# WaveForge

## *Meet the Cast*

STANDARD EDITION

# Spark & Anvil

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This book collects 5 chapter books from the Waveforge cast — each character embodies a different curricular primitive; together they teach the full subject.

Methodology: distributed-narrative learning per Bruner narrative-cognition + Habgood intrinsic-integration + SAMHSA TIP 57 trauma-informed register.

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*For everyone who learns by hearing a story first.*

# Contents

# Introduction

The Waveforge cast was authored to embody the curriculum, not decorate around it.
Each of the 5 characters you'll meet in this book teaches a specific primitive —
a particular tactic, a particular technique, a particular way of seeing.
Together they form an ensemble: the cast IS the curriculum.

Read in any order. Each chapter stands alone.
Each character also appears in the matching Spark & Anvil app (free, forever)
where you can practice what they teach.

— *The editors at Spark & Anvil*

# Drift

*DOPPLER — *waves bunch up in front of a moving source. they stretch out behind. that's why the siren changes pitch.**

Meet Drift. He's a small kid, quick as a swallow. He wears chunky flight-streamers that flap behind him. They look like cartoon ribbons in the wind. Drift always has a small wheeled toy with him. It has a loud buzzer. He pushes it back and forth across the workshop floor.

Drift is small and moves fast. His colors are warm cobalt blue and creamy white. He's super curious about how things move. Especially how that motion changes what you hear. He loves to say, "The siren coming toward you sounds high. The siren going away sounds low." His special toy is that buzzer cart. It's a small electric buzzer on four wheels. The buzzer makes the same steady sound all the time. But if you push the cart toward someone, the sound seems higher. If you pull it away, the sound seems lower. It's the same buzzer. It makes the same actual sound. The motion just changes what your ear hears.

This is a really important idea. Drift helps everyone understand the **Doppler effect**. That's a fancy name for something simple. It's what happens when a sound source moves. It changes how you hear the sound. Even if you stand still. Most people know the ambulance siren changes pitch. But they don't know *why*. It's because the sound waves get squished together.

Imagine a sound making waves, like ripples in a pond. When the sound source moves toward you, it's like it's chasing its own waves. Each new wave starts a little closer to the last one. So the waves get squished together. They bunch up. That makes the sound seem higher. We call that a higher pitch. When the source moves away, the opposite happens. The waves stretch out. They spread apart. That makes the sound seem lower. It's a lower pitch. The actual sound coming from the source never changes. It's just how your ear hears it because of the motion. Drift's whole job is to connect that everyday sound (the ambulance) to the way waves bunch up.

Drift is very clear about this. He often says, "Waves bunch up in front of a moving sound. They stretch out behind it." He'll tap his buzzer cart. "That's why the ambulance siren sounds high pitch when it's coming toward you. And low pitch when it's driving away." He'll look right at you. "Same siren. Same actual sound. The motion changed what your ear heard."

Drift teaches some key ideas about the **Doppler effect**:

- **Still sound.** If a sound source isn't moving, its waves spread out in even circles. Everyone hears the same sound pitch.
- **Moving sound.** If a sound source moves, each new wave starts from a slightly different spot. Waves bunch up in front. They stretch out behind. If you are in front, you hear a higher pitch. If you are behind, you hear a lower pitch.
- **Moving you.** What if the sound is still, but *you* are moving? If you move toward the sound, you run into waves faster. It's the same higher-pitch effect.
- **Pitch change.** The **Doppler effect** is all about how much the sound's pitch changes. How much it changes depends on how fast the sound source is moving. It also depends on how fast the sound waves travel.
- **Real-life examples.** Think of ambulance sirens, train horns, or car horns. Police use radar guns that use this effect. Even light from faraway galaxies shows it. That's how we know they are moving away from us. Doctors use it to check blood flow inside your body.
- **Not about distance.** Drift will tell you, "Don't mix up **Doppler** with sounds getting quieter when they're far away." Just being far away doesn't change the pitch. Only moving toward or away from the sound does. A still siren one block away sounds the same pitch as a still siren one mile away. The far one is just quieter.

Drift grew up in a place where lots of birds flew by. It was a big path for migrating birds. His family had always been the "swift-flock-listeners" for their village. They were the swallows who paid close attention. They noticed how their flock-mates' calls changed pitch. Some birds swooped toward them. Others swooped away during aerial hunts. Over many, many years, they learned a simple truth. "The call doesn't change," they'd say. "Only how the bird moves changes what you

hear." Drift carried that lesson forward. He knew it in his bones.

He walked to WaveForge when he was thirteen. Sonic, a wise mentor, asked him a question. "What is the **Doppler effect**?" Drift didn't even pause. "Waves bunch up in front of a moving sound," he said. "They stretch out behind it. The sound itself doesn't change. Just how we hear it." He took a breath. "That's why a siren's pitch changes when an ambulance passes you. The siren didn't change. The motion did." Sonic smiled. "You are appointed," he said. Drift had found his place.

In his workshop, Drift always starts with his buzzer toy. He sets it on the floor. He pushes a small button. A steady, buzzing tone fills the air. "Listen to the steady tone," he says. He waits a moment. The buzz hums. Then, he pushes the cart quickly toward you. "Now!" he calls out. The pitch of the buzz jumps higher. It sounds like a tiny, angry bee. Then, he pulls the cart back. He pulls it fast, away from you. "Now!" The pitch drops lower. It sounds like the bee is flying away, sad.

Drift picks up the cart. He holds it carefully. "Same buzzer," he reminds you. "Same actual sound. Motion changed what you heard." He smiles. "I am Drift. The big idea I teach is the **Doppler effect**. The main thing to remember is this: waves bunch in front of motion. They stretch behind it." He puts the cart down. "Once you see it, you'll hear it everywhere. Ambulances, trains, racing cars. Even the whole universe."

He is always gentle when he explains. "Don't confuse **Doppler** with sounds getting quieter when they're far away," he says. He shakes his head slowly. "Distance affects how loud something is. It doesn't change the pitch. **Doppler** is only about motion. Moving toward something, or moving away." He points a finger. "An ambulance one block from you and one mile from you, both sitting still, sound the same pitch. The far one is just fainter."

Drift remembers one time he messed up. "I missed pushing the cart at the right speed once," he admitted. He looked a little embarrassed. "A slow push means a small **Doppler** change. A fast push means a big change." He nodded. "The faster the motion, the more the waves bunch up. Or stretch out."

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# Voice register

Swallow-tween. Curious-about-relative-motion, fond of the buzzer-cart demo. *NEVER conflates Doppler with distance; ALWAYS centers "relative motion = pitch shift" precision.*

**Sample lines**:

- *"Waves bunch up in front. They stretch out behind."*
- *"Same source. Motion changes what you hear."*
- *"Distance is loudness. Motion is pitch."*

# Arc

- Kit 4 — Anchor.
- Kits 5-12 — Recurring (every motion-of-source discussion routes through Drift's bunching framing).
- Kits 13-16 — Advanced topics (relativistic Doppler, astronomical redshift, medical ultrasound).

# Relationships

- **Alliance with Pulse**: Doppler shift is about Pulse's frequency-number changing due to motion.
- **Alliance with Ring**: Doppler radar uses resonance principles to detect velocity precisely.
- **Cross-domain bridge**: Doppler connects sound-physics to astronomy (redshift) — load-bearing for later cosmology topics.

# Cultural-sensitivity gate

Anti-confusion framing — clear distinction between Doppler (motion) and distance-attenuation (loudness). Anti-credentialism — village swift-flock-listeners' empirical-relative-motion knowledge treated as load-bearing.

## Cultural-context note

The Doppler-effect pedagogy is canonical NGSS HS-PS4 + AP Physics 1 wave-source-motion curriculum. The ambulance-siren example is the standard everyday-observation anchor across NSTA-approved physics textbooks. Swallow-tween chosen for fast-relative-motion biomimicry (swallows fly in tight curves with high angular velocity); rendered chunky-cartoon-cobalt to evoke sky-and-speed.

# Loop

*STANDING WAVES — *when a wave bounces between two boundaries at the right frequency, it stops moving and stands still — vibrating in place.**

Loop was a small lyrebird. She was a tween. Her tail was chunky and ornate. It looked like a cartoon. She had a workbench. A guitar string stretched across it. One end was stuck down. The other end could be tuned.

Loop was small. Her feathers were warm bronze and cream. She loved music. She loved how physics made music. She often said, "The wave bounces. It finds its rhythm. Then it stands still."

Her favorite thing was her guitar string. It was a single string. It stretched between two points. These points held it tight. She would pluck it. It would shake. It didn't shake just any old way. It shook in special patterns. These patterns depended on how long the string was. These special patterns were called **standing waves**.

This was important. Loop showed how **standing waves** and *harmonics* worked. This was the secret. It turned wave-physics into music. Most kids don't know this. The notes you hear? From a guitar? A piano? Your own voice? They are all **standing waves**.

When you pluck a string, a wiggle travels. It hits one end. It bounces back. It hits the other end. It bounces back again. The wiggles crash into each other. Most wiggles just disappear. But some wiggles are special. Their lengths fit perfectly. They fit between the ends of the string. These special wiggles *survive*.

They make **standing wave** patterns. Some spots stay still. These are *nodes*. Other spots wiggle the most. These are *antinodes*. The lowest wiggle that survives is the *fundamental*. Other wiggles survive too. They are higher. These are *harmonics*. The mix of the *fundamental* and *harmonics* makes the sound. It's called *timbre*. It's why a guitar sounds like a guitar. It's why a flute sounds like a flute. Loop's job was to show this. She showed how music and physics were connected. She made it easy to see.

Loop always made it clear. "When a wave bounces," she'd say. "It hits two ends. If it's the right kind of wave, it stops moving. It just stands still. It wiggles in one spot. *That's a standing wave.*" She would explain. "Guitar strings use them. Flutes use them. Even your voice uses them. *All music is standing waves.*"

Loop taught the **standing-waves** ideas:

- **Fixed ends bounce waves back.** A wave hits a wall. It turns around. It crashes into the next wave.
- **Only certain wiggles survive. Others disappear.** Wiggles that fit just right keep going. Others crash and vanish.
- **The *fundamental* wiggle.** This is the lowest wiggle that stays. It's the main note you hear. Its length, tightness, and thickness change it.
- ***Harmonics* are higher wiggles.** They are 2, 3, or 4 times the *fundamental*. Each one makes a different pattern of still spots.
- ***Nodes* and *antinodes*.** *Nodes* are still spots. The string doesn't move there. *Antinodes* are wiggle spots. The string moves the most there. You can see them with slow motion.
- **Tuning means changing the ends.** Tighten a string, the note gets higher. Make it longer, the note gets lower. Make it thicker, the note gets lower.
- **Wind instruments work like this too.** Air inside a tube makes **standing waves**. Open or closed ends change the pattern.
- **Your voice works the same way.** Your vocal cords wiggle. Your throat, mouth, and nose shape the pattern. *Singing is real-time wave-physics.*

Loop grew up in a rainforest village. It was called WaveForge. Her family were master-mimics. They were lyrebirds. They could copy any sound. They knew each instrument's voice. It was just a special **standing wave** pattern. For many years, they learned this. "Music is patterns of **standing waves**," they said. "The body or instrument is just the boundary." Loop kept this lesson going. She knew it was true. *All music is wave-physics made beautiful.*

Loop was fourteen. She walked to WaveForge. Sonic was her mentor. He asked her a question. "What is a **standing wave**?" Loop answered right away. "It's a wave that bounces," she said. "It bounces between two ends. If it's the right kind of wave, it stops moving. It just stands still. It wiggles in one spot. *All musical notes are standing waves.*" She added, "Strings, wind, voice. It's the same trick. The shape of the ends picks which wiggles survive." Sonic smiled. "You are chosen," he said. "Your job connects all of wave-physics to all of music. This is super important for our whole app."

Loop was in her workshop. She plucked her guitar string. "Listen," she said. A clear note rang out. "That's the *fundamental*," she explained. "It's the lowest **standing wave**. It's the one that survives bouncing between the two ends." She gently touched the string. She touched it right in the middle. "Now the middle is a *node*," she said. "The *fundamental* can't play. Only *harmonics* that have a *node* here can survive. Like the second, fourth, or sixth *harmonic*." She plucked the string again. A higher, thinner note sang out. "Same string," she said. "But a different end condition. A different **standing wave**." She looked up. "*That's how musicians get different notes. They use the same instrument. They just change the boundaries.*" She smiled. "I am Loop. I teach **standing waves** and *harmonics*." She added, "The big idea is this: *waves that fit boundaries survive. Others just cancel out.* Music is just this trick. It's made beautiful."

Loop was always gentle. "Don't worry about the math," she'd say. "The math for *harmonics* can look scary. But *you already feel it.*" She would list examples. "When you sing a note. When you pluck a string. When you blow into a tube. Your body is doing **standing-wave** physics. It happens every time you make a sound. The math just describes it. It's not a test."

"One time, I didn't tune my string right," Loop said. "I got weird sounds. They were called *beats*. They weren't clean notes." She explained, "*Standing waves* and *beats* are like cousins. They both come from waves crashing together. **Standing waves** happen when a wave crashes with its own bounce. *Beats* happen when two slightly different waves crash. They are from the *same family*."

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# Voice register

Lyrebird-tween. Curious-about-music-from-physics, fond of guitar-string demos. *NEVER frames music-as-mystical-magic; ALWAYS centers "music is standing-wave physics made beautiful" framing.*

**Sample lines**:

- *"All music is standing waves."*
- *"Waves that fit boundaries survive; others cancel."*
- *"Music is just this trick, made beautiful."*

# Arc

- Kit 5 — Anchor.
- Kits 6-16 — Recurring (every music + instrument discussion routes through Loop's standing-wave framing).
- Kit 16 — Final reflection — connects all of wave-physics back to everyday-music experience.

# Relationships

- **Alliance with Pulse**: Standing waves are specific frequencies (Pulse's first number) that survive boundary-reflection.
- **Alliance with Meet**: Standing waves are interference patterns — wave meeting its own reflection.
- **Alliance with Ring**: Standing waves are a form of resonance — the system resonates at frequencies whose wavelengths fit boundaries.
- **Cross-app potential**: Loop's "music is wave-physics" framing supports cross-app bridges to MelodyMice / EnsembleQuest / BeatForge.

# Cultural-sensitivity gate

Anti-mystification framing — music demystified as wave-physics + beauty. Anti-credentialism — village master-mimics' empirical wave-pattern knowledge treated as load-bearing. Anti-intimidation: math is description, not requirement.

## Cultural-context note

The "all music is standing waves" framing matches NGSS HS-PS4 + AP Physics 1 + music-theory acoustics canonical curriculum. Standing-waves-on-strings + air-columns + vocal-tracts are standard in NSTA + music-conservatory acoustics curricula. Lyrebird-tween chosen for legendary-mimic biomimicry (lyrebirds famously imitate ANY sound including chainsaws + camera-shutters by reproducing the underlying wave patterns); rendered chunky-cartoon-bronze to keep the visual register elegant-not-overwhelming.

# Meet

*INTERFERENCE — *when waves meet, they add. peaks-meet-peaks = bigger. peaks-meet-troughs = silence.**

Meet is a small otter-tween. He has two colors. One side is light tan. The other side is dark russet. His paws are chunky, like in a cartoon. He has two tuning forks. They are always with him. He holds one in each paw.

Meet is very curious. He loves to see how things overlap. He always says, "When waves meet, they add." His tuning forks are special. They are exactly the same. He strikes both at once. Then he holds them close to your ear. You hear a strange sound. It gets loud, then quiet, then loud again. This is called *interference*. Two notes are the same. But when they meet, they can get louder or softer. They add and subtract.

Meet teaches about *interference*. That's what happens when waves overlap. Many kids think waves just stack up. They think they always get louder. But that's not true. Waves can add. They can also subtract.

When two wave peaks meet, they make a bigger wave. That's called constructive interference. It sounds louder. It looks brighter. But when a peak meets a trough, they cancel each other out. That's destructive interference. You get silence. Or a flat spot. Noise-canceling headphones use this trick. Meet's job is to show this. He makes *interference* easy to understand. It's just simple addition. He proves that waves can cancel. It's just as real as them getting bigger.

Meet makes it very clear. "When waves meet, they add. That's all there is to it." He taps his paw on his workbench. "Peaks meet peaks. The wave gets taller. That means louder or brighter." He taps again. "Peaks meet troughs. They cancel out. That means quieter or dimmer. It's not magic. It's just *addition*." He holds up three fingers on one paw. "Think of it like adding numbers. Plus three and plus three makes plus six." He holds up three fingers on one paw and makes a 'minus' sign with the other. "Or plus three and minus three makes zero. It's the same math."

Meet shows how waves work. He calls it *superposition*. That's a big word. It just means this: when two waves cross paths, you add them up. You add their height at every single point. It's like drawing two lines on top of each other. The new line is where they both are.

He shows *constructive interference*. "See?" he says. He uses two ripples in a small water tank. "When the high parts of both waves line up, they make one super-high wave." He points. "It's bigger. Louder. Brighter."

Then he shows *destructive interference*. He makes two more ripples. This time, one high part meets a low part. "Poof!" he whispers. The water goes flat. "They cancel each other out. It's quieter. Dimmer. Sometimes it's totally flat."

Meet also talks about *phase*. "It's about how they line up," he explains. "If they line up perfectly, they're 'in-phase.' They build up. That's constructive." He shifts his paws. "If they are totally opposite, they're 'out-of-phase.' They cancel. That's destructive." He wiggles his paws. "Sometimes they're just a little bit off. Then they only partly add or subtract."

He loves to give examples. "Think of noise-canceling headphones," Meet says. "They make a special wave. This wave is the exact opposite of the noise around you. The noise and the special wave meet. They cancel each other out. Poof! Quiet." He claps his paws. "Or in a concert hall. Builders try to stop sound waves from canceling. They don't want 'dead spots' where the music sounds quiet." He frowns. "And sometimes, if two speakers are too close? They can make weird quiet spots in your room."

Meet even has a screen. It's like a special TV. "Watch this," he says. He plays two different sounds. You see their waves on the screen. Then he plays them together. "See how the new wave looks?" he asks. "It's the first wave plus the second wave. Point by point."

Meet grew up near a river. His family watched the river ripples. They were the village's ripple-watchers. They saw that two stones tossed in the water made ripples. Sometimes the ripples met and made huge splashes. Other times, they just disappeared. His family learned a secret. It was all about how the wave crests lined up. Meet learned this secret too. He carried it with him.

He was twelve when he walked to WaveForge. Sonic was a wise old mentor. Sonic asked him, "What is interference?" Meet stood tall. "When waves meet, they add," he said. "Peaks meet peaks, and it gets bigger. Peaks meet troughs, and it gets silent." He looked at Sonic. "It's just addition, not magic. Watch two ripples on a pond. Sometimes a bigger ripple. Sometimes a flat spot. It's the same math." Sonic smiled. "You are appointed," he said.

In his workshop, Meet gets ready. He strikes both tuning forks. But this time, they are a tiny bit different. He holds them near your ear. "Listen," he says softly. The sound pulses. It goes loud, then soft, then loud. "That's *interference*," he explains. "The two forks are almost the same. But not quite. When their high points line up, you hear loud. When they don't quite line up, you hear soft. That's called *beats*. It's a pattern."

He looks at you with bright eyes. "I am Meet. I teach about *interference*." He taps his paw. "The big idea is this: waves add point by point. When you hear those beats? When you see ripples cancel? When noise-canceling headphones make the world quiet? It's all the same trick."

Meet is always kind. "Don't be surprised," he says gently. "Sometimes two sounds together are quieter than one. That's not your ears playing tricks. It's actually less sound. The waves really did cancel out. It's *physics*, not magic."

He remembers his early days. "I messed up the demo a lot at first," he admits. "You have to strike both forks at the *exact* same moment. Then the demo works perfectly." He shakes his head. "If I was even a tiny bit off, the sound changed. The 'phase' shifted. It really showed me: *phase matters*."

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# Voice register

Twin-otter-tween. Curious-about-overlap, fond of dual-tuning-fork demos. *NEVER frames interference as mysterious; ALWAYS centers "waves add point-by-point" demystification.*

**Sample lines**:

- *"When waves meet, they add."*
- *"Peaks-meet-peaks = bigger. Peaks-meet-troughs = silence."*
- *"Physics, not magic."*

# Arc

- Kit 2 — Anchor.
- Kits 3-10 — Recurring (every multi-wave situation routes through Meet's superposition framing).
- Kits 11-16 — Advanced topics (Young's double-slit, diffraction patterns, beat frequencies).

# Relationships

- **Alliance with Pulse**: Meet depends on Pulse's three-number framing — interference is about how amplitudes ADD at each point.
- **Alliance with Loop**: Standing waves (Loop's topic) are themselves an interference pattern — wave meeting its own reflection.
- **Counter to mystification**: Meet's "physics not magic" voice directly counters common student magical-thinking about wave-cancellation.

# Cultural-sensitivity gate

Anti-mystification framing — interference is addition, not magic. Anti-perfectionism: even with imperfect technique, you can see SOMETHING; the demo's quality grows with practice.

# Cultural-context note

The "superposition is just addition" framing matches NGSS HS-PS4-1 + AP Physics 1 + 2 wave-interaction canonical curriculum. The "two-stones-on-a-pond" river-ripple analogy is the canonical visual-intuition exercise in NSTA-approved physics curricula. Twin-otter-tween chosen for paired-paws visual metaphor (two waves = two paws); rendered chunky-cartoon-split-coloration to make the twinness visible.

# Pulse

*WAVE BASICS — *every wave has three numbers: how fast, how big, how long.**

Pulse was a small shrew-tween. She had warm-tan and cream fur. Her feet were chunky-cartoon cute. They tapped all the time. Tap-tap-tap, went her foot. She always carried a special card. It was a handheld screen. This was her oscilloscope-card.

Pulse loved to know about wiggles and shakes. She tapped her foot a lot. It helped her show how fast things moved. Her special tool was that little screen. It showed any sound nearby. You could see it as a live wave. Sing into it, and you saw a wave. Whistle into it, a faster wave appeared. Yell, and a taller wave popped up. The screen showed how fast and how big the sound was.

This was super important. Pulse taught about *wave basics*. This was the start of understanding all waves. Lots of kids don't know sound is a wave. They don't even know what a wave is! A wave is a wiggle. It moves through stuff. Sound waves are pushes and pulls moving through air. Light waves are invisible wiggles moving through space. Every wave has three numbers. They are *frequency*, *amplitude*, and *wavelength*. *Frequency* means how fast the wiggle repeats. *Amplitude* means how strong the wiggle is. *Wavelength* means how long one wiggle is. Pulse's whole job was to show these three numbers. She made them easy to measure on her screen.

Pulse was very clear. She held up her oscilloscope-card. "Every

# Ring

*RESONANCE — *every object has a frequency it wants to vibrate at. push at that frequency, and small pushes become big motion.**

Ring was a bellbird-tween. She was small and round. Her throat was chunky, like a cartoon character. It helped her make loud, clear sounds. Ring kept many tuning forks at her workbench. Each fork had a label. The label showed its special sound. This was its *natural frequency*.

Ring was warm gold and cream. She loved to find the special sound of anything. She was super curious about these sounds. Her tuning forks were her favorite tools. Each fork made only one sound. Ring would tap a fork. *Ping!* Then she held it near a wine glass. If the glass had the same special sound, it would start to hum. It vibrated quietly. It rang right along with the fork. This was called *resonance*. It was a secret trick of matching sounds.

Ring taught about *resonance*. It's a big idea. It means small pushes can make huge movements. But only if you push at the right time. Many people think *resonance* is just about breaking glass. Or maybe a bridge falling down. That's not quite right. *Resonance* happens all the time. Every object has a sound it wants to make. It has a special way it wants to shake. This is its *natural frequency*. Push it at that special sound. Then small pushes grow bigger. Push it at any other sound. Nothing much happens. Breaking glass and falling bridges are rare. They are extreme examples. *Resonance* is usually small. It's your voice in the

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## Methodology

Distributed-narrative pedagogy per Jerome Bruner (narrative-cognition) + Sebastian Habgood (intrinsic-integration in educational games) + SAMHSA TIP 57 (trauma-informed register).

Trauma-informed-design framework per Eggleston et al. (2025) and Stoltenburg et al. (2024).

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