ABCs of Quantum Networks
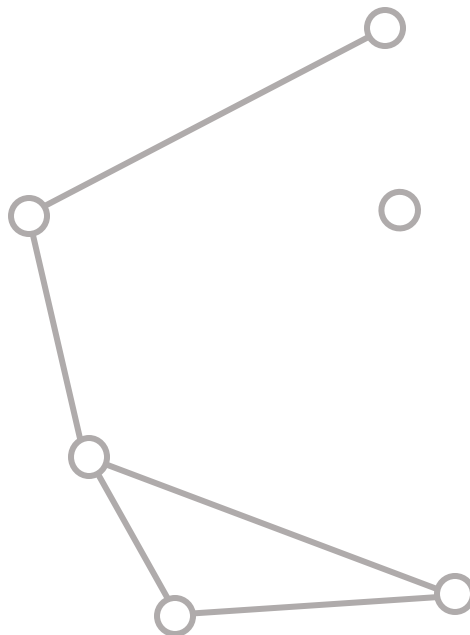
A coloring & activity book for the
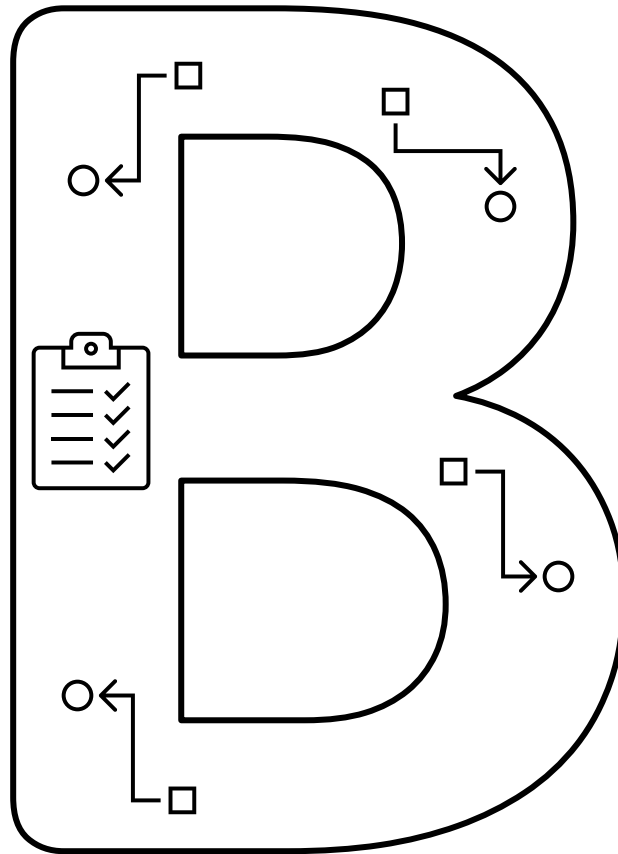
PUBLIC QUANTUM NETWORK
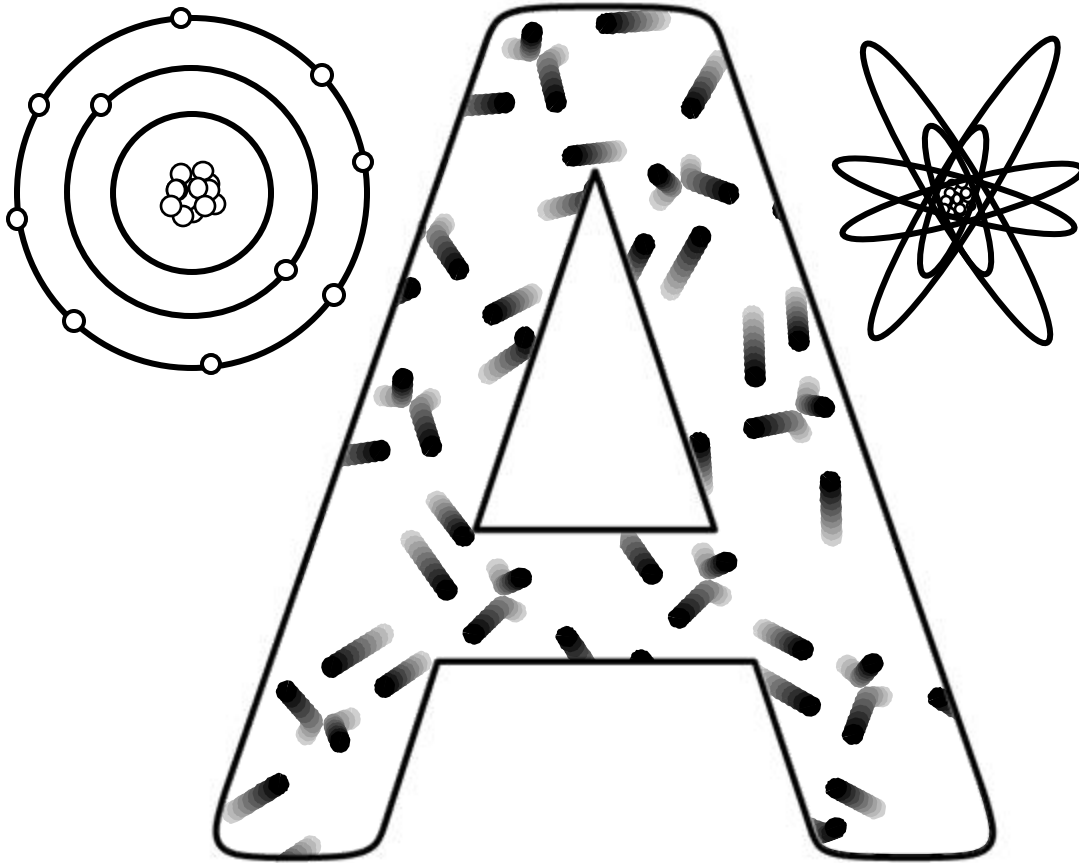
Atoms

Everything that takes up space and has mass is called matter. **Atoms** are the building blocks of matter.

Atoms can be used to "catch" light and store it, like memory in a computer.
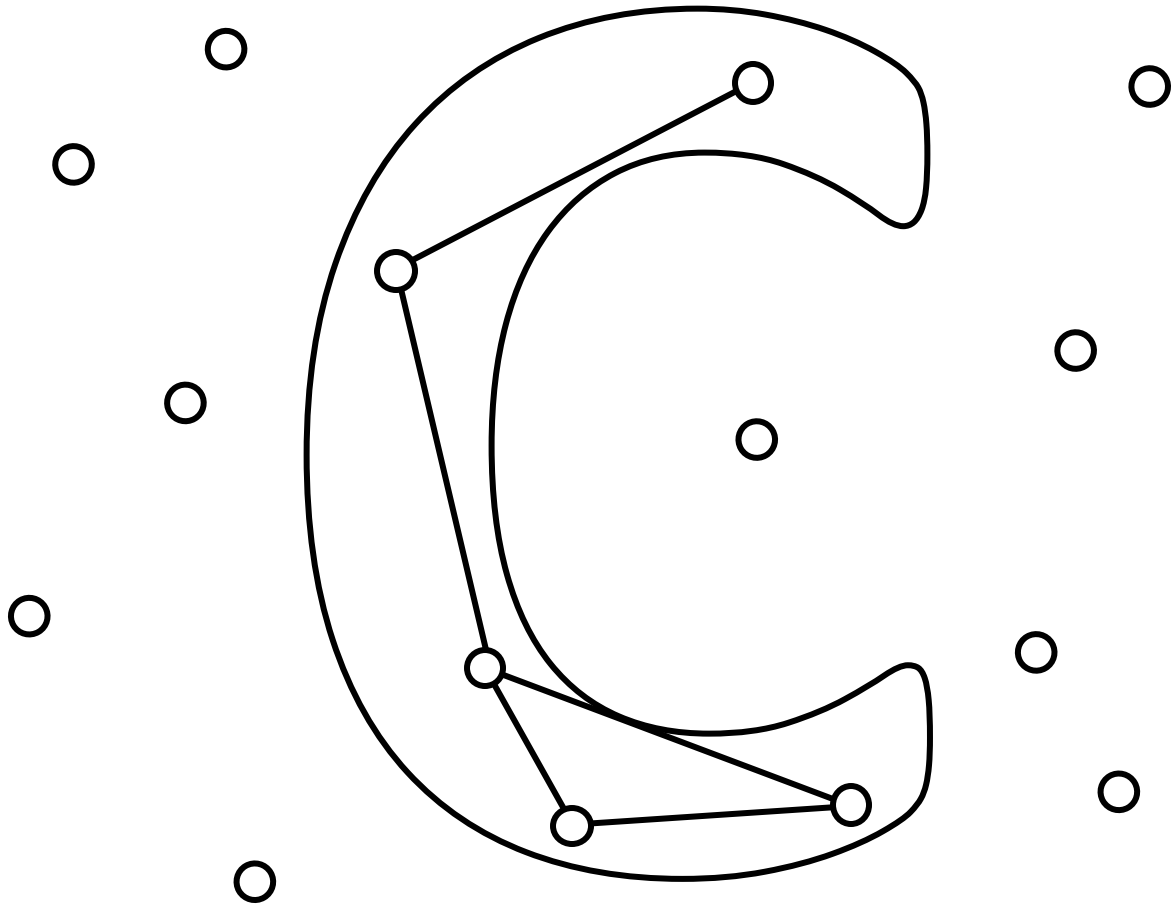
Bell Test

The **Bell test** is an experiment to check that quantum science is correct. The 2022 Nobel Prize in physics went to scientists who did some of the first Bell tests.

Try it out! You can do your own test using the Public Quantum Network at The Urbana Free Library!
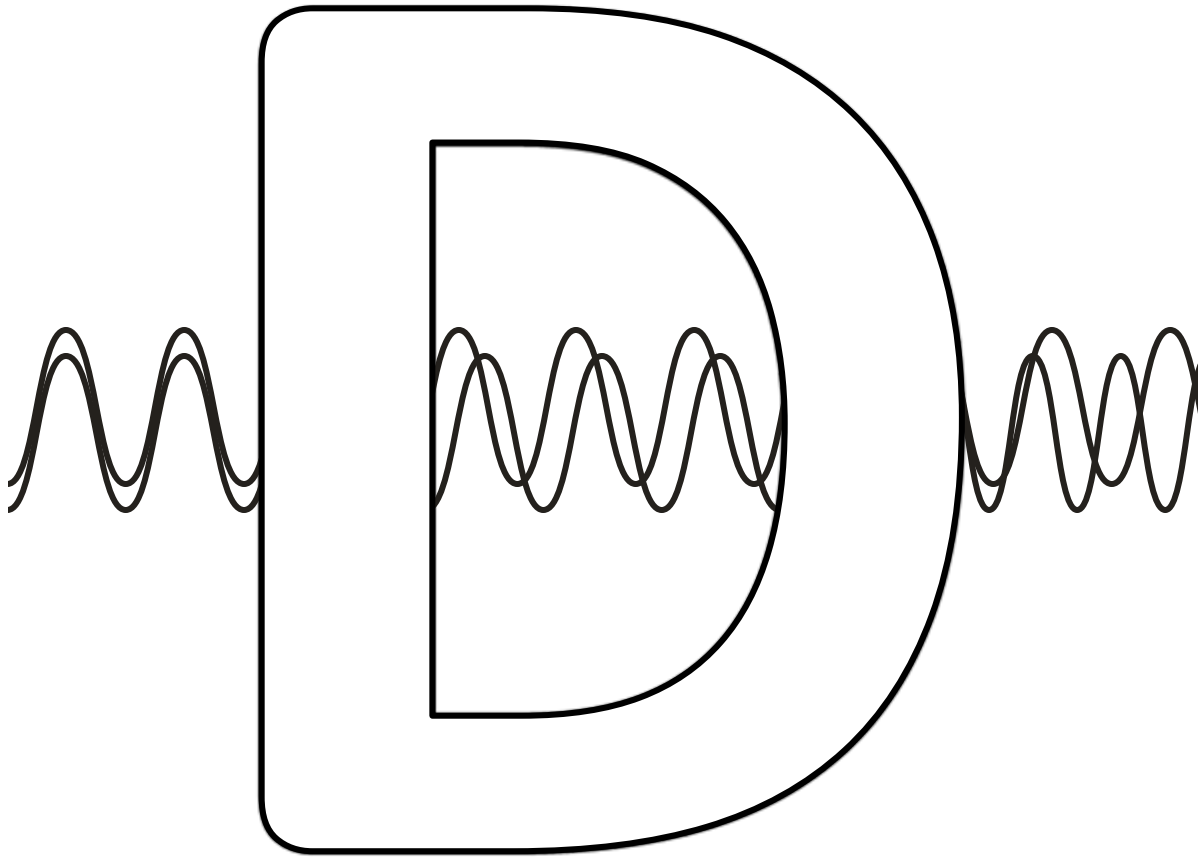
Communication

We **communicate** all of the time by talking and also online with email and text. Light waves (bunches of photons) carry information across the internet. Single photons can carry your information more securely.

Look and see! What are the ways that you communicate with your friends, teachers, and family? Which way is your favorite?
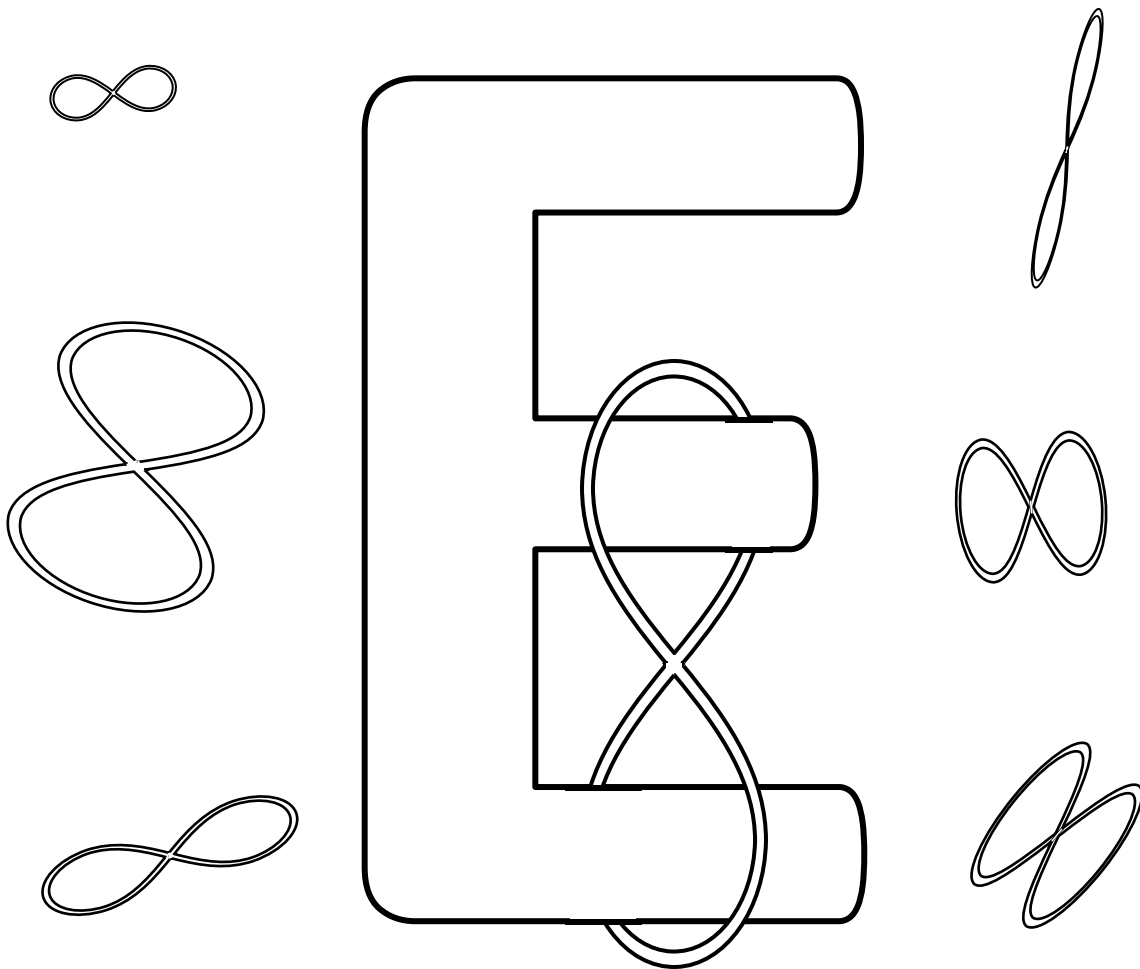
Decoherence

When you drop a pebble in water, the waves close to where the pebble landed have clear peaks and troughs (the waves are *coherent*). As the waves spread, they bump against rocks and change shape. This is **decoherence**.

Decoherence also happens with light waves. When light waves lose their shape we can't use them to carry information.

Entanglement

Entanglement ties quantum particles together (they act like they are connected), even if they are very, very, very far apart. We can create entanglement in a lab and use it for technology like quantum networks.

Speed limits: Entanglement still doesn't let us send messages faster than the speed of light.
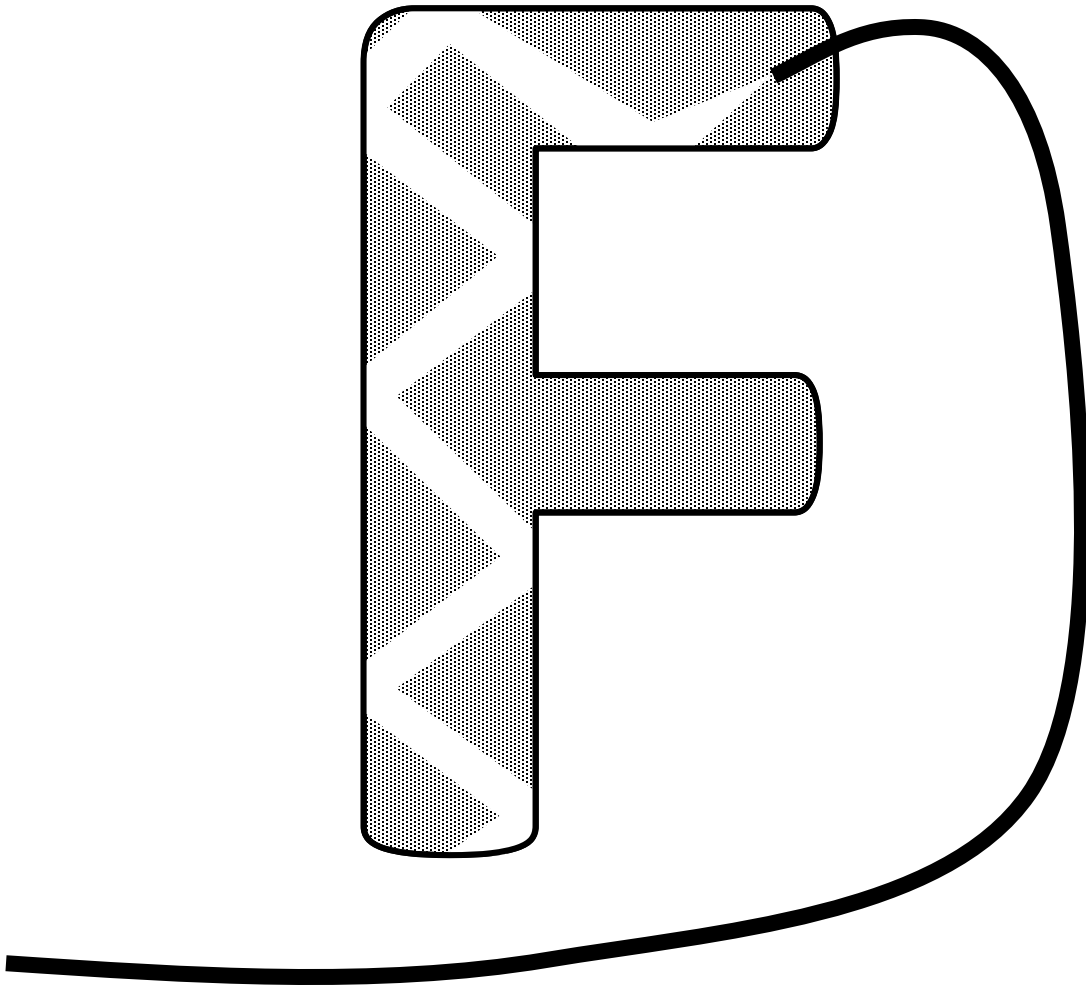
Fiber-Optic Cable

Fiber-optic cables are thin threads of glass that can guide light from one point to another.

They are used to share information over the internet. Fiber networks are installed underground and even across the ocean floor between continents.
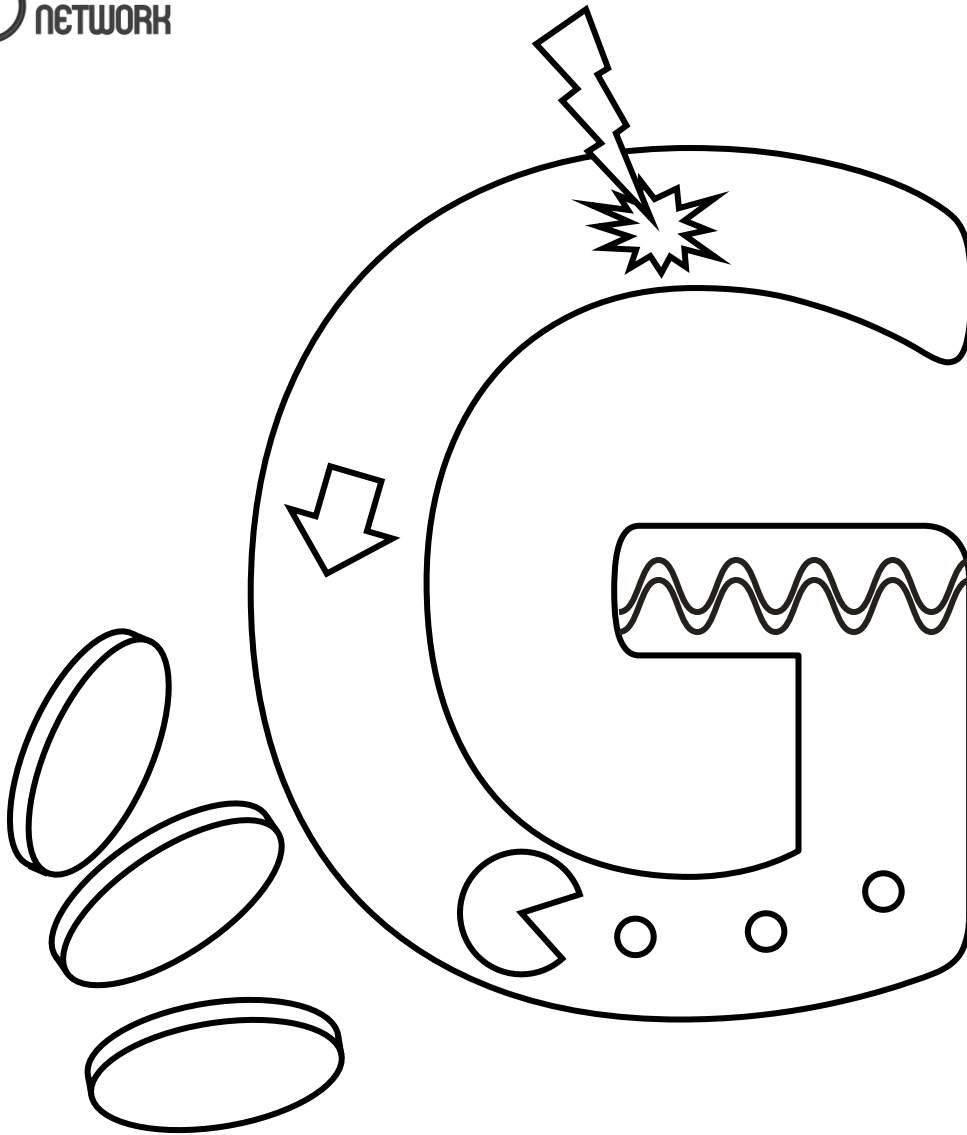
Games

Playing **games** is a fun way to learn about science and technology!

Try it out at home! Check out this website to play some quantum games:
https://q12education.org/quantime
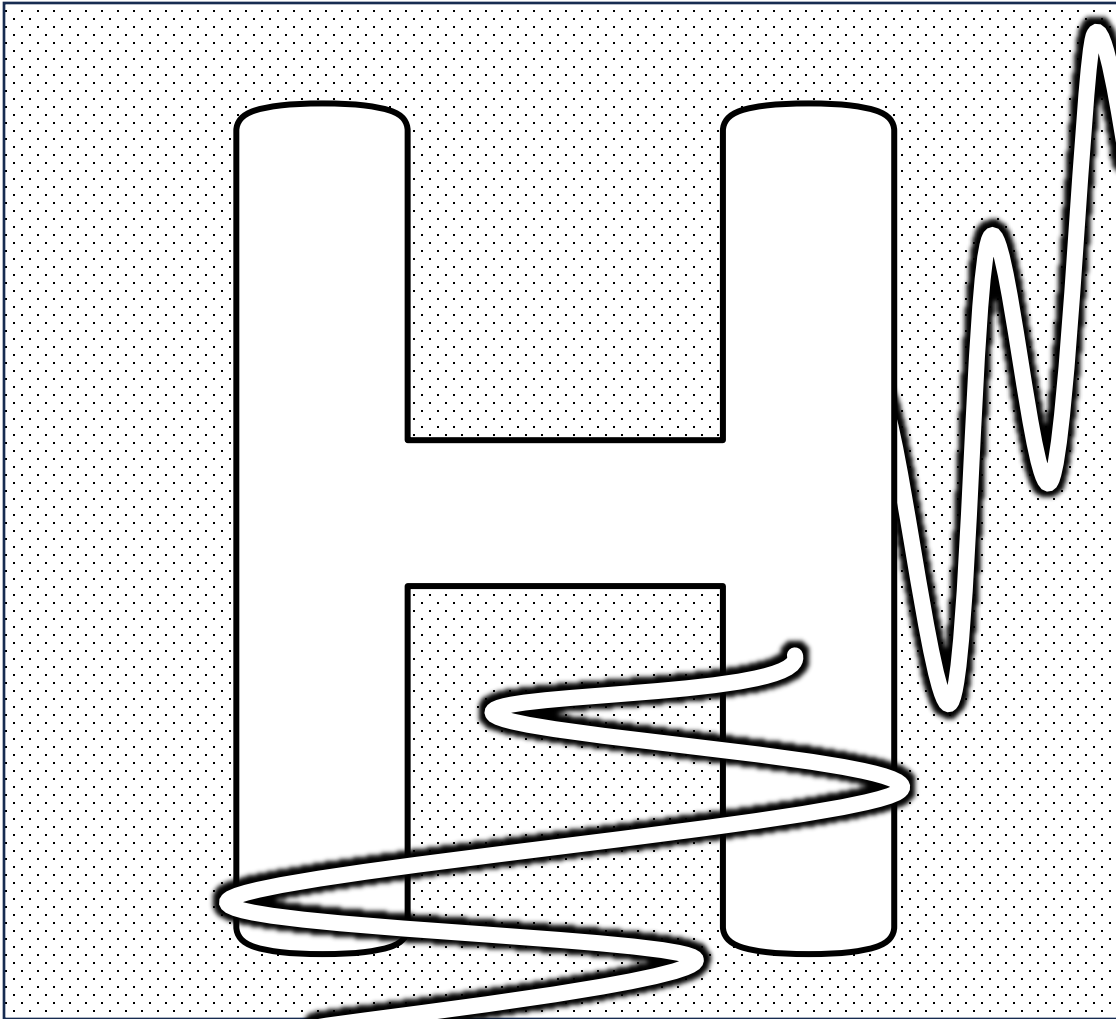
Half-Wave Plate

Light is a wiggly wave. A **half-wave plate** is a clear material that changes the direction light wiggles, or its polarization. Polarizing sunglasses are half-wave plates that block light that is wiggling left to right

Try it out at home! Put on sunglasses and see if rotating them affects what you see on a screen. If the screen gets darker when you rotate, the lenses on your glasses are polarizing.
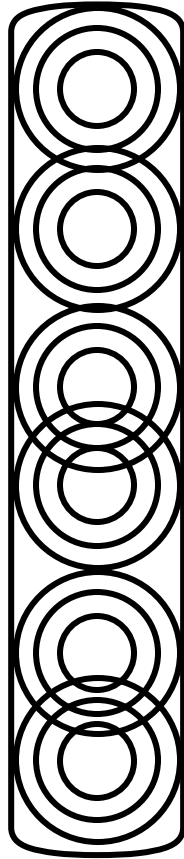
Interference

Interference is common in nature. It happens when waves combine to make higher or lower peaks. You can experience this with light, water, and sound.

Try it out at home! Throw a couple pebbles into a large bucket of water, kiddie pool, or pond. Watch the waves mesh together, creating an interference pattern of higher or lower peaks.
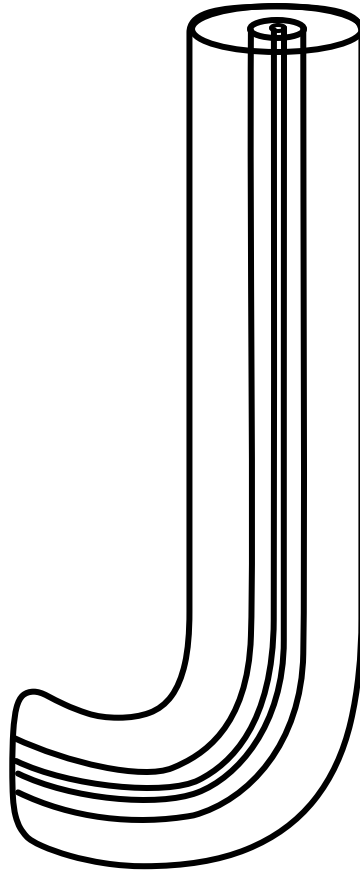
Jacket

Optical fiber is a thin thread of glass that can carry light over large distances. It has three main parts: the inner glass core that carries the light, the glass cladding that keeps the light from escaping, and the outer **jacket** that protects the fragile glass from damage.
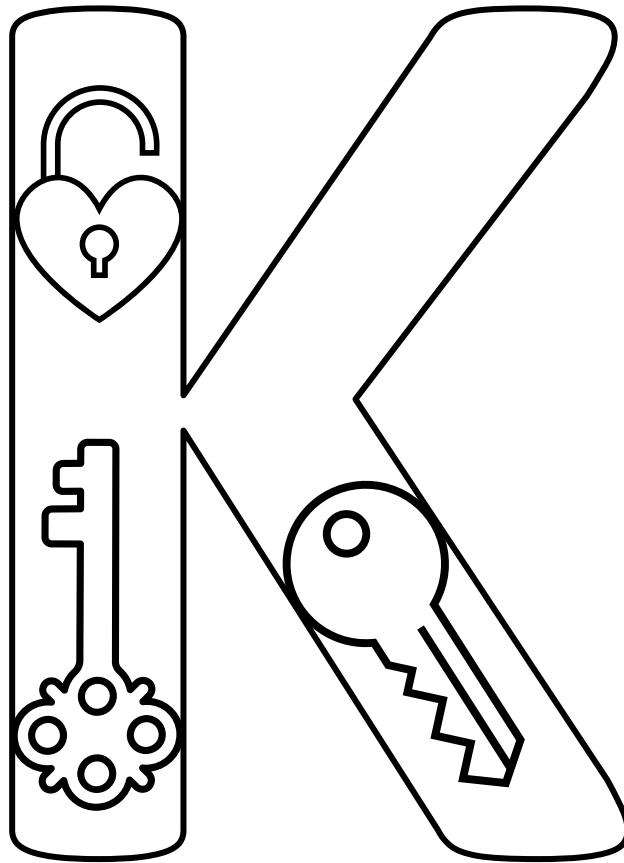
Key

Keys keep online communication safe, like locking a note in a box. We can use particles of light to make a key and share it with friends. The key acts like a code that scrambles your message so no one else can read it. Your friend can use the key to unscramble it.

Try it out at home! Make up a secret code to scramble a message to a friend, teacher, or family member. See if anyone you know can figure out your message. See the last page for an example.
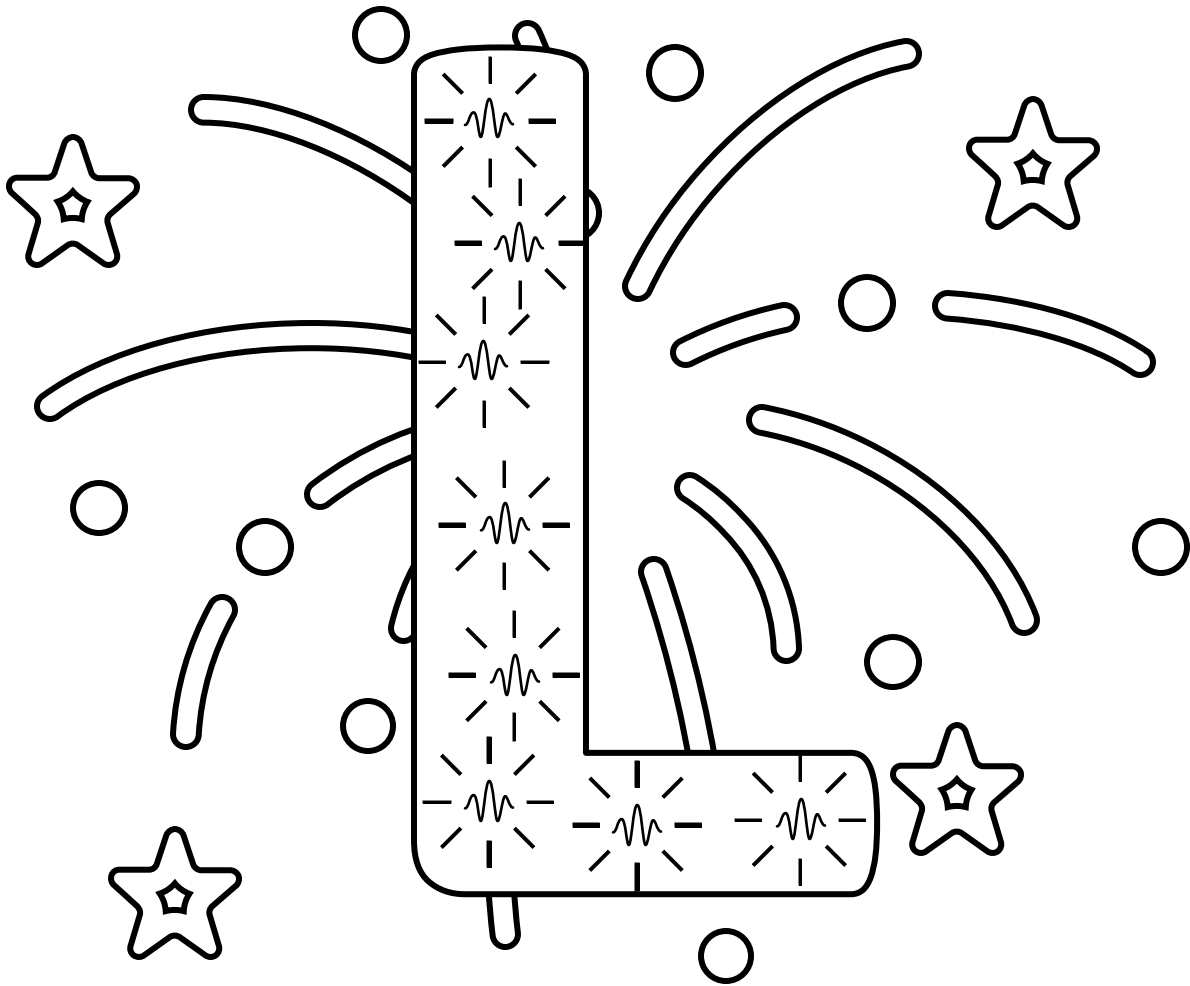
Light

Light is radiation and comes in many colors. We can't see all types of light. The smallest blip of light is called a photon. We also say that photons are particles of light.

The speed of light is 299,792,458 meters per second!

Look and see! How many sources or kinds of light did you see today?
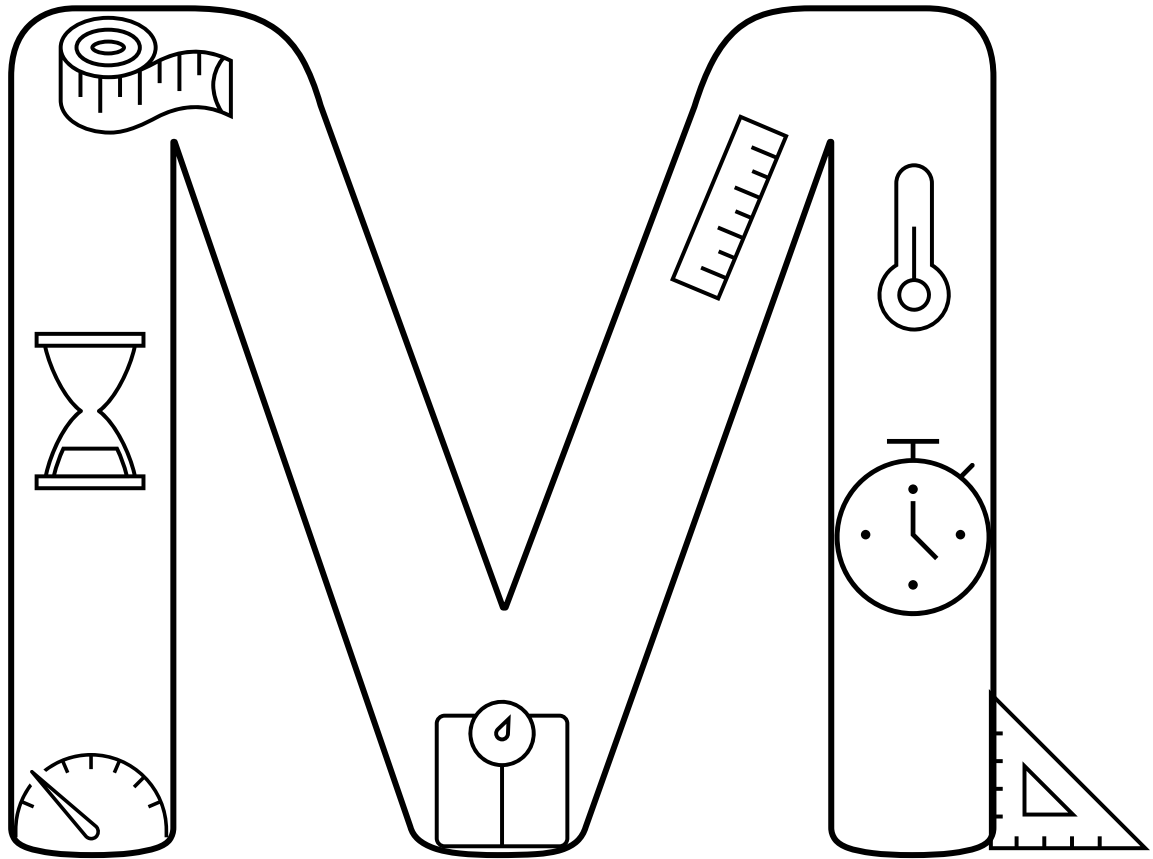
Measurement

Measurement can affect the properties of a quantum particle. This is different than what usually happens when we measure something in everyday life, like the length of a table. We don't expect the table's length to change due to the measurement!

Try it out at home! What tools do you use to make measurements at home or at school?
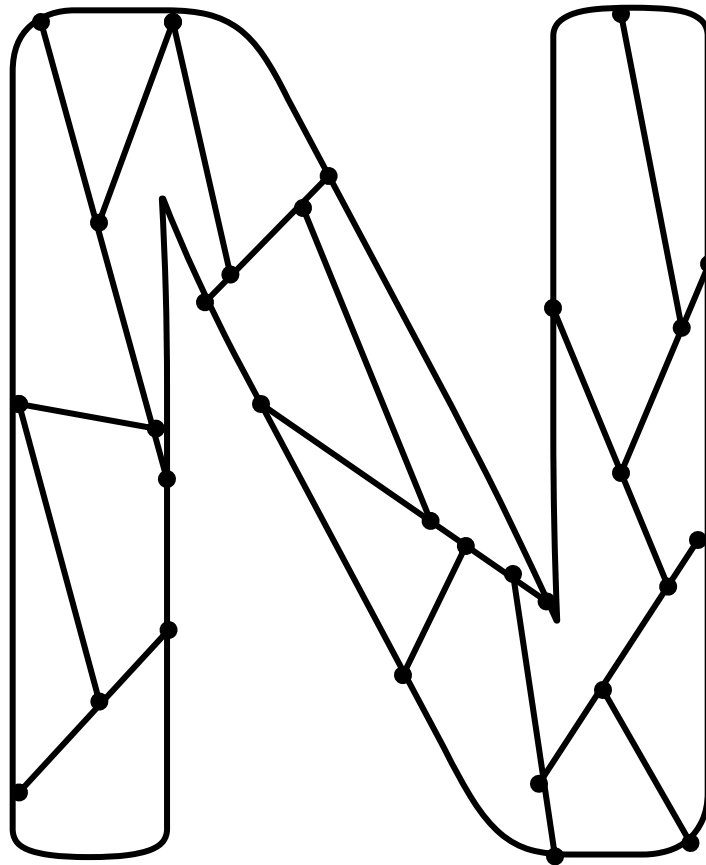
Network

A **network** links people, places, or objects together. The internet is an example of a network of computers and smaller computer networks. The internet is shared over long distances using light waves (bunches of photons).

A quantum network uses single photons to carry information. In the future we will also use quantum networks to connect quantum computers.
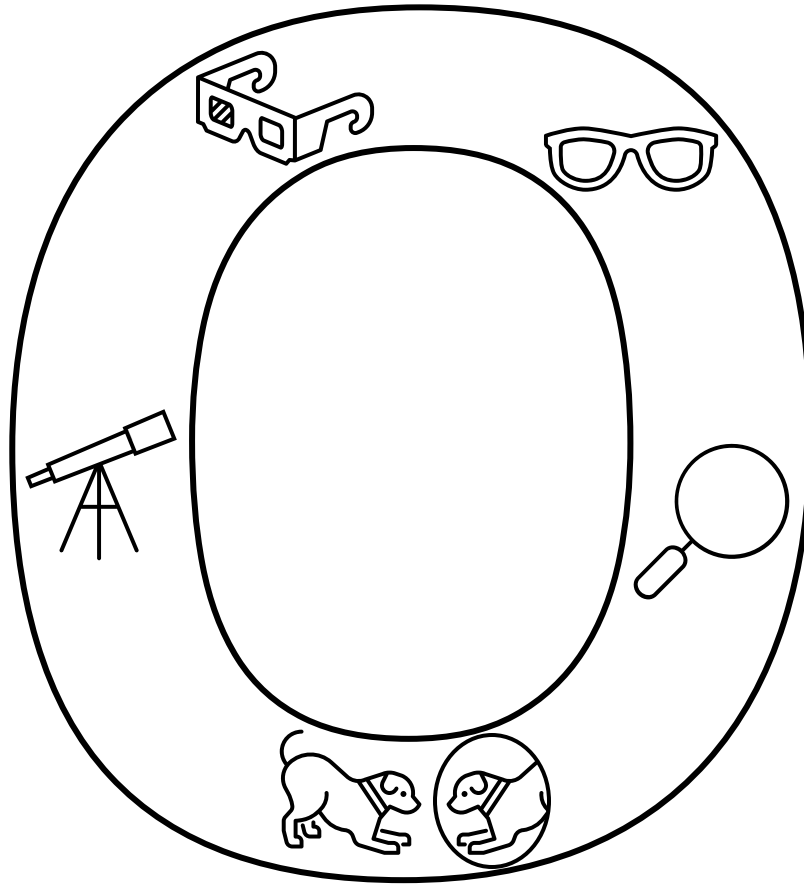
Optics

Optics guide light and change its properties. Mirrors and lenses (glasses) are examples of optics. Optics can help us see more clearly, watch 3D movies, look into space, and peer at tiny stuff like cells. Optics (and lasers!) are used in physics labs to study quantum science.

Try it out at home! Go through your house and count how many objects in your home use optics. What do the optics in your home do for you?

PUBLIC QUANTUM NETWORK
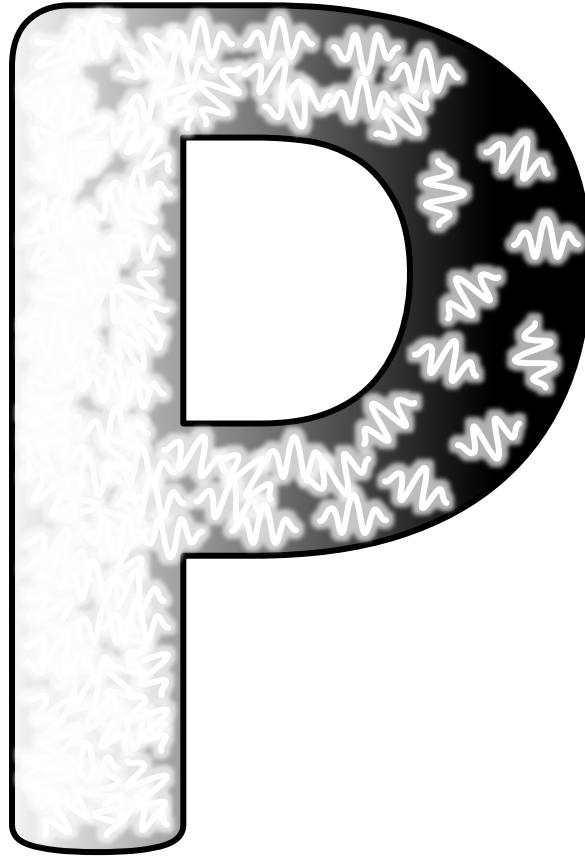
Photon

Photons are the smallest possible specks of light. Amazingly, your eyes can see just a few photons if you are in a very dark room.

Photons carry information in a quantum network. Photons do not weigh anything, so they are the fastest particles in the universe.

Quantum

Quantum science helps us understand nature when things get very tiny. Even germs are too big for quantum science!

Examples of quantum particles: atoms, electrons, photons, neutrons, protons.
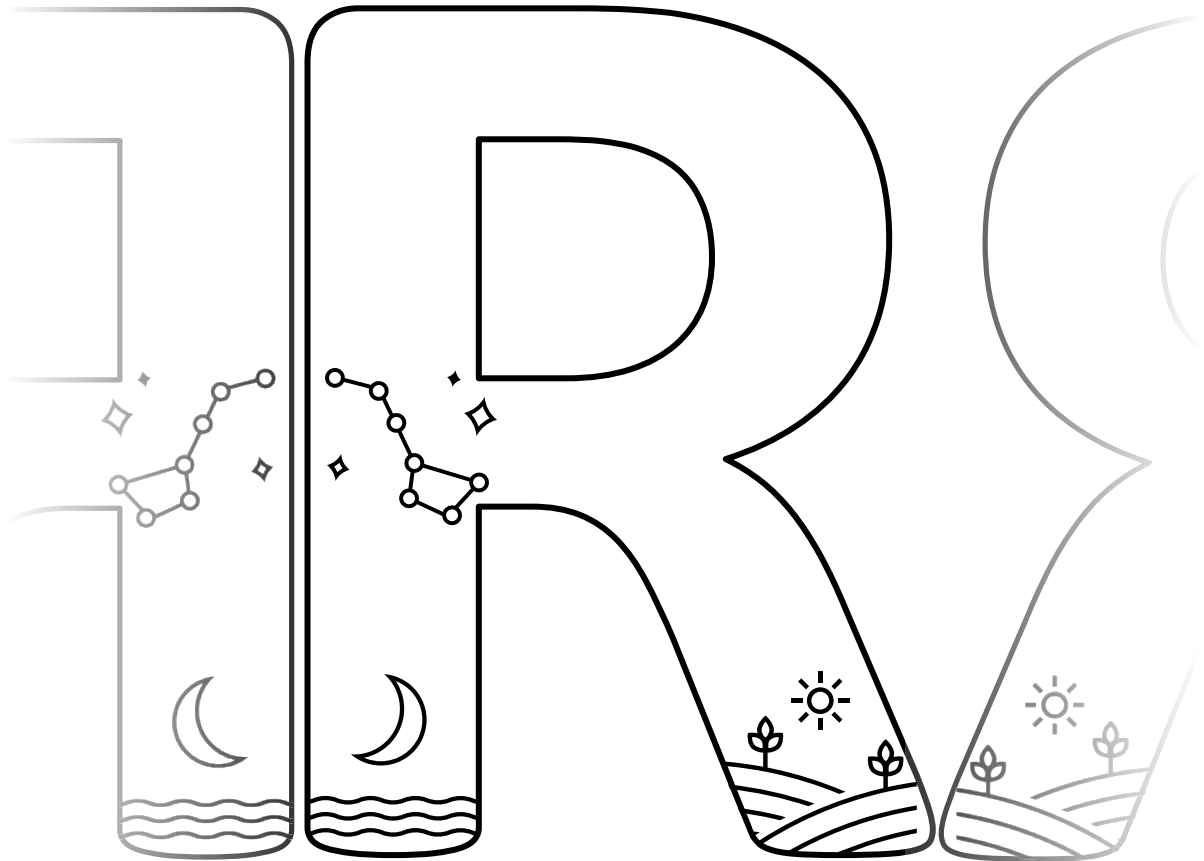
Reflection

Light can bounce off mirrors and other surfaces. This is called **reflection**. Reflection can be used to guide light through a string of glass called a fiber.

Look and see! Sometimes water fountains have lights to make the water glow. This effect is caused by light reflecting off of the surfaces of the water.
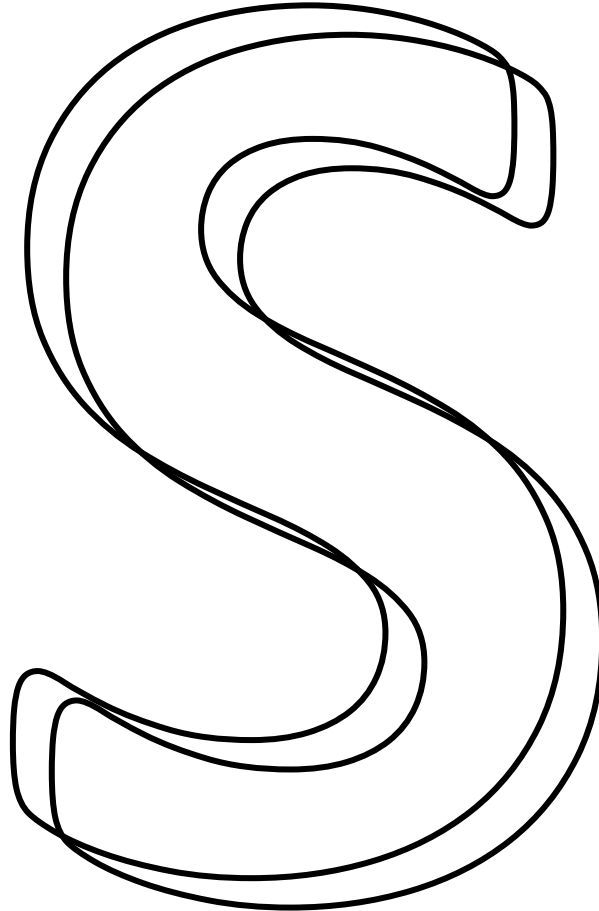
Superposition

When a quantum particle is in a **superposition**, its properties are not set to only one value. For example, a particle of light can be both red and blue at the same time. It won't be either one until we make a measurement of its color.
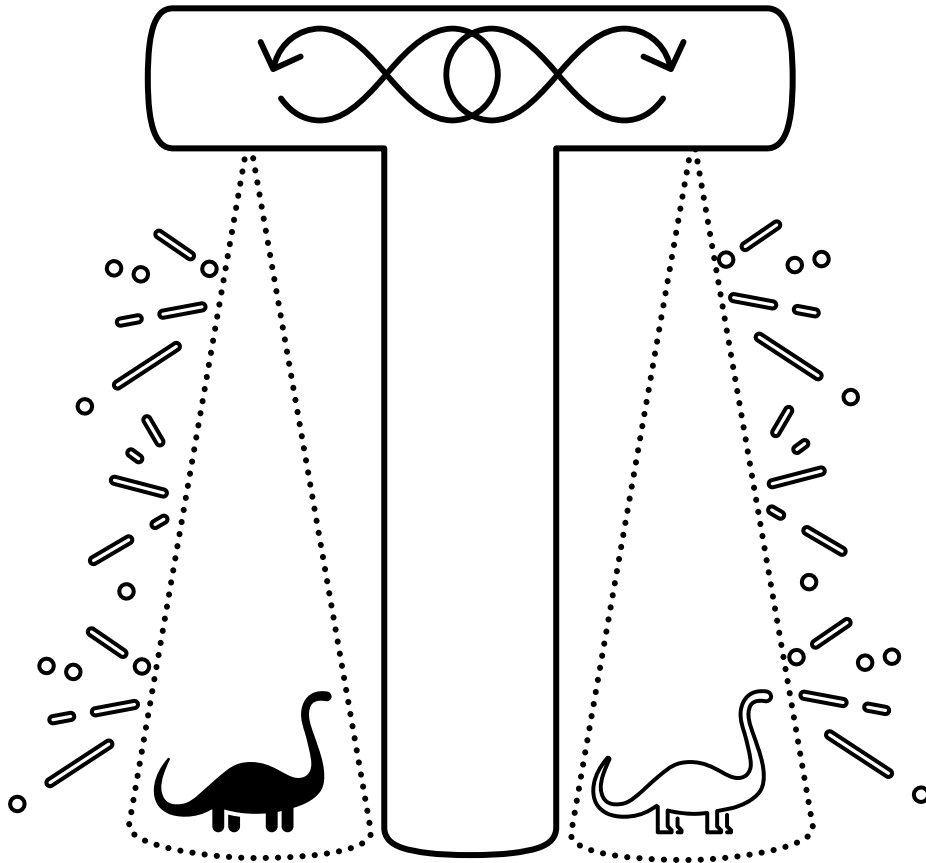
Teleportation

Teleportation transfers one particle's properties onto another without moving any particles around.

Caution: Teleportation cannot happen faster than light.

Uncertainty

A quantum particle's properties, like location or energy, can be **uncertain**. For example, a quantum particle's location is not set until you measure it.
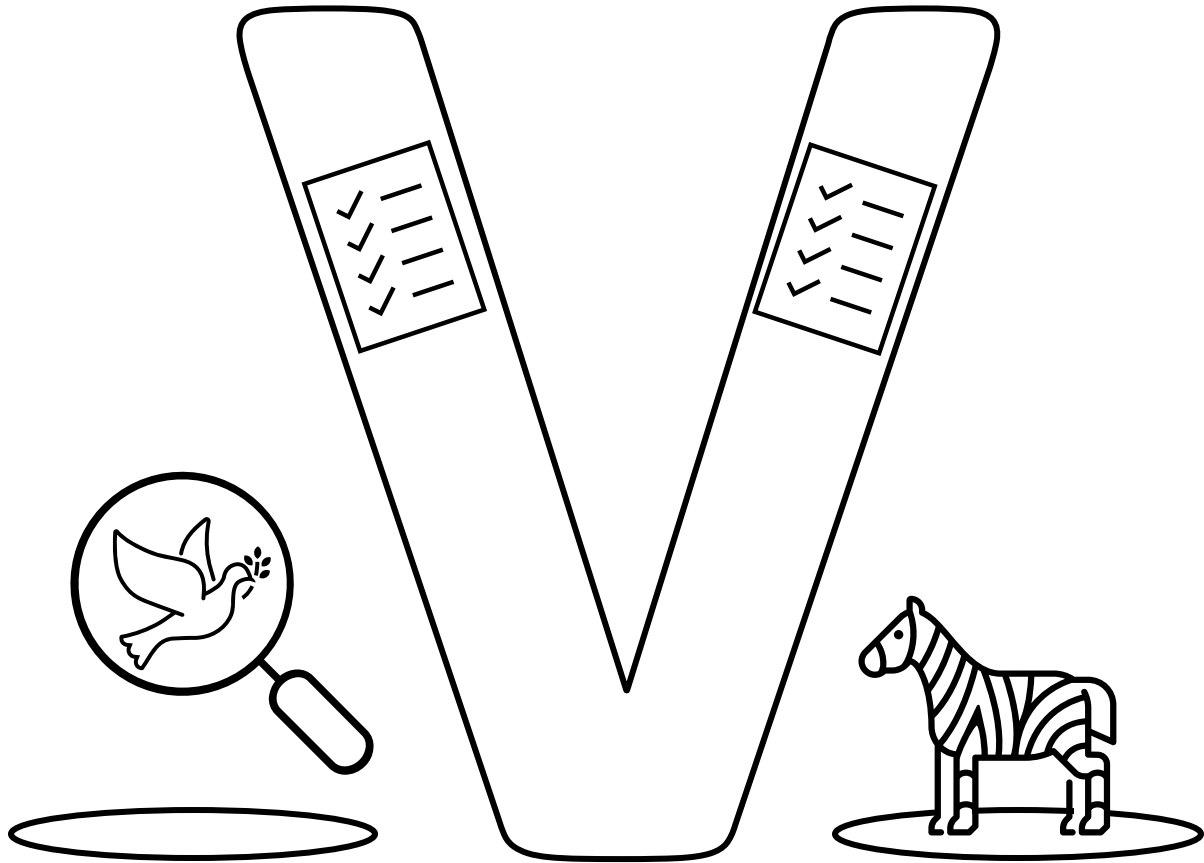
Verification

Quantum networks give us new ways to **verify**, or make sure, that the person we are communicating with isn't pretending to be somebody else.
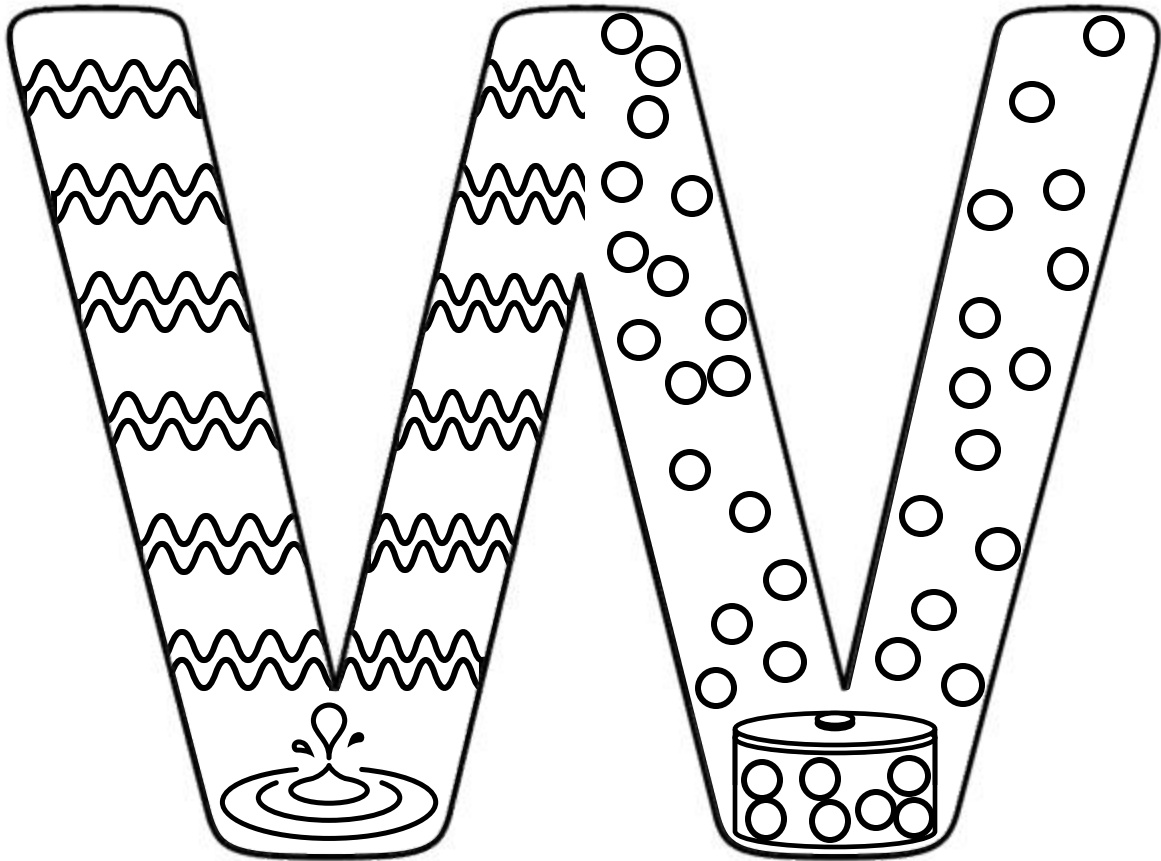
Wave-Particle Duality

Do you ever feel sleepy and hungry at the same time? Quantum particles can be two things at the same time, too. They can act as both waves and particles. We call this **wave-particle duality**.
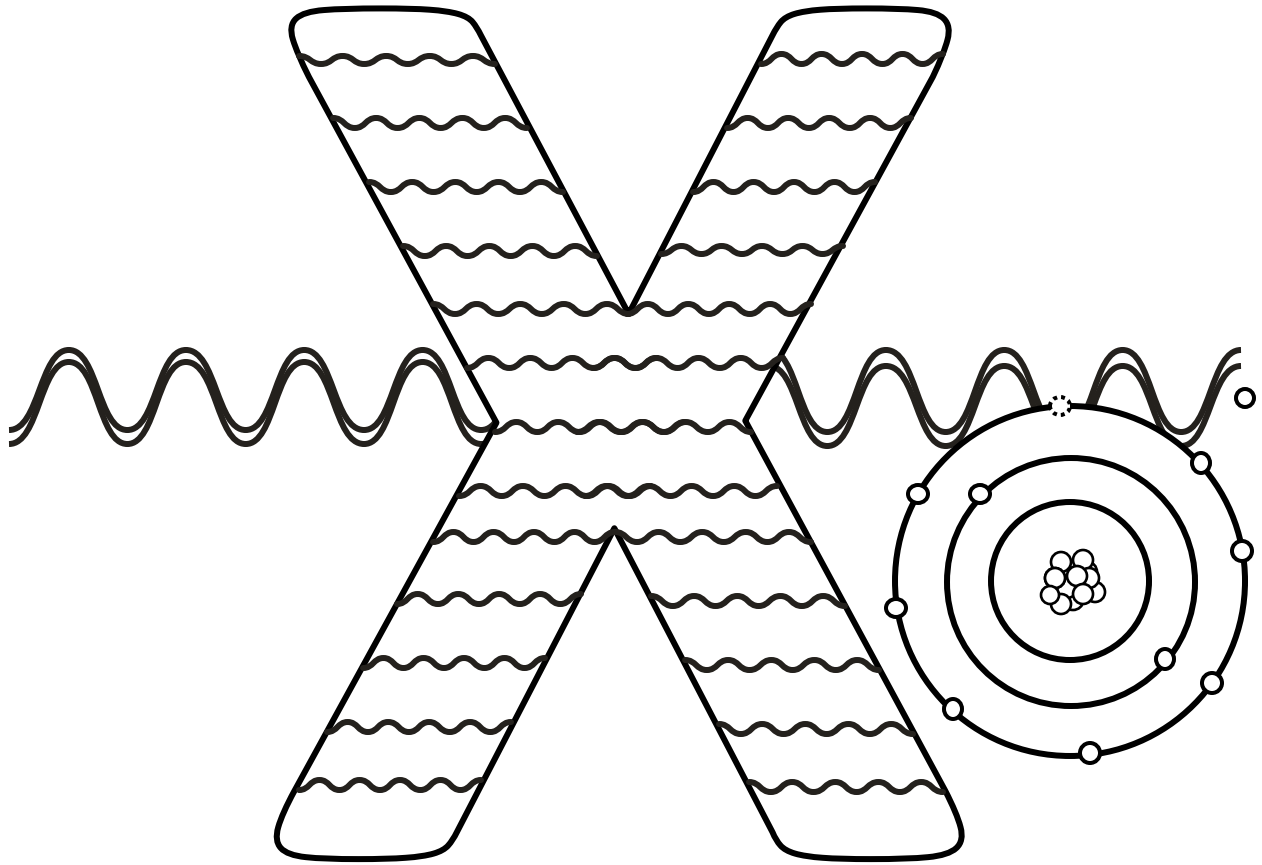
X-Ray

X-rays are a kind of light that we can't see with our eyes. Just like all light, X-rays are made out of photons. They have a lot of energy and can make atoms lose their electrons.

Look and see! Next time you go to the dentist or doctor ask about X-rays. Since X-rays can pass through skin, people use these to look at your bones and teeth.
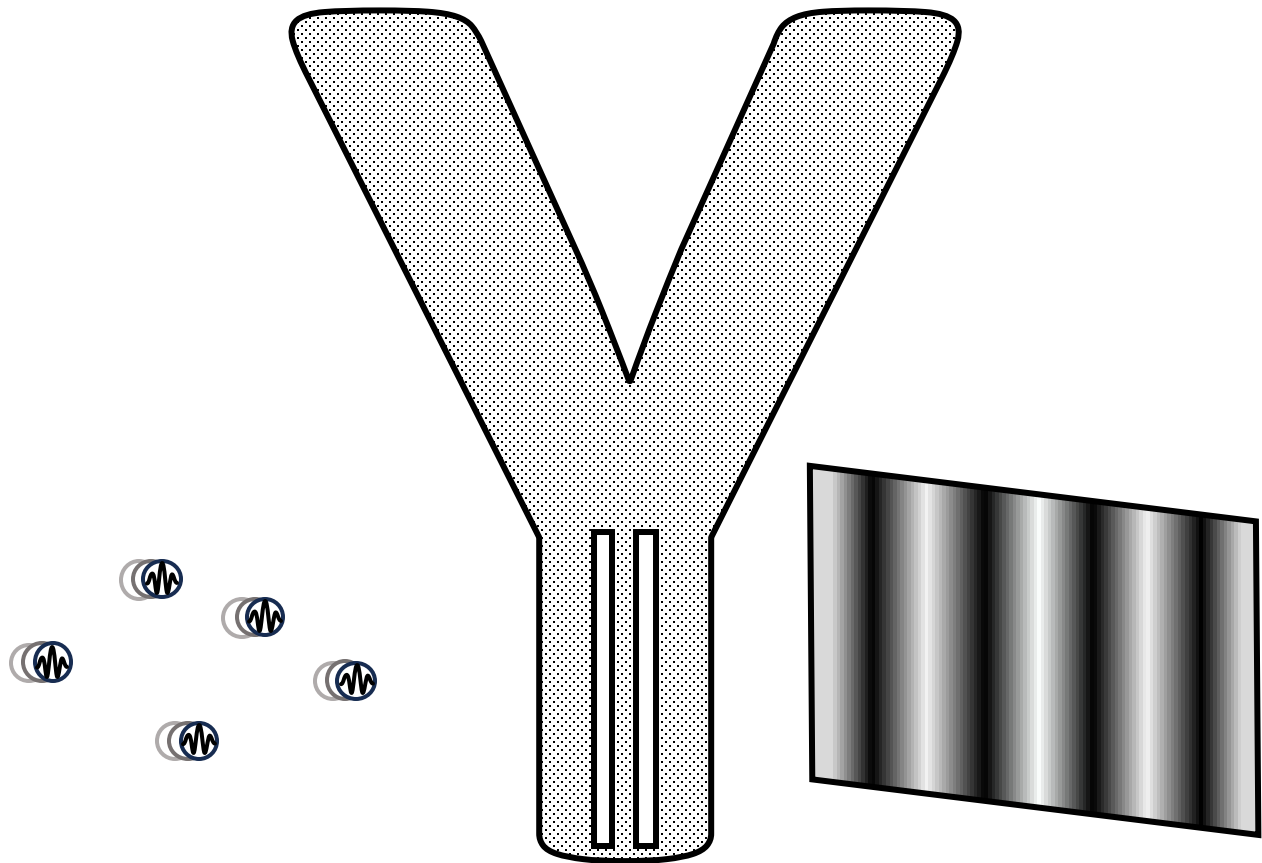
Young's Double Slit

When quantum particles flow through two slits they don't clump into two piles like you would expect in everyday life. They make a bigger pattern. Thomas **Young** was a scientist that did the first **double slit** experiments.

Try it out at home! Put a strand of hair very close to a flashlight and look at the shadow it creates – do you see multiple shadows? That's because light particles also act like waves.

01010110101010101110100100010
101010101...01010101001
011101101010101...10100101
10100101001001...000011101
0010001000...00101010100
1010010101...01010101110001
01010101...01001010010110
1010101...0111010
110100100010...00010101
0010010100011101010101101011
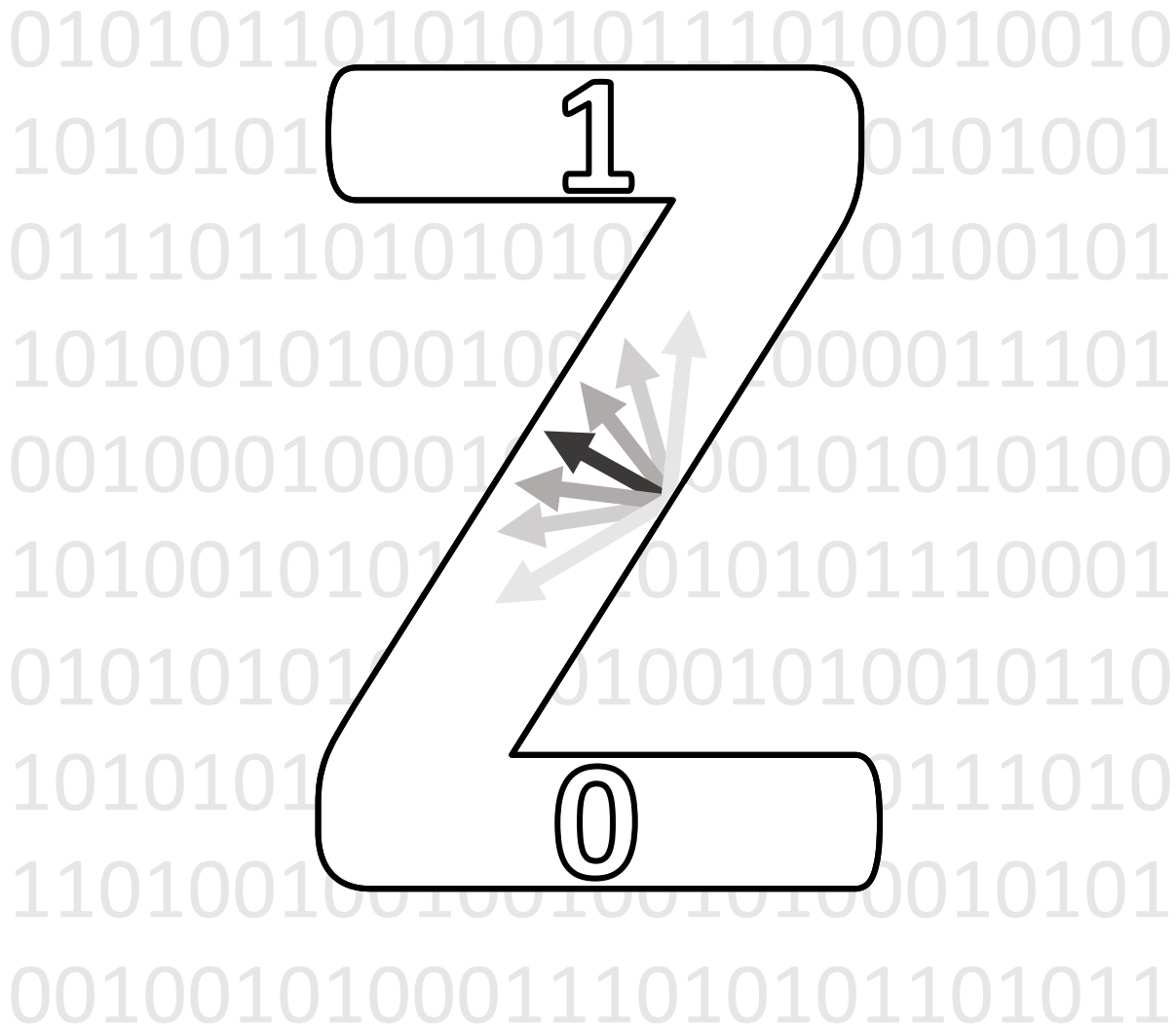
Zeros and Ones

We can send information using patterns of **zeros and ones** ("bits"). With a quantum particle we can send the possibility of both 0 and 1 at the same time (quantum bit = "qubit"). The number won't be set until we measure the qubit.

Try it out at home! Make a bracelet that shares a message using zeros and ones (binary code). Website: https://code.org/curriculum/course2/14/Teacher

Quantum Network Word Search Puzzle

Can you find all these words about quantum networks?

Bell Test	Light
Entanglement	Measurement
Fiber-Optic Cable	Photon
Games	Polarization
Half-Wave Plate	Quantum
Interference	Superposition

```
E  A  M  K  A  Q  V  B  F  P  P  E  P  E  X  O
X  L  P  E  S  K  E  L  O  V  C  V  H  T  D  D
S  H  B  C  A  L  M  I  H  N  J  X  O  A  R  P
Y  A  W  A  L  S  O  W  E  W  I  E  T  L  D  K
U  T  L  T  C  E  U  R  S  I  S  U  O  P  L  W
O  O  E  N  U  C  E  R  V  M  O  Z  N  E  Z  L
C  S  H  E  W  F  I  C  E  Z  G  L  C  V  M  D
T  N  N  U  R  Z  K  T  S  M  I  L  L  A  U  Z
J  H  M  E  O  S  K  Y  P  Y  E  I  E  W  T  R
M  S  T  L  I  G  H  T  K  O  O  N  O  F  N  Q
Y  N  E  S  E  A  A  K  D  H  R  H  T  L  A  B
I  R  R  M  U  D  M  L  F  G  R  E  L  A  U  I
N  O  I  T  A  Z  I  R  A  L  O  P  B  H  Q  B
U  K  Z  T  H  G  L  P  V  A  B  C  R  I  V  N
S  U  P  E  R  P  O  S  I  T  I  O  N  D  F  Q
T  N  E  M  E  L  G  N  A  T  N  E  P  V  F  Z
```

Puzzle created using https://puzzlemaker.discoveryeducation.com/

Decode the message

Each letter in the phrase has been replaced with a random number.
Try to decode the message.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
													16		9	19									

```
  P                          Q        N              N                                    :
  9  13  14   4  22   2     19  13   8  16   5    13  11     16  24   5  18  10  25   6       18   3  24  25  24

                N                           N        P                                    Q           N
 24   7  24  25  21  10  16  24       2   8  16      9   4   8  21     18  22   5   3     19  13   8  16   5  13  11
  P                                    .                                    P
  9   8  25   5  22   2   4  24  26       2  10  11  24     24  23   9   4  10  25  24     18  22   5   3

                                      !
                                  13  26
```

Puzzle created using https://puzzlemaker.discoveryeducation.com/

To learn more about quantum networks visit the Public Quantum Network website:
https://iquist.illinois.edu/pqn