent."
Example: A ball hit at 45 degrees with a speed of 161 ft per second would travel 419 ft on a hot and humid day, and 382 ft on a cold and dry day.

18. **A FREE THROW IS MORE LIKELY TO GO THROUGH THE HOOP IF IT HAS….** BACK SPIN
Physics of Basketball-by John Fontanella
https://www.wired.com/2014/04/basketball-physics/

"The backspin on a free throw is typically about 2 rotations per seconds, and comes from throwing the basketball with the fingers and a flick of the wrist. This time is not for stability (the basketball is round, so there is no preferred direction as there is for a spiral pass in football.) This time, it has to do with a "softer" shot. If the ball with backspin hits the rim, then the friction with the rim slows it down more than it would a non- spinning ball.
It is better able to go through the hoop, even it eventually bounces off the backboard, than if it bounces hard off the rim."



19. **IF A BASKETBALL PLAYER JUMPS UP 4 FT WHILE DOING A SLAM DUNK, HOW LONG WILL HE/SHE BE AT LEAST 3 FT OFF THE GROUND**. 50% OF THE TIME.
A ball dropped from rest, will fall 1 ft in 0.25 seconds. $D=1/2at^2$
A ball dropped from rest will fall 4 ft in 0.50 seconds.
Therefore a dropped ball will spend 50% of its time above 3 ft. The same thing is true while going up.

20. **WHICH WHITE TAIL DEER IS MORE SUITABLE FOR A NORTHERN US CLIMATE COMPARED TO A SOUTHERN US CLIMATE?** ONE OF LARGER SIZE AND MASS
https://www.acs.org/content/acs/en/education/resources/highschool/chemmatters/past-issues/archive-2013-2014/animal-survival-in-extreme-temperatures.html
"Within a given species, animals tend to be larger in colder climates and smaller in warmer climates, an observation known as Bergmann's rule. For example, whitetail deer in the southern part of the United States tend to have a smaller body size and less overall mass than whitetail deer in the far northern states.
There are exceptions but, overall, this rule holds true, for the following reason: As the volume of an object decreases, the ratio of its surface area to its volume increases. In other words, the smaller an animal is, the higher the surface area-to-volume ratio. These animals lose heat relatively quickly and cool down faster, so they are more likely to be found in warmer climates. Larger animals, on the other hand, have lower surface area-to-volume ratios and lose heat more slowly, so and they are more likely to be found in colder climates."

21. **WHAT IS THE COST OF THE ELECTRIC ENERGY REQUIRED TO ROTATE THE FALKIRK WHEEL A HALF ROTATION AND LIFT THE BOAT 24 METERS.** $0.38
Falkirk Wheel Wikipedia
It takes 22.5 kilowatts (30.2 hp) to **power** ten hydraulic motors, which **consume** 1.5 kilowatt-hours (5,100 BTU) per half-turn, roughly the same as boiling eight kettles of water. Each of the two caissons is 6.5 metres (21 ft) wide, and can hold up to four 20-metre-long (66 ft) canal boats. In Scotland, it costs about 25 cents per kilowatthour. The Caissons have approximately

300,000 kg each, but they the torque is virtually zero. One Caisson goes up while another comes down. They weigh the same whether or not boat is in the Caisson, because of the displaced water.

The boats are lifted up 24 m (79 ft).

22. **How much antimater would be needed to meet the World's energy needs (18 Terawatts)** 100 MILLIGRAMS/SEC

    We can create antimatter in particle accelerators, but if all of the antimatter ever made by humans were annihilated at once, the energy produced wouldn't be even enough to boil a cup of tea. Making one gram of antimatter would require approximately 25 million billion kilowatt-hours of energy and cost over a million billion dollars.   1 gram of antimatter fuel produces 180 Trillion Joules of energy . The worlds energy consumption is 18 Terrawats (18 Trillion Joules per second), so it would require 100 milligrams of antimatter per second.

    The Tech manual for Star Trek quotes an output in the terawatt range for the Enterprise. Knowledgable fans speculate that at cruising velocities the warp core outputs 7.1 terawatts normally, and this figure climbs as demand requires. Obviously, the Enterprise would need a very compact way of storing energy and anti-matter would fit the bill. Now they just need to find a way to produce it cheaply and easily.

23. **APPROXIMATELY HOW MUCH ANT-MATTER HAS BEEN CREATED SO FAR IN PARTICLE ACCELERATORS**? 50 NANOGRAMS

    Estimates from various source aren't in agreement, but they are pretty much all in the nanogram (1×10^{-9} grams) range.

24. **HOW TALL WOULD A STACK OF 10 GB HARRD DRIVES, EACH 1 CM THINCK, NEED TO BE TO PROPERLY TRANSPORT (BEAM DOWN) A HUMAN?** 1,000 LIGHT YEARS

    The Physics of Star Trek by Lawrence M. Krauss Chapter 5

    According to Lawrence Kraus, if you want to do a Transport correctly, then you would have to encode the information in every atom of the body. "Even then, there is the question of whether we are simply the sum of all of our atoms. More precisely, if I were to re-create each atom in your body, in precisely the same chemical state of excitation as your atoms are in at this moment, would I produce a functionally identical person who has exactly all of your memories, hopes, dreams, spirit?" If we estimate 10^{28} atoms. You would need to encode its location, internal state (whether it is bound to another atom, vibration or rotation, energy levels occupied by the electrons, etc.) He estimates 1 kilobyte per atom. Now we have 10^{28} kilobytes of information to encode and store. An estimate of the information in all of the books ever written would be about 10^{12} kilobytes. If we stored the information of one person on 10GB hard drives, 1 cm thick, then it would be stack of hard drives that is 1000 light years tall.

25. **WHY IS GRAVITY SO DIFFEENT FROM THE OTHER FORCES?(I.E. IT IS ABOUT 1036 TIMES WEAKER THAN THE OTHER THREE FORCES)**

WE HAVE NO IDEA

We have No Idea by Jorge Cham and Daniel Whiteson Chapter 6

This is the same answer for Why do protons attract electrons, Why does the universe have a speed limit, What is dark matter, etc.