Lecture 3 Summer Session June 17,2020

From the sky down: How falling works

PARABOLIC MOTION

Physicist like to start simple and add complexity to their understanding (1:50)….(minute Locator on computer corner)

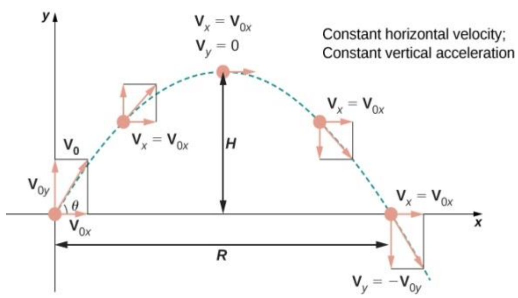
> Physics has a rich history of making simplifying approximations in its calculations. Physicists will often ignore important parameters when studying a problem in order to get at the big ideas. Then, they tweak the equations to include more and more complicating effects.

What goes up must come down(2:18) - Is that written on the Voyager Space Probe?

Disclaimer- I am not responsible for the math portion of the program….

Parabolic Motion (2:45)

What are the important things that govern the trajectory of a ball thrown on Earth by a baseball player? Rene Descartes, a French Philosopher and Mathematician, first used a graphing method to help visualize mathematical relationships.



Gravity points downward and has a value of 9.8 meters per second squared. (3:38) That's the acceleration due to gravity. ..3:50

Do not confuse with weight which is a force of gravity…(3:45)

Table 1 The Five Key Equations of Accelerated Motion

	Equation	Variables found in equation	Variables not in equation
Equation 1	$\Delta\vec{d} = \left(\frac{\vec{v}_f + \vec{v}_i}{2}\right)\Delta t$	$\Delta\vec{d}, \Delta t, \vec{v}_f, \vec{v}_i$	$\vec{a}_{av}$
Equation 2	$\vec{v}_f = \vec{v}_i + \vec{a}_{av}\Delta t$	$\vec{a}_{av}, \Delta t, \vec{v}_f, \vec{v}_i$	$\Delta\vec{d}$
Equation 3	$\Delta\vec{d} = \vec{v}_i\Delta t + \frac{1}{2}\vec{a}_{av}\Delta t^2$	$\Delta\vec{d}, \vec{a}_{av}, \Delta t, \vec{v}_i$	$\vec{v}_f$
Equation 4	$v_f^2 = v_i^2 + 2a_{av}\Delta d$	$\Delta d, a_{av}, v_f, v_i$	Δt
Equation 5	$\Delta\vec{d} = \vec{v}_f\Delta t - \frac{1}{2}\vec{a}_{av}\Delta t^2$	$\Delta\vec{d}, \vec{a}_{av}, \Delta t, \vec{v}_f$	$\vec{v}_i$

$d(t)=d_0 + v_0t + 1/2at^2$ ..(4:33)

- d = distance
- t = time
- d_0 = a starting point to that distance
- v_0 = the starting speed
- a = acceleration of gravity

One of the key points to using this equation in physics is that motion in the x direction (horizontally) and in the y direction (vertically) can be treated completely independently.(5:04) On Earth, gravity (which has a value of 9.8) is only in the vertical direction— specifically downward—which means that $a_y = -9.8$ (5:41) for the acceleration due to gravity. And because there is no acceleration due to gravity in the horizontal, or x, direction, $a_x = 0$. (5:49) This simplifies the equations slightly…..

one for X one for Y (5:13)

$x(t) = x_0 + v_{x,0}t$ **$y(t) = y_0 + v_{y,0}t\ 1/2\ gt^2$**

You can work with these equations as they are, but you can simplify again by calling the position at which the ball is released to be the origin, which means that both x_0 and y_0= 0. (6:08)

$(x_0,y_0) = (0,0)$ ..

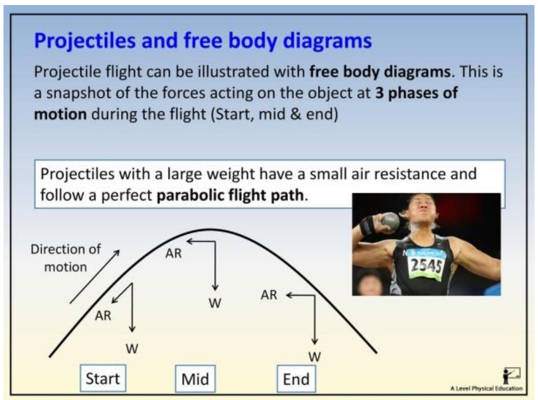
And if you do that, you can further reduce the quadratic equations and get

$x(t) = v_{x,0}t$,

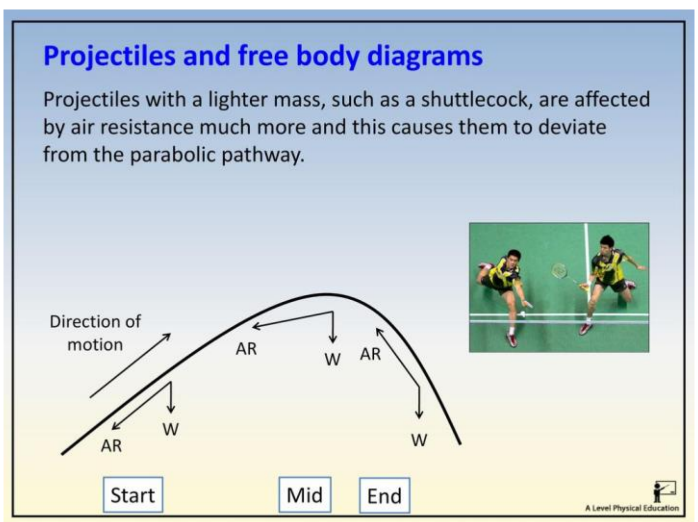
$y(t) = v_{y,0}\ t - 1/2\ gt^2$ (6:26)

Basically, if you set up a camera to record the path of the ball, what shape would that path be? 6:49
The easiest way to do that is to get rid of the t variable. So, from the first step, you get
$t = \frac{X}{Vx0}$..
Finally, you get the equation for the vertical position y as a function of horizontal position x:
$y = \frac{Vy0}{Vx0}$ x - $1/2 \frac{g}{v_{x0}^2}$x^2

These initial velocities are a constant, and so is the acceleration due to gravity, g.(7:43) So, this whole thing is a very basic algebra equation, where those constants can be replaced with just 2 symbols for constants—for example, A and B: **y = Ax^2 + Bx.**(7:52)
That's the equation of a parabola. ……Ball paths go the way of the parabola (8:18)
Air Resistance (8:29)
It works pretty well for a baseball, but throw a feather just as hard and you'll see that it doesn't follow the same path. (8:44) And that's due to air resistance
What factors come into play when you consider air resistance? (9:13)
If you drive your car 60 miles per hour and put your hand out the window, you'll feel the air pushing backward on your hand pretty hard. (9:40)



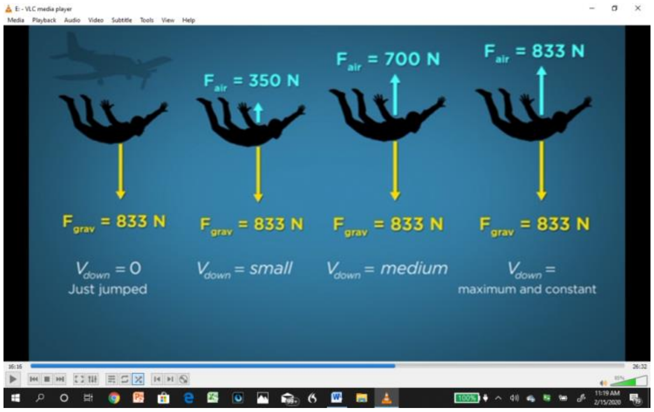
The air resistance is proportional to velocity. How does this affect parabolic motion? .
Suppose you shoot an object, with something like a cannon or a catapult, with an initial angle with respect to the Earth's surface. The moment the object leaves the cannon is typically the time when it has the highest velocity—and when it therefore experiences the largest amount of air resistance, or the drag force. (10:41)That's when air is slowing down the object the most. The other thing is that if you shoot an object at some angle, the drag force—which is opposite the direction of motion—is also at an angle.)(10:57)
As the object is lofted upward, the vertical motion is slowing down, and when the object gets to the peak, its motion stops in the vertical direction. (11:39) No vertical velocity means no drag, because the drag force is proportional to velocity. But the horizontal motion is still going, which means that there is still a horizontal drag force. .. (11:50)



As the object starts to fall, it starts with zero vertical motion and zero vertical drag, but gravity causes the object to speed up faster and faster. That means that the vertical drag force will become increasingly greater.(1200) (drag force and projectile motion)

Now you know enough to understand qualitatively how the drag force will change an object's path from a parabola. The object goes upward kind of like you'd expect, (12:12) but the distance that the object goes before it hits the ground is less than if there is no air resistance. Also, the path isn't really parabolic anymore. The downward path is steeper than the upward one. .(12:22)

There are a lot of things that go into a drag force, such as the object's shape and size, so it's not possible to talk about drag in detail without a lot of work. But it is possible to see how air resistance causes the motion of an object to no longer be a parabola. Drag force can be proportional to the velocity or velocity squared.(13:17) The motion of a vertical and horizontal when measured together may not always produce a parabola…an objects origin is when an object location is 0 When Vh And Vv are both 0. ……



V(t)=-gt (15:28) velocity goes faster and faster..
Remember: as velocity increases drag force increases. (15:52)
Velocity is down drag force is upwards. (16:00)
Terminal Velocity: when the force going down = the force going up and you don't fall faster.(16:26)

- Imagine that you are in Texas with a super-strong bow and a very robust arrow. You take aim at the North Pole and let the arrow fly. What would you expect (for the moment ignoring air friction)?(17:56)

what really happens is that the arrow would start to bear off to the right. .(18:20).(an arrow shot due North and the pathway)
This effect was understood as early as 1651, when Italian scientist Giovanni Battista Riccioli realized that the Earth's rotation would make a cannonball shot northward deflect toward the east. (19:15) While there were many early contributors to the mathematics of this theory, its modern name comes from French physicist Gustave-Gaspard Coriolis, (19:25) who published a paper in 1835 on the forces felt on the rotating parts of industrial machinery, specifically water wheels. (19:30) The modern name, Coriolis force, didn't become common until about 1920.
How does the Coriolis force work? . (19;39)

Hurricanes begin as areas of low air pressure, which causes air to flow inward toward them. But due to the Coriolis effect, the air is deflected to the right in the Northern Hemisphere and to the left in the Southern. The net effect is that this causes the air to start rotating. And this explains why hurricanes rotate counterclockwise in the Northern Hemisphere and clockwise in the Southern one.

The Earth rotates once a day. The circumference of the Earth at the equator is about 25,000 miles. If it takes 24 hours to rotate, then the surface of the Earth at the equator is moving at around 1042 miles per hour, which can be rounded to 1000 miles per hour for simplicity. (19:58)
In contrast, a person standing about 4 feet from the North Pole is traveling much more slowly. Over the course of a day, a person travels on a circle about 24 feet in circumference, or about 1 foot per hour. ..(20:06) Halfway between the equator and the North Pole is Minneapolis, Minnesota. Over the course of a day, this city moves a little less than 18,000 miles and therefore moves a bit more than 700 miles per hour. And the situation is the same on the Southern Hemisphere, with Oamaru, New Zealand, standing in for Minneapolis. ..(20:22)
This means basically that the equator is the fastest-moving place on the planet. So, if you start on the equator and shoot a projectile northward, the projectile has a velocity of 1000 miles per hour eastward. (20:36) Minneapolis, at 700 miles per hour, is moving more slowly and can't keep up. So, to the point of view of a person on the Earth, a projectile shot northward from the equator will deflect eastward, or to the right. ..(20:45)
Now consider a projectile shot southward from the North Pole. Because the North Pole doesn't move, any location to the south of it moves more quickly. This means that the projectile seems to an Earth-bound person to be deflected westward, but again to the right
Any projectile shot horizontally on the Earth's surface will be deflected to the right on the Northern Hemisphere and to the left on the Southern Hemisphere.(21:16)

Hurricanes

the Coriolis effect as only large-scale effects over large distances, which affects weather patterns(21:27) when there is air pressure which causes air to move into them (21:38) due to the Coriolis effect the care is shifted to the right in the northern hemisphere and to the left in the southern hemisphere due to the Coriolis effect (21:43)

Foucault Pendulum – 24:56 when a heavy pendulum oscillates it 25:01

> You might've heard the myth that the Coriolis effect is the reason why toilets swirl counterclockwise in the Northern Hemisphere and clockwise in the Southern. But this effect is very small on an object as small as a toilet; the swirling only has to do with the direction the jets are pointed.

Lecture 4 Summer Session June 17,2020

The Truth is in Here the Science of Aliens.

00:14 The Beginning of Information
Silicon Based Life Forms. 2:55
Life is based on carbon.(3:03)

Table 2.1 Naturally Occurring Elements in the Human Body

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Symbol	Element	Atomic Number (See p. 29)	Percentage of Human Body Weight
O	Oxygen	8	65.0
C	Carbon	6	18.5
H	Hydrogen	1	9.5
N	Nitrogen	7	3.3
Ca	Calcium	20	1.5
P	Phosphorus	15	1.0
K	Potassium	19	0.4
S	Sulfur	16	0.3
Na	Sodium	11	0.2
Cl	Chlorine	17	0.2
Mg	Magnesium	12	0.1

Trace elements (less than 0.01%): boron (B), chromium (Cr), cobalt (Co), copper (Cu), fluorine (F), iodine (I), iron (Fe), manganese (Mn), molybdenum (Mo), selenium (Se), silicon (Si), tin (Sn), vanadium (V), and zinc (Zn).

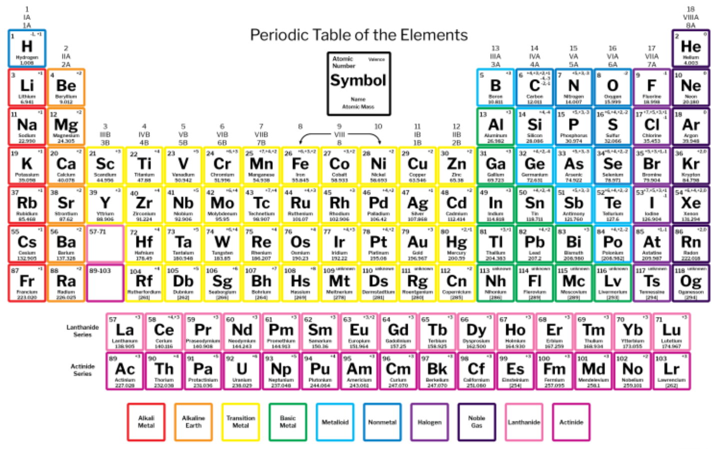
Carbon, oxygen, hydrogen, nitrogen, calcium, and phosphorus make up 99% (3:15) of your body. By weight, oxygen is the most common element in your body, at about 65%. That's because blood has a lot of water, of which oxygen is a heavy component. (3:19) But carbon is the second most common, at about 19%. (3:24**)** **C HOPKINS CaFé Mg**

THE PERIODIC TABLE OF THE ELEMENTS

The periodic table was first proposed in the mid-1800s by Russian chemist Dmitri Mendeleev. His original table contained only a fraction of the chemical elements that we know of now. ..(3:37)

The modern periodic table is organized in the following way: All elements in the same column react in similar ways, and as you go from the top to the bottom, the elements go from light to heavy. (4:26) The column on the far right contains the noble gases: helium, neon, argon, krypton, xenon, etc. Their defining feature is that they don't interact with other elements. On the far left are the alkali metals: hydrogen, lithium, sodium, potassium, etc. They are incredibly reactive. (4:46)

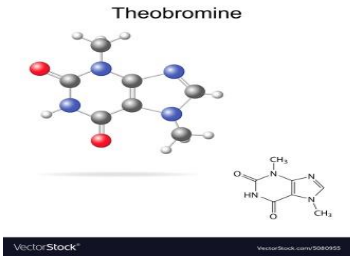
The reason why each column has different reactivity has to do with the configuration of electrons surrounding them. The electrons surrounding atoms are in a series of orbitals, which are a little like cups, and the electrons are like marbles. (5:22)

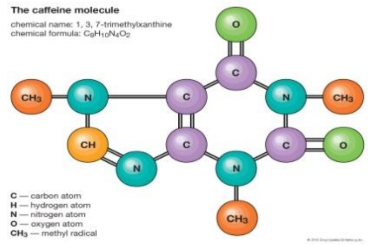


You can put marbles into the cup until the cup is full, at which point the cup doesn't want any more marbles. In this analogy, the full cups correspond to the noble gases. These atoms have all the electrons they **want,** so they don't interact with others. (5:40)
Chemical bonds are just atoms sharing electrons, so if an atom doesn't have a full orbital, it can accept electrons from other atoms, just as a cup with a missing marble could take a marble from another atom.(5:54)
The column of atoms next to the noble gases contains fluorine, chlorine, bromine, iodine, etc. The elements in this column don't quite have a full cup. It's as if they're missing a marble. Accordingly, they can accept one marble from some other cup—meaning they can accept an electron. Chemists say that elements from this column can make one bond with other elements. (6:14)
Hydrogen is the simplest element, with one marble to spare, so it can be used as a way to illustrate the way that elements connect. For example, when fluorine, which is at the top of the column, interacts with hydrogen, the result is hydrogen fluoride, or HF, which is one hydrogen atom and one fluorine atom. (6:34)

The elements one column to the left—with oxygen, sulfur, selenium, etc.—are missing 2 electrons, like a cup without 2 marbles. These elements can make 2 atomic bonds. For example, oxygen can connect to 2 hydrogen atoms to make H_2O, or water. (6:58)
The next column—with nitrogen, phosphorous, arsenic, antimony, etc.—the pattern continues, this time with 3 missing marbles, or really electrons. For example, nitrogen can make 3 bonds with hydrogen, making NH_3, or ammonia. (7:08)
The column with carbon, silicon, germanium, and tin contains elements that can make 4 atomic bonds. For example, carbon combined with hydrogen makes CH_4, or methane.(7:15)
The analogy would suggest that the elements in the next column— boron, aluminum, gallium, and indium—could make 5 bonds, and there is some truth to that. However, as you move more and more to the left, the situation starts to look less and less like a cup missing a few marbles and more like a smaller cup with a few too many marbles sitting on the top.(7:45) So, rather than being atoms that accept electrons (or cups accepting marbles), they become more like atoms that donate electrons to other atoms. (7:56)
At some level, this is why a lot of chemistry involves atoms on the left side of the periodic table interacting with atoms on the right—because some cups have marbles to give and some need marbles to fill up.(8:10)
CARBON-AND SILICON-BASED LIFE-FORMS ..(9:08)
Life as we know it is based on the element carbon. This is because of its ability to make 4 atomic bonds with other elements.

Inorganic molecules, which do not contain carbon, include the hydrogen molecule (H_2), ammonia (NH_3), and water (H_2O). (9:15) With these elements, there are a handful of atoms connected together by a few bonds. Organic molecules—such as caffeine ($C_8H_{10}N_4O_2$), (9:30) and theobromine ($C_7H_8N_4O_2$), and even DNA— contain carbon and are complex.





Theobromine Caffeine

The reason people think that silicon-based life might be possible is because silicon is below carbon on the periodic table and can also make 4 bonds. (10:20) So, it stands to reason that you could just as easily make complicated molecules with silicon, resulting in silicon-based life. It makes perfect sense—except it's not true. (10:30)

In the episode from the original Star Trek series called "The Devil in the Dark," the gang encounters the Horta, (10:48) which was basically a living rock that was killing miners for taking rocks they didn't know were the Horta's eggs.(10:53) Scientifically, the Horta is extremely unlikely.

Silicon and carbon can both form 4 bonds. On Earth, silicon is much more prevalent than carbon. Basically, silicon is found in sand and rock. Silicon makes up 28% of the Earth's crust. (11:33) Carbon, in contrast, is about 1000 times less common—yet it makes up life, while silicon doesn't. If silicon were a contender, the fact that it is so common would give it a huge advantage. But it falls short. ..

When carbon makes 4 atomic bonds with all of its neighbors, the bonds tend to be the same strength. (11:58) In silicon, the first bond is much stronger than the others, which means that the first bond is much more stable than the others. It's because the first bond is formed when the electrons from each atom reach across directly to the other atom in a metaphorical handshake. The other bonds are formed from electrons that are farther away, and they effectively don't get as good a grip.(12:21)

In addition, when carbon connects with other chemicals common in organic molecules, the bonds are of similar strength. (12:32)Carbon-carbon, carbon-oxygen, carbon-hydrogen, and carbon-nitrogen bonds are all pretty similar. From an energy standpoint, this means it's pretty easy to swap out atoms, which is a physicist's way of saying that chemical reactions occur. (12:50)

However, the silicon-oxygen bond is much stronger than, say, silicon-hydrogen or silicon-carbon bonds, or even silicon-silicon bonds. This means that once silicon interacts with oxygen, it's very hard to break them apart. This decreases the ease and versatility of silicon chemical interactions as compared to ones involving Carbon. (13:17)

The technical term for trying to detect alien civilizations is the search for extraterrestrial intelligence (SETI).

When you breathe, you take in oxygen and breathe out carbon dioxide, or CO_2. The corresponding silicon molecule is silicon dioxide, or SiO_2, which is rock. Thus, a silicon-based creature using oxygen as part of its energy cycle would be breathing out sand. (13:50)

So, while a simple understanding of the chemistry of carbon and silicon suggests that silicon-based life is possible, if you dig a bit more deeply, it seems that silicon-based life isn't that likely. (14:27)Initially, the chemistry seems compelling, but perhaps the most compelling argument for the advantages of carbon is simply the fact that life on Earth is made of carbon, in spite of there being much more silicon around. If silicon were competitive, a silicon-based life-form on Earth would have come into existence and outcompeted our ancestors. (14:48)

THE DRAKE EQUATION (17:01)

Enrico Fermi. (17:09) the namesake of the Fermi Question….(Questions that have estimated answers in orders of magnitude.) 225 out of 290 piano tuners is remarkably close based on estimation.(18:30).The art of intelligent guessimating.(18:57)- A Fermi Question….

SETI – the Search for Extra–Terrestrial Intelligence (1936)

In 1961, radio astronomer Francis Drake turned a 25-meter-wide radio telescope in Green Bank, West Virginia, to 2 nearby sun like stars, Tau Ceti and Epsilon Eridani, and listened for radio transmissions from other civilizations.(20:22) But he heard no signal. Although Drake failed to find evidence of extraterrestrials, he certainly wasn't dissuaded. He came up with a quantifying set of parameters to turn the question from an undisciplined one into a scientific one. This set of parameters is now called the Drake equation:

Francis Drake's Project Ozma was the first scientific attempt to find civilizations on planets around stars other than our own.(20:36)

$$N = R^* \times f_p \times ne \times f_L \times f_i \times f_c \times L,$$

Where:

N - is the number of civilizations in our galaxy,
R* - is the average rate at which stars are formed in our galaxy,
fp - is the fraction of those stars that host planetary systems, n_e is the average number of Planets around the star that can support life,(21:49)
n_e-the average number of stars around a planet that can support life
f_L - is the fraction of planets that could support life that actually do support life,
f_i - is the fraction of planets that develop life that go on to develop intelligent life,
fc - is the fraction of planets with intelligent life that develop civilization and technology that We can detect
L - is the length of time each civilization emits radio waves (or whatever) that we can detect.

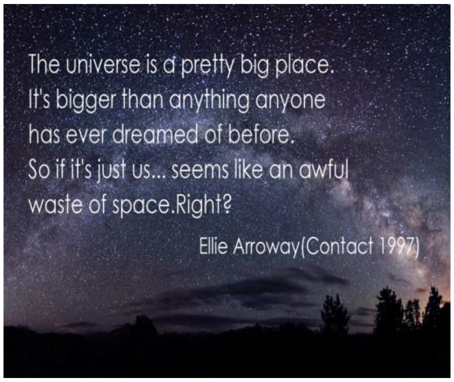
Parameter	Estimate 1961	Estimate 2018
R*	1 per year	1.5-3.0 per year
Fp	0.2-0.5	1
Ne	1-5	0.4
fL	1	1
Fi	1	0-1
Fc	0.1-0.2	unknown
L	1,000-100,000,000 years	unknown
N	20-50,000,000 civilizations	unknown

Obviously, we don't know the answers to all of these questions, so we have to guess. In 1961, Drake suggested the parameters in the following table, from which he and his colleagues estimated that the number of civilizations in the Milky Way Galaxy was somewhere between 20 civilizations and 50 million civilizations. There are many people who think the Drake equation is a good estimator of the number of civilizations in our galaxy and that if we just figured out all the parameters, we'd have it all nailed down. (23:37)

But that's the misconception. The Drake equation is actually a very simplified one, and it neglects important parameters. For example, it doesn't take into account the very likely possibility that a single species could travel to many stars, (23:53) and therefore we would expect to hear radio transmissions from many more sources. In addition, the equation assumes that when a civilization loses the ability to emit radio waves, it is gone forever(26:14) —but even if everyone died, presumably the civilization would rebuild and start over. ..

But just because there are some problems with the Drake equation doesn't mean that it wasn't a very

good first step.(26:45) It was. If nothing else, it identifies some of the key parameters that go into understanding whether we are alone in the universe. (26:52)
One or more of the factors in the Drake equation has to be much rarer than we imagine. (28:26) Maybe intelligent life just doesn't evolve very often. Maybe civilizations only emit radio waves for a short time and find(1) other ways to communicate. Or maybe civilizations (2) aren't around that long; once they develop technology involving nuclear weapons, they simply wipe themselves out. ..(28:44)
The fact is that we don't know what makes it seem like we are alone in the universe. Maybe we are.(28:52)



Readings:
Lincoln, Alien *Universe*
Plaxco and Gross, *Astrobiology*
Vakoch and Dowd, *The Drake Equasion*
Ward and Brownlee, *Rare Earth*
Webb, *If the universe is teeming with Alien, Where is everybody?*

The Drake Equation explained.
https://schoolworkhelper.net/drake%E2%80%99s-equation-explained/

https://www.seti.org/drake-equation-index