What Einstein Told His Barber

More Scientific Answers to Everyday Questions

Robert L. Wolke

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What Einstein Told His Barber

More Scientific Answers to Everyday Questions

ROBERT L. WOLKE

A Dell Trade Paperback

I dedicate this book to my late father, Harry L. Wolke, to whom fate denied the opportunity of pursuing his own inclinations toward scien and language, or even of seeing his son become a scientist and an author.

This one's for you, Pop.

Acknowledgments

I want to express my dying gratitude to all of my friends who said, “Hey, Bob, I thought of a great question for your book the other day, b forgot it.”

I earnestly thank two nice guys with whom it has been a pleasure to work: my agent, Ethan Ellenberg, and my editor, Mike Shohl. Eth skillfully navigated my proposal through the “shohls” of contract negotiation, while Mike wielded his blue pencil with understanding and restra getting all my jokes and allowing them to survive.

Diana Zourelias's delightful drawings add an even lighter touch to what would otherwise have been a relentlessly gray-paged volume. A did was give her a paragraph describing each situation to be illustrated, and her whimsical creativity took it from there.

I am indebted to Richard E. Eckels for guiding me to a true explanation of how airplanes fly.

The two women in my life, my daughter, Leslie, and my wife, Marlene, never flagged in their encouragement or in their regard for my w despite my computer's often competing with them for my time. For that and for their love and admiration I am grateful every day of my life.

Contents

Introduction

1 Movin' and Shakin'

Newton discovered three laws of motion

… but he never considered these:

Why do we drive on the right? Why are cloverleaf intersections so complex? Can Earth's orbit be changed if a billion people jump at the same time? Can jumping up at the last instant save you in a falling elevator? Where does the rubber go when a tire wears out? Can a bu fired into the air come down and kill somebody? Why does the Lone Ranger use silver bullets? What *really* keeps an airplane up? A astronauts weightless? If you drive your car faster than the speed of sound, can you hear the radio? … And more.

2 Looky Here!

Seeing is believing

… but not until we understand what we see.

What makes Day-Glo colors so bright? Why is snow white? Why are there two sets of primary colors? How do fluorescent and halog lamps work? Why do mirrors seem to reverse left and right, but not top and bottom? Why do stagecoach wheels appear to turn backwa Why do wet things look darker? Why is glass transparent? Why do WintOGreen Life Savers make sparks? … And more.

3 Hot Stuff

If you can't stand the heat, get out of the universe

… because heat is the ultimate form of energy.

Is 100 degrees twice as hot as 50 degrees? What is temperature, anyway? How cold can it get? Why is the bathroom floor so cold on y bare feet? How hot can it get? How does a flame know which way is up? Why is a candle flame tapered at the top? Could we counter global warming by turning on all our air conditioners? What's so dangerous about high voltage? Why doesn't it rain dead sparrows? … A more.

4 The Earth Beneath Our Feet

O happy Earth, whereon thy innocent feet do ever tread!—SPENSER

… And thy innocent mind doth ever strive to understand.

Why does Earth pull everything toward its exact center? How does hot air defy gravity by rising? If hot air rises, why is it colder in mountains? Does it ever get too cold to snow? If Earth is spinning so fast, why don't we fly off? Can the astronauts see Earth turning bene them? Would a polar bear weigh less at the equator? Do toilets flush counterclockwise in the northern hemisphere and clockwise in southern hemisphere? Can you stand an egg on end during the vernal equinox? Why is nuclear energy unique on Earth? How do radiocarbon dating work? … And more.

5 Heavens Above!

These earthly godfathers of heaven's lights
That give a name to every fixed star
Have no more profit of their shining nights
Than those who walk and know not what they are.

—SHAKESPEARE

Sorry to disagree with you, Will, but it's much more fun if you know what they are. The air, the sky, the moon and the stars are all up there us to comprehend.

How do odors find your nose? Can you operate a vacuum cleaner in a vacuum? Why does a lion tamer's whip make such a loud "crac What is the sound barrier made of? Why does thunder sound the way it does? Why is the moon so much bigger when it's near the horizo Why do the stars twinkle? How does the moon keep one side always facing Earth? How do the oceans' tides work? Does the moon ever t blue? Why is it cold in space—or is it? … And more.

6 All Wet

You can lead a horse to water, but you can't make him think.—WOLKE

We humans, however, can ponder the remarkable properties of the most abundant chemical on Earth.

What color is water? Why are the oceans blue? And salty? Precisely where is sea level? Why does spilled coffee dry to a ring? Why do your shower curtain cling to you? Where do your socks go when they disappear in the laundry? What's the most expensive ingredient in laun detergents? (Advertising.) Is glass a liquid? What makes ice cubes cloudy? If the humidity got to be 100 percent, would we drown? How c you clear your fogged-up windshield? Can a farmer smell rain? … And more.

7 Stuff and Things

He who dies with the most stuff wins.—YUPPIE PHILOSOPHY

We have surrounded ourselves with hundreds of material things that we use but may not really understand.

Are airplanes safe? How does an eraser erase? Why does rubber stretch? Why are cars noisy? Why do clothes wrinkle? How doe skateboard work? What happens when you shake a bottle of soda? Can you get electricity out of a lemon? Are smoke alarms radioactiv Can fertilizer explode? How do sailors keep clean? If you stopped dusting, how long would it take to be buried in dust? Can you unbur match? … And more.

Some Techspeak Buzzwords

Introduction

I know what you're thinking. You're thinking, “Did Einstein even *have* a barber?”

You've seen his pictures, right? And it's perfectly clear that the great man devoted a lot more time to cultivating the inside of his head th the outside.

But this book isn't about barbers, and it isn't even much about Einstein. (His name comes up only four times.) It is a book of scientific sn talk, the kinds of things that Einstein *might* have talked about with his barber—simple things that may have been trivial to the great scient but that the rest of us may wonder about.

There are many science-is-fun books for young readers. But it isn't only children who wonder “Why?” or “How?” Curiosity doesn't enc puberty, nor does the genuine fun of understanding why things happen. And yet, once we are “done with science” in school we encounter f books for people of any age who are simply curious about their everyday surroundings and derive pleasure from knowing what makes th tick. This is that kind of book.

Maybe you are convinced that science is “not for you,” that it is inherently difficult stuff, and that if you were to ask a question the answ would be too technical and complicated for you to understand. So you just don't ask. You may have come to these conclusions because unfortunate experiences with school science classes or simply from the science stories in newspapers and magazines and on televisi These stories are by their very nature guaranteed to be technical and complicated, because they are about the latest discoveries of lead scientists. If they weren't, they wouldn't be news. You won't see a TV special on why the bathroom floor feels so cold on your bare feet. But explanation of that phenomenon is science, every bit as much as a discussion of quarks or neutron stars.

Science is everything you see, hear and feel, and you don't have to be an Einstein or even a scientist to wonder *why* you are seeing, hear and feeling those things, because in most cases the explanations are surprisingly simple and even fun.

This is not a book of facts. You will not find answers here to questions such as “Who discovered …?” “What is the biggest …?” “How ma …are there?” or “What is a …?” Those aren't the kinds of things that real people wonder about. Collections of answers to such contriv questions may help you win a trivia contest, but they are not satisfying; they don't contribute to the joy of understanding. The joy and the come not from mere statements of fact but from *explanations*— explanations in plain, everyday language that make you say, “Wow! Is *tha* there is to it?”

There are well over a hundred explicit questions addressed in this book, but that by no means limits the number of things that are actu explained. The physical world is a complex web of goings-on, and nothing happens for a single, facile reason. In science, every answ uncovers new questions, and no explanation can ever be complete.

Nevertheless, I have written each question-answer unit to be self-contained, to be read and understood independently of all the others. T must inevitably lead to some overlap—an essential link in logic cannot be omitted simply because it is treated in greater detail elsewhere. as every teacher knows, a bit of repetition never hurt the learning process.

Whenever another Q&A unit contains closely related information, you will be referred to the page number on which that unit *appears*. Th there is no need to read the book sequentially. Read any unit that catches your eye at any time. But don't be surprised if you are lured int web of related units by the page references. Follow the lark. That way, you'll be following trains of thought sequentially, as if they had been l out in a (heaven forbid) textbook, which neither of us wants. You've been there, and I've done that. And whenever a complete explanat requires a little more detail than you may be in the mood for, that detail is banished to a Nitpicker's Corner. There, you may either contir reading or just skip it and move on to another question. Your call.

I have studiously avoided using scientific terms. I believe that any concept that is capable of being understood should be explainable ordinary language; that's what language was invented for. But for their own convenience, scientists use linguistic shortcuts that I “Techspeak.” When a Techspeak word is inescapable, or when it is a word that you may have heard and avoiding it might seem contrived define it in plain language on the spot. You will find the definitions of some useful Techspeak words in the back of the book.

I assume no previous scientific knowledge on your part. There are three ubiquitous Techspeak words, however, that I use without taking t trouble to define each time: atom, molecule and electron. If you're a bit skittish about your familiarity with them, check them out in Techspeak list before you begin.

Scattered throughout the book you will find a number of Try Its—fun things that you can do in your own home to illustrate the principles be explained. You will also find a number of Bar Bets that may or may not win you a round of drinks, but that will certainly get a spirited discuss going.

When Albert Einstein was in residence at the Institute for Advanced Study at Princeton University, an eager young newspaper repo approached him one day, notebook in hand. “Well, Professor Einstein,” he asked, “what's new in science?”

Einstein looked at him with his deep, soft eyes and replied, “Oh? Have you already written about all the *old* science?”

What he meant was that science isn't to be characterized only by the latest headline-making discovery. Scientific observation has be going on for centuries, and in that time we have learned a tremendous amount about the world around us. There is a vast heritage knowledge that explains ordinary, familiar happenings.

That's the “old science.” Everyday science. That's what this book is about.

1

Movin’ and Shakin’

Everything is moving.

You may be sitting quietly in your armchair, but you are far from motionless. I don't mean merely that your heart is beating, your blood coursing through your veins and you are panting at the prospect of learning so many fascinating things from this book. In short, I don't me simply that you are physically and mentally alive.

I mean that while you are sitting there so peacefully, Earth beneath your feet is spinning you around at about 1,000 miles per hour (1,6 kilometers per hour). (The exact speed depends on where you live). Mother Earth is simultaneously hauling you around the sun at 66,600 mi per hour (107,000 kilometers per hour). Not to mention the fact that the solar system and all the stars and galaxies in the universe are rac madly away from one another in all directions at incredible speeds.

Okay, you knew all that. Except maybe for the exact speeds. But we're still not done.

You are made of molecules. (Yes, even you.) And all your molecules are vibrating and jiggling around to beat the band, assuming that yo body temperature is somewhere above absolute zero. In motion also are many of the atoms of which your molecules are made, and electrons of which the atoms are made, and the electrons, atoms and molecules of everything else in the universe. They were all set i motion about 12 billion years ago and have been quivering ever since.

So what *is* motion? In this chapter we'll see how every-thing from horses to speeding automobiles, sound waves, bullets, airplanes a orbiting satellites move from one place to another.

Horsing Around on the Highway

Why do they drive on the left in some countries and on the right in others?

It goes back to the fact that most humans are right-handed.

Long before we had modern weapons such as guns and automobiles, people had to do battle using swords and horses. Now if you a right-handed, you wear your sword on the left, so that you can draw it out rapidly with your right hand. But with that long, dangling scabba encumbering your left side, the only way you can mount a horse is by throwing your free right leg over him. And unless you are in a Mel Broo movie and want to wind up sitting backward on your steed, that means that the horse's head has to be pointing to your left. To this day we s train horses to be saddled and mounted from their left sides.

Now that you are mounted, you will want to stay on the left side as you start down the road, because anyone coming toward you will be your right, and if that someone turns out to be an enemy, you can whip out your sword with your right hand and be in position to run scoundrel through. Thus, prudent horsemen have always ridden on the left side of the road.

This left-side convention was also honored by horse-drawn carriages in order to avoid annoying collisions with horse-men. When horsele carriages made their appearance, some countries continued the habit, especially during the overlap period when both kinds of carriages w competing for road space.

So why do people drive on the right in the U.S. and many other countries?

When swords went the way of bows and arrows, the need for defending one's right flank disappeared and traffic rules were suddenly up grabs. Younger or less tradition-bound countries migrated to the right, apparently because the right-handed majority feels more comforta hugging the right side of the road. It quickly occurred to left-handed people that it was unhealthy to argue with them.

Some countries that I've been in must have large populations of ambidextrous people, because they seem to prefer the middle of the roac

Four-Grief Clovers

Why do highway and freeway intersections have to be so complicated, with all those loops and ramps?

They enhance the traffic flow—from construction companies to politicians' campaign chests.

Sorry.

They allow us to make left turns without getting killed by oncoming traffic. It's a matter of simple geometry.

When freeways and superhighways began to be built, engineers had to figure out how to allow traffic to make turns from one highway to intersecting one without stopping for red lights. Because we drive on the right-hand side of the road in the U.S., right turns are no problem; y just veer off onto an exit ramp. But a left turn involves crossing over the lanes of opposing traffic, and that can cause conflicts that are be imagined than expressed.

Enter the cloverleaf. It allows you to turn 90 degrees to the left by turning 270 degrees to the right.

Think about it. A full circle is 360 degrees; a 360-degree turn would take you right back to your original direction. If two highways intersec right angles, a left turn means turning 90 degrees to the left. But you'd get the same result by making three right turns of 90 degrees each. the same as when you want to turn left in the city and encounter a “No Left Turn” sign. What do you do? You make three right turns around t next block. That's what the loop of a cloverleaf does; it takes you 270 degrees around three-quarters of a circle, guiding you either over under the opposing lanes of traffic as necessary.

The highway interchange is a *four*-leaf clover, rather than a two- or three-, because there are four different directions of traffic—going, example, north, east, south and west—and each of them needs a way to make a left turn.

For readers in Britain, Japan and other countries where they drive on the left, just interchange the words “left” and “right” in the preced paragraphs, and everything will come out all right. That is, all left. You know what I mean.

Ready, Set … Jump!

If every person in China climbed to the top of a six-foot (two-meter) ladder and then all jumped off at the sar time, could it nudge Earth into a different orbit?

No, but it sure would create a windfall for Chinese podiatrists.

I suppose that everybody picks on China when they ask this question because China is the most populous country on Earth, containing billion potentially sore feet.

There are really two questions here, aside from the question of why people who ask this question don't have anything better to do. (J kidding; it's fun to wonder about such things.) The first question is how strong the jump-thump would be, and the second question is whet any size thump at all could change Earth's orbit.

It's easy to calculate the amount of energy from a gravitational fall. (And don't tell me they're not falling because China is upside dov Assuming a population of 1.2 billion Chinese weighing an average of 150 pounds (68 kilograms) each, their collective pounce would hit ground with an energy of 1.6 trillion joules. (A joule is just a unit of energy; don't sweat it.) That's just about the amount of energy released i medium-sized earthquake measuring 5.0 on the Richter scale. Such earthquakes have been occurring for millions of years, and there is evidence that they have nudged Earth into different orbits.

But no amount of earthquake or footquake energy could change the orbit anyway, so both earthquakes and Chinese ladders are irreleva Planet Earth continues circling the sun because it has a certain amount of momentum, which means that it has a certain amount of mass an certain velocity, because momentum is a combination of mass and velocity. Our planet carries along with it everything that is attached to it gravity, including jumping Chinese and acrobats on trampolines. We're all one big package of mass, and no amount of jumping up and do can change Earth's total amount of mass. Nor can it change the planet's velocity, because all the Chinese are being carried along throu space at the same speed as the rest of the planet; we're all in one big, interconnected spaceship. You can't change the speed of your car pushing on the windshield, can you? Nor can you lift it by pushing on the inside of the roof.

We might put it in terms of Newton's Third Law of Motion, which you must have heard a million times (and will again, if I have anything to with it): “For every action there is an equal and opposite reaction.” Push on a brick wall and the wall pushes back. If it didn't, your hand wo go straight through. When the Chinese land, their feet hit the ground with a certain amount of force, but at the same time the ground hits th feet with an equal amount of force in the opposite direction. Thus, (a) there is no net (unbalanced) force that could affect our planet's mot and (b) their feet hurt.

Jump … Now!

If I'm in an elevator and it starts to fall to the bottom of the shaft, can I jump up at the last instant and cancel t impact?

Ho hum. I don't know how many times this question has flashed into the minds of worrywarts in elevators, or how many times it has be asked of every friendly neighborhood physicist. It is easy to answer in one word (No), but thinking about it does raise a whole bunch of questions.

First, here's the quick answer: Your objective is to arrive at the bottom of the shaft like a feather, without any appreciable downward spe right? That means that you have to counteract the elevator's downward speed by jumping upward with an equal amount of speed. The eleva (and you) might be falling at, say, 50 miles per hour (80 kilometers per hour). Can you jump upward with anywhere near that speed? The b basketball players can jump at maybe 5 miles per hour (8 kilometers per hour). End of quick answer.

Let's consider the instant before your elevator's cable snaps. In the seventeenth century, long before elevators, Sir Isaac Newton (164 1727) realized that when a body exerts a force on another body, the second body exerts an equal and opposite force on the first body. Tod that's known as Newton's Third Law of Motion. When you're standing on the elevator floor and gravity (force number one) is pulling you do against the floor, the floor is pushing you back up with an equal force (force number two). That's why gravity doesn't win out and make you down the shaft. It's the same with the elevator car itself; in this case it's the cable's upward pull that counteracts gravity's downward pull on car. So neither you nor the elevator falls down the shaft. You both move upward or downward at a speed that is controlled by a motor's sl winding and unwinding of the cable from a big drum at the top of the shaft.

When the cable snaps, both the upward pull of the cable and the upward push of the floor are suddenly gone, so both you and the eleva are free to succumb to gravity's will and you both begin to fall. For an instant you are left floating—feeling “weightless” because the custom push of the floor on your feet is gone. But following that instant of blissful suspension, gravity has its way with you and you fall, along with elevator.

NITPICKER'S CORNER

About that moment of “weightlessness” when the elevator begins to fall: Obviously, you haven't really lost weight. Earth's gravity is pulling on you as it always has, and the strength of that pull is what we call weight. What you've lost is *apparent weight.* Your weight just i apparent because you're not standing on a scale or a floor that feels your pressure and presses back upon your feet.

Of course, this whole question of falling elevators is hypothetical because elevator cables just don't snap. And even if they did, there spring-loaded safety devices that would keep the car from falling more than a couple of feet. But, as roller coasters prove, some people se to enjoy the contemplation of imminent disaster.

If you happen to be one of those roller coaster fans, that “floating” feeling you get as the car falls from one of its high spots is exactly same thing you'd feel in a falling elevator. It's called *free fall*. Astronauts in orbiting spacecraft also feel it.

Dead Tread

When my car's tire treads wear out, where has all the rubber gone?

It has been rubbed off—and no, that's not why they call it rubber—onto the road, whence it was scattered in the form of fine dust into t vast, complex everywhere that we call the environment. Some of it was then washed off the road and into sewers by rain, or else it was blo around by the wind and eventually fell or was rained out of the air onto any and all surfaces. Eventually, all the rubber joined the soil and seas as part of the Earth from which it was born. Like everything else, a dead tread returns unto dust.

We tend to think of automobile tires as rolling smoothly along, without any scuffing against the road that might scrape away rubber. T could be true only if there were no resistance whatsoever between the tire's surfaces and the road's surface. And if there were no resistan your tires couldn't get a grip and you'd go nowhere. You'd get a spectacular warranty on a set of tires like that, because they'd never wear ou

Between any two surfaces that are attempting to move past each other—even a tire and a road—there is always some resistance; it's cal friction. Even rolling wheels experience friction against the road, although rolling friction is a lot less than sliding friction. When necessary, y can roll your car straight ahead by pushing, but just try to slide it sideways.

Friction gobbles up some of the energy of motion and spits it out as heat. If there were no diminishment of motion by the conversion of so of it to frictional heat, a machine could go on forever without slowing down: perpetual motion. Because there always must be some frictio heat loss, however small, every device that has ever been touted as a perpetual motion machine has to be a fake, however well-intentioned inventor.

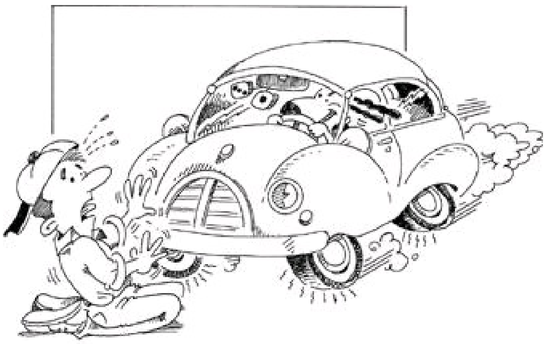
TRY IT

If you don't think that tire-against-road friction makes heat, just feel your tires before and after driving for an hour or so on the freeway. Mu of the heat you'll feel comes from friction against the road, but some comes also from the continual flexing and unflexing of the rubber.

Regarding the disappearing tread on your tires: Wherever there is frictional resistance between two materials, one of them has to “give that is, have some of its molecules scraped off by the other. Between your soft tire and the hard highway, it's no contest; it's the rubber t gives and gets rubbed off gradually in tiny particles.

If all of our roads were made of a substance that is softer than rubber, the roads would wear out instead of the tires. Instead, our society h decided that it's less trouble for car owners to replace their tires than for governments to continually replace road surfaces. Then why, you m ask, do we continually have to dance the orange barrel polka to get through interminable road reconstruction zones? Unfortunately, I c answer only scientific questions, not political ones.

The squealing tires in movie car chases are the result of sliding friction: rubber scraping, rather than rolling, on the pavement. Or microscopic scale, we would see the tire alternately grabbing and slipping thousands of times per second, producing a series of chatter vibrations that fall in the frequency range of a screech. It's easy to see that with all of this frictional dragging of rubber against the road, a lo rubber will be rubbed off. In fact, the friction makes enough heat to melt some of the rubber, which paints itself onto the road as a black s mark.



You Didn't Ask, but …

Why are the tires on racing cars so smooth? You'd think they'd need all the traction they could get.

That's precisely why they're smooth. Regular tires waste a lot of their potential road-grabbing surface by having grooves, which act l gullies to channel out rain and mud. But racing cars usually compete in good weather, so the rain-and-mud grooves aren't necessary. They just wasted space that can better be used to add more road-grabbing rubber for better handling in turns and better braking response. To g even more road-grabbing surface, the tires are made much wider than those on your family chariot. And they're made of a softer rubber t wears off like crazy onto the track. You think *you* don't get good tire mileage? Why do you think they're always stopping to change tires?

Ready, Aim, Scram!

In movie westerns, and even in many parts of the world today, people fire guns straight up into the air warning shots or just to make noise during a celebration. But those bullets have to come down somewhe How dangerous will they be if they hit somebody?

Quite dangerous. As we'll see, physics tells us that when it hits the ground the bullet will have the same velocity it had when it left the muz of the pistol, which can be 700 to 800 miles per hour (1,100 to 1,300 kilometers per hour). But that ignores air resistance. More realistica the bullet's landing speed can be around 100 to 150 miles per hour (160 to 240 kilometers per hour). That's fast enough to penetrate hum skin, and even if it doesn't penetrate it can still do a lot of damage. But just try to tell that to the idiots who like to shoot their guns “harmles into the air.

There are two kinds of forces that affect the bullet's speed on the way up and on the way down: gravity and air resistance. Let's look firs the effects of gravity, neglecting air resistance entirely.

It will be easier to understand the bullet's flight if we consider it in reverse. That is, we'll start at the instant at which the bullet has reached top of its flight and is just starting to fall downward. Then we'll consider its upward journey and compare the two.

Gravity is a force that operates on a falling object—and is indeed what makes it fall—by pulling on it, attracting it toward the center of Earth, a direction that we call “down.” As long as the object is in the air, gravity keeps on tugging on it, urging it to fall faster and faster. T longer it falls, the more time gravity has to work on it, so the faster it falls. (Techspeak: It *accelerates.*)

The strength of Earth's gravitational field is such that for every second of pull—that is, for every second that an object is falling—the obj speeds up by an additional 32 feet per second (9.8 meters per second) or about 22 miles per hour (35 kilometers per hour). It doesn't ma what the object is or how heavy it is, because the strength of the gravitational field is purely a characteristic of Earth itself. So for every seco of downward fall, the bullet gains 22 miles per hour (35 kilometers per hour) of speed. If it falls for ten seconds, its speed will be 220 miles hour (350 kilometers per hour), and so on.

But gravity was pulling on the bullet with the same force when it was on its way up. That's what slowed it down so much that it eventu reached zero speed at the top of its flight before starting to fall. For every second that it was on its way up, gravity's pull *removed* 22 miles hour (35 kilometers per hour) of speed. The total amount of speed removed on the way up must be the same as the total amount of spe regained on the way down, because the gravitational effect was the same all the time. If that weren't true, the bullet would have to ha acquired some speed or lost some speed because of some other outside force. And there was no other outside force (except air resistan and we'll get to that).

So we see that what gravity taketh away on the way up, gravity giveth back on the way down. On the basis of gravitational effects alone, th the bullet would have no more or less speed when it hits the ground than it had when it left the gun: its muzzle velocity, and that's how fast it be going when it hits the ground.

… Or an innocent bystander.

Up to now, we've ignored the slowing-down effect of the air. As you can tell by sticking your hand out the window of a moving car, the fas you go the more the air tries to hold you back. So as our bullet falls faster and faster under the influence of gravity, air resistance tries to ma it go slower and slower. Pretty soon, the two conflicting forces become equal and cancel each other out. After that, no matter how much fart the object falls it won't go any faster. It has reached what physicists like to call its *terminal velocity*, which is Techspeak for final speed.

(Because “terminal velocity” is such an impressive-sounding term, many an innocent physics student—I was one—gets the impression t it's some kind of fundamental limitation of Nature, like the speed of light. But there's absolutely nothing sacred or fixed about it. The final spe of a falling object simply depends on its size and shape, and on how it catches the air. If you fall out of an airplane, your terminal velocity certainly be a lot less if you're wearing a parachute. Teams of sky divers adjust their air resistance by making their bodies more compact more extended, so they can rendezvous at the same terminal velocity and frolic around together before pulling their rip cords.)

If a shooter is fairly close to a target, there isn't much opportunity for air resistance to slow the bullet down during its short flight. Even wh fired into the air, a streamlined object like a bullet doesn't suffer much air resistance on the way up, because it is pointing straight ahead alo its path. But during its fall it is probably tumbling, or even more likely falling base-first, because that's the most stable orientation for a bul shaped object. The air resistance on a tumbling or base-first bullet is quite a bit greater than on a straight flyer, so it may be slowed do substantially on the way down and end up quite a bit slower than its muzzle velocity. One expert estimates that a.22LR bullet with a muz velocity of 857 miles per hour (1,380 kilometers per hour) might fall to the ground with a velocity of 96 to 134 miles per hour (154 to 2 kilometers per hour), depending on how it tumbles. That's more than enough speed to do serious or lethal damage to a cranial landing site.

And by the way, the jerk who fires the bullet isn't very likely to be hit by it, no matter how carefully he aims straight up. In one experiment, of five hundred.30-caliber machine-gun bullets fired straight upward, only four landed within 10 square feet (3 square meters) of the gun. W has a great effect, especially since.22- to.30-caliber bullets can reach altitudes of 4,000 to 8,000 feet (1,200 to 2,400 meters) before fall back down.

War Is … Swell

Why do guns put spin on their bullets?

A spinning bullet flies farther and truer than it would without the spin. And if your favorite sport is football rather than shooting, just ab everything I'm going to say about spinning bullets also goes for spiraling passes.

The fact that a spinning bullet or football goes farther may sound strange, because you'd think that the range would depend only on amount of energy it gets from the gunpowder charge or the quarterback's arm. But bullets and footballs have to fly through the air, and air dr plays an important part in any projectile's trajectory, whether it is fired from a handgun, rifle, machine gun, howitzer or arm.

First, let's see how a gun makes the bullet spin.

Running the length of the inside of the barrel are spiraling grooves, called rifling. As the bullet passes through the barrel, these grooves into it, making it rotate to conform to the spiral. Some guns have grooves that twist to the right and some have grooves that twist to the lef doesn't matter. (And no, they don't twist one way in the northern hemisphere and the other way in the southern hemisphere.)

Early bullets were round balls of lead, like miniature cannonballs. Bullet-shaped (Techspeak: *cylindroconoidal*) bullets were develop around 1825, when it was found that they maintained their speed better in flight. That's because for a given weight of lead an elongat tapered-nose shape meets with less air resistance than a round ball; it's streamlined.

But there's a problem with elongated bullets that spherical bullets don't have. When an elongated bullet is fired, any tiny irregularities on surface can catch the air and push it slightly sideways, so that its nose is no longer pointing straight ahead. This slight misalignment increas the air resistance on the forward side, which turns the bullet even more. Pretty soon it is tumbling end-over-end, which causes even more drag, seriously shortening its range and pushing it off-course. Thus, both distance and accuracy suffer.

That's where the rifling comes in. If the bullet is spinning properly around its long axis as it flies, it resists any change in its orientatior direction of flight. The reason for that is that a heavy, spinning object has a lot of momentum. Not only does it have momentum along direction of travel (linear momentum), but because of its spin it also has rotational momentum, or what physicists call angular momentum. A momentum, whether linear or angular, is hard to upset. In fact, the momentum of an object will remain unchanged unless and until it is disturb by some outside force. (Techspeak: *Momentum is conserved.*) The spinning bullet, therefore, will maintain its angular momentum by spinn with its axis in the same direction for as long as it is in the air, because there is no outside force to disturb it. Those tiny surface irregularit are now peanuts compared with the bullet's substantial amount of angular momentum.

With its nose pointed straight ahead, the projectile encounters less air resistance and thus flies farther and truer. When it ultimately hits object, its momentum—both linear and angular—still won't disappear, but will be transferred to the unfortunate target—or in the case o football, the fortunate receiver.

International law actually requires that bullets spin. Otherwise, a tumbling bullet might hit its victim sideways, doing more damage than had made a nice, clean, round hole. It's just one of those niceties of war: If you're going to kill somebody, please do it neatly.

The Geneva Convention spells out certain other niceties about how to kill people. For example, because lead is soft and deformable, it go splat when it hits its target, again producing a very unsightly hole. So bullets have to be jacketed with a harder metal, such as copper. T world's military establishments gladly comply with that requirement, but it's not because of any humanitarian motives. It's because mod military assault weapons fire their bullets at such high speeds that if they weren't jacketed with high-melting copper the lead would melt fr friction with the air, making them fly erratically and miss their targets. After all, a clean, round hole in an enemy is so much preferable to no h at all.

You Didn't Ask, but …

Why does the Lone Ranger use silver bullets?

They serve mostly as a calling card, but they do have a very slight advantage over lead.

Ordinary bullets are made of lead because lead is so heavy, or dense. And it's cheap. We want a bullet to be as heavy as possible becau we want it to have as much damage-causing energy as possible when it hits its target, and energy is a combination of mass and spe (Techspeak: *Kinetic energy is directly proportional to the mass and to the square of the velocity.*) It's easier to gain energy by increasing bullet's mass than by increasing its velocity, because increasing the velocity would require a longer barrel in order to give the explosio gases more time to accelerate the bullet.

A silver bullet is about 7.5 percent lighter than a lead bullet of the same length and caliber. Since a given powder charge imparts the sa amount of energy to any bullet, the lighter silver bullet must travel faster. It works out to be 4 percent faster than a lead bullet.

So the Lone Ranger's silver bullets get to their targets very slightly sooner than a lead bullet would. If the bullet's velocity is 1,000 feet second (300 meters per second) and an outlaw fifty feet (fifteen meters) away is drawing his gun, the silver bullet gives our hero a tw millisecond advantage—not even long enough for Tonto to say, “Ugh!”

Also, because silver is a lot harder than lead, when the Lone Ranger shoots the gun out of a bad guy's hand—he never shoots the g himself—it must really sting. And when it strikes, instead of the dull thud of lead, a silver bullet makes a great “ping” sound for the micropho that seem always to be nearby.

BAR BET

The Lone Ranger's silver bullets fly faster than lead bullets.

How to Stop an Airplane

When there's an airplane flying overhead, why is it that when I walk in the opposite direction it looks as if i almost stationary? Certainly my walking speed is peanuts compared with the plane's speed, so how can it having any effect?

Whether we realize it or not, we judge the motion of an airplane in the sky by its relation to common things on the ground, such as tre telephone poles and houses. That's the only way motion can be detected: in relation to something else. There's no such thing as absol motion; it's all relative to something else. So the faster the plane appears to be passing the trees and houses, the faster we judge the plane be moving.

But when you yourself are moving in relation to the trees and houses, you upset this simple association because the trees and hous appear to be moving also. As you walk forward, they appear to be moving backward, don't they? Of course, you know that they're not *rea* moving backward because your daddy told you so when you were two years old.

So as you walk forward (which, I trust, is your customary direction of locomotion), but in the *opposite* direction from the airplane's, the tre and houses also appear to be moving backward with respect to your direction; that is, they appear to move *in the same direction as plane.* It appears, then, that the airplane and the houses are moving together; the plane doesn't seem to be overtaking them. And any airpla that can't even pass a house would seem to be one very slow airplane.

Want to do the passengers a favor and get them to their destination sooner? Just walk in the same direction as the plane. As the trees a houses “move backward” it'll look as if the plane is passing them even faster.

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