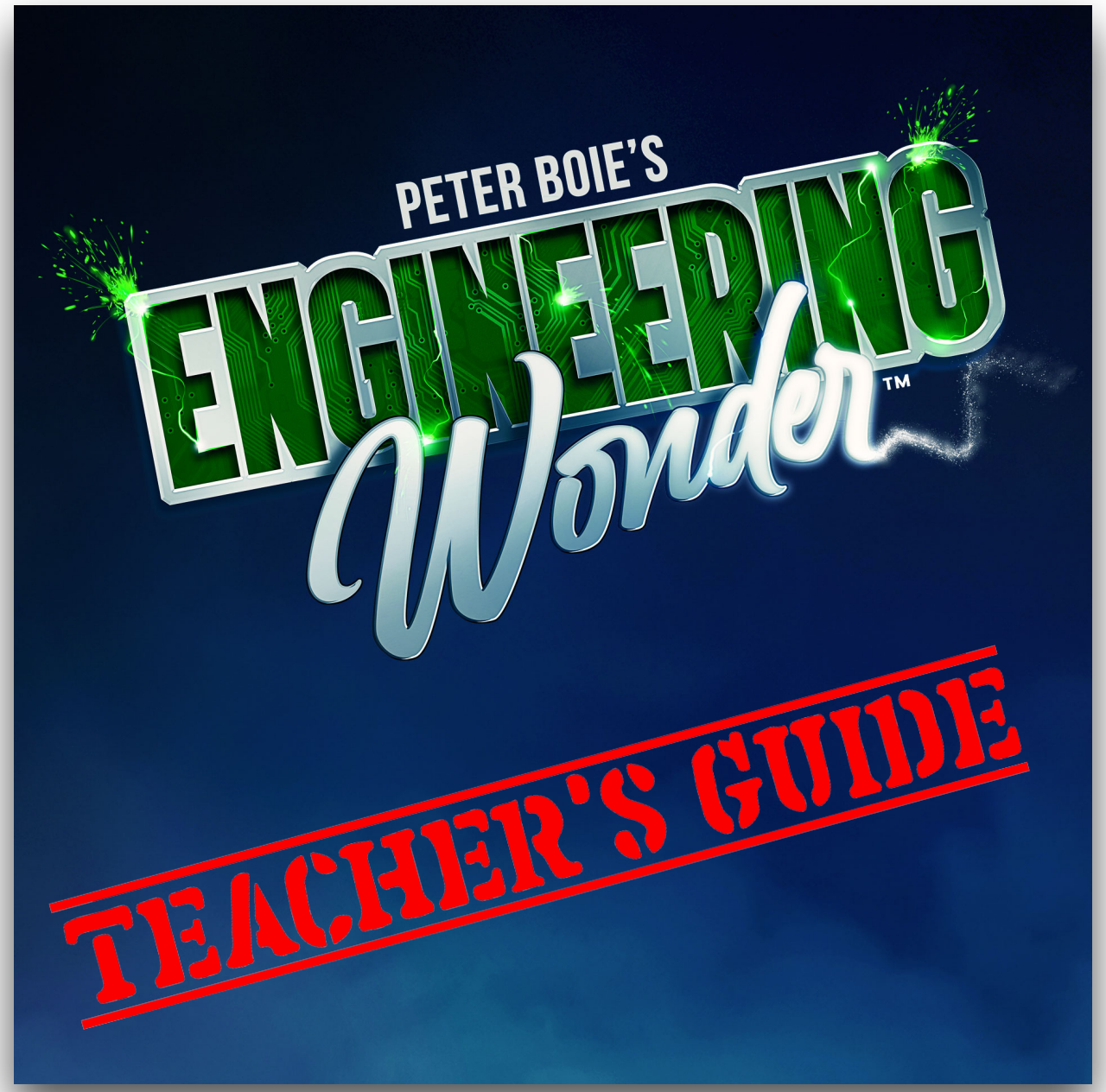

Understanding basic electronic's concepts, vocabulary, and inspiring creativity.

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Table of Contents

Cover Page 1

Table of Contents 2

Biography 3

How to Use this Guide 4

Reviewing Concepts, Science Standards, & In-Class Activities 4

- How Electricity Works 4
- How Batteries Work 5
- How Electric Motors Work 6
- How Radio Waves Send Information 7
- How Propellers Work 8
- Scientific History 9
- The Three C's of Learning 9

Review 11

Final Thoughts 11

Vocabulary Word Search Grades 5+ 12

Vocabulary Word Search Grades K-4 13

Vocabulary Crossword Puzzle Grades 5+ 14

Binary Code Activity 15

Biography

Peter Boie started learning magic at the age of eleven when he checked out a magic book from his local library in Maine. His natural curiosity for secret knowledge, and aptitude for creating miracles with humble materials started him on a path towards becoming a professional magician. His first professional show was at the age of 16 and he has never looked back.

Peter has toured theaters and colleges across the country for over 18 years. He has been featured on local television programs and the national television show Penn & Teller Fool Us. He has performed for various celebrities such as Tom Brady, and Neil Young, and is a best selling magic inventor.

Several years ago he received an electronics kit with an Arduino Uno micro controller in it as a gift which sparked his excitement and creativity for electronics and coding. A year after that he was gifted his first 3d printer which also sparked his excitement for designing in 3d and making those designs real with the printer. His excitement to create with his new skills and tools was boiling over and he wanted to share that knowledge and excitement with the world. That is when Engineering Wonder was born.

"Your performance of that for us was beautiful." - Penn & Teller

"We loved Engineering Wonder! It's an interactive, educational, and magical experience. The 3rd-8th graders (and the teachers!) in attendance were engaged and amazed from start to finish. Peter does an awesome job working in science and magic into an unforgettable program that left audience members inspired to learn more about engineering - and magic!"
- Mia Banco, Education Director-The Waldo Theatre

"Peter Boie certainly Engineered Wonder at our residential middle and high school! Students and staff alike loved the magic while learning about scientific principles. Peter did not hesitate to accommodate our special needs, and even met with our teachers to help plan a school wide STEM-based project. We hope to have him back!"
- Kimmy Ellinwood-The Wediko School

How to Use this Guide

This guide should be distributed to all teachers whose class will be attending the *Engineering Wonder* show. It should be given prior to the performance so they can familiarize themselves with the material and projects. It is also ok to give it to just the STEM/science teachers if your school has dedicated teachers for those subjects. The material in this guide is to be utilized AFTER the show and should be used the day of or in the days following the show as the excitement from the performance will still be fresh. Momentum is a powerful tool, and teachers will want to take advantage of any spark in the students that is generated from the show to review these concepts and ideas.

For each concept covered in this teacher's guide there will be the basic lesson that is conveyed, vocabulary for that lesson, in-class activities, and the science standards that align with the lesson . The standard may be connected directly to the concept and/or to the in-class activity.

Reviewing Concepts, Science Standards, & In-Class Activities

How Electricity Works

Knowledge

Electricity is when negativity charged particles called electrons travel over a conductor when the conductor is connected in a circuit.

Big Idea

Electricity is everywhere and electrical devices power many essential systems in our lives. More and more of the things we use everyday use electricity and circuits.

In-Class Activity

Create a simple circuit using a battery, wires and an LED or electric motor. There are two great projects on www.engineeringwonder.show that will put these concepts into action. One is the Vibrating Bug Bot and the other is the Electronic Bill Snatcher prank. Click the links to take you to the projects.

Essential Questions

- Can you come up with different designs to make the bug bot move faster? Sketch out your designs and test them against other student's designs.
- Can you come up with different designs to make the bug bot move in a straight line or circle? Sketch out your designs and test them against other student's designs.
- What happens to the bill snatcher when you use batteries with lower or higher voltages?

- What happens to both projects if all the conductors (wires) aren't connected in a circuit?
- For the Bill Snatcher project: Print out the spool using the .stl file and try and re-create it using Tinkercad and digital calipers. Can you make a better design?

Vocabulary

- Conductor: Any material that electricity will travel over. Examples include metals, and water.
- Insulator: Any material that electricity will NOT travel over. Examples include rubber, and plastic.
- Circuit: A closed loop made of a conductor that electrons travel in.
- Electron: A small particle with a negative charge that is found in all atoms.

Science Standards

Maine: **Elementary**: K-2-ETS1-1, K-2-ETS1-2, K-2-ETS1-3, 4-PS3-2, 4-PS3-4 **Middle**: MS-ETS1, MS-PS2-3, MS-PS3-5 **High**: HS-PS3-3

Massachusetts: **Elementary**: K-2-ETS1-1, K-2-ETS1-2, K-2-ETS1-3, 4-PS3-2, 4-PS3-4 **Middle**: MS-PS2-3, MS-PS3-5, MS-ETS2-4, MS-ETS2-5 **High:** HS-PS3-3

NGSS: **Elementary**: K-2-ETS1-1, K-2-ETS1-2, K-2-ETS1-3, 4-PS3-2, 4-PS3-4 **Middle:** MS-ETS1, MS-PS2-3, MS-PS3-5 **High:** HS-PS3-3

How Batteries Work

Knowledge

Batteries contain two electrical terminals called the cathode (negative terminal) and the anode (positive terminal), separated by a material called an electrolyte. When the battery terminals are connected in a circuit a chemical reaction happens in the electrolyte that releases electrons to flow through the circuit.

Big Idea

Batteries are like electron dams waiting to be released. When you connect the terminals in a circuit the dam is released.

In-Class Activity

In the *Engineering Wonder* show Peter creates a battery made from lemons and lights up an LED with the power from the lemon juice of four lemons. The acidic lemon juice is the electrolyte, which creates a chemical reaction with the zinc nail when connected in a circuit. You can re-create this experiment in class! Some students think there is a trick to this (even though Peter's best efforts to tell them it's science), so doing it in class will drive home that it is real. Check out the Lemon Battery Tower project on the website for details on how to do this in your classroom.

Essential Questions

- How might changing the quantity of lemons connected in series affect the LED?
- How might changing the quantity of lemons connected in parallel affect the LED?
- How might changing the quantity of lemons connected in series change the volts and amps produced? (Measure with a multimeter)
- How might changing the quantity of lemons connected in parallel change the volts and amps produced? (Measure with a multimeter)

Vocabulary

- Cathode: The negative terminal of a battery or electrical device.
- Anode: The positive terminal of a battery or electrical devise.
- Electrolyte: A solution that allows electrically charged particles to pass between the anode and cathode of a battery.

Science Standards

Maine: **Elementary**: 4-PS3-2**,** 4-PS3-4 **Middle:** MS-PS2-3 **High**: HS-PS1-2, HS-PS1-4, HS-PS3-3, HS-PS3-5

Massachusetts: **Elementary**: 4-PS3-2, 4-PS3-4 **Middle**: MS-PS2-3, MS-ETS2-4, **High**: HS-PS3-3, HS-PS3-5, HS-PS1-10, HS-PS2-9

NGSS: **Elementary**: 4-PS3-2**,** 4-PS3-4**Middle:** MS-PS2-3 **High**: HS-PS1-2, HS-PS1-4, HS-PS3-3

How Electric Motors Work

Knowledge

An electric motor converts electrical energy into mechanical energy. The motor uses magnets and electromagnets to cause a rotor to spin.

Big Idea

Being able to convert electrical energy into mechanical energy opens up a world of possibilities to have electricity power many of the machines in our lives.

In-Class Activity

In the *Engineering Wonder* show Peter creates a simple electric motor using a battery, two paperclips, a magnet and copper wire. You can re-create this experiment in class. Watch this video to learn how to make the same electric motor.

Bonus experiment: Try making just an electromagnet using copper wire, an iron nail and a battery. You can use this electromagnet to pick up paperclips.

Essential Questions

- How would changing the size of the magnet affect the motor?
- How does the number of times you wind the wire affect the motor?
- Can you construct a simple machine with this motor to do something useful?

- Try using batteries with different voltages. How does that affect the motor?
- In the bonus experiment, what metals are or are not attracted to the electromagnet?

Vocabulary

- Magnet: A piece of metal that can attract or repel certain types of metal.
- Rotor: The part that spins which is connected to a part that does not move.
- Electromagnet: A type of magnet in which the magnetic field is produced by an electric current.

Science Standards

Maine: **Elementary**: 3-PS2-3, 3-PS2-4, 4-PS3-3, 4-PS3-4 **Middle**: MS-PS2-3, MS-PS2-5, MS-PS3-5 **High**: HS-PS2-5, HS-PS3-3, HS-PS3-5

Massachusetts: **Elementary**: 3-PS2-3, 3-PS2-4, 4-PS3-2, 4-PS3-4 **Middle**: MS-PS2-3, MS-PS2-5, MS-PS3-5, MS-ETS3-3 **High**: HS-PS2-5, HS-PS3-3, HS-PS3-5

NGSS: **Elementary**: 3-PS2-3, 3-PS2-4, 4-PS3-2, 4-PS3-4 **Middle:** MS-PS2-3, MS-PS2-5, MS-PS3-5 **High:** HS-PS2-5, HS-PS3-3, HS-PS3-5

How Radio Waves Send Information

Knowledge

Radio waves are electromagnetic radiation. Electronic devices can produce radio waves and modulate (modify) the waves to send binary code to the electronic device that receives the wave. Two common ways to modulate waves are amplitude modulation and frequency modulation.

Big Idea

There are approximately 7,000 languages in the world and binary code is the one computers use to communicate. It's amazing that at the base of everything our computers do is an instruction as simple as on and off. Computers can process information faster than the human brain can. Imagine having to talk to other humans in binary code!

In-Class Activity

At the end of this guide there is a binary code activity. Listed out are the binary codes for the uppercase alphabet, the lowercase alphabet and numbers. Have the students do the activity and spell their name in binary code! The name 'Peter' in binary is: 1010000110010111101001100101111001O.

Bonus knowledge: Every digit in binary code takes up one bit of memory in a computer and when you have eight bits together that is called a byte. That means every letter uses one byte of memory.

Essential Questions

- Can you decode a binary message written on the whiteboard by the teacher?

- How can you send binary code to a friend in class without using radio waves?

Vocabulary

- Electromagnetic Radiation: Radiation that has both electric and magnetic fields and travels in waves. It can occur naturally or from human made sources.
- Amplitude: The height of a wave.
- Frequency: The number of waves that pass a fixed point in a unit of time.
- Binary Code: A number system that only uses two digits: 1 and 0. All the instructions a computer reads uses binary code.

Science Standards

Maine: **Elementary**: 4-PS4-3 **Middle**: MS-PS4-3 **High**: HS-PS4-1, HS-PS4-2, HS-PS4-5

Massachusetts: **Elementary**: 4-PS4-3 **Middle**: MS-PS4-3, MS-ETS3-1 **High**: HS-PS4-1, HS-PS4-5, HS-ETS3-2

NGSS: **Elementary**: 4-PS4-3 **Middle**: MS-PS4-3 **High:** HS-PS4-1, HS-PS4-2, HS-PS4-5

How Propellers Work

Knowledge

A propeller is a rounded blade that when spun pushes air through it creating thrust. The more air that is pulled behind the propeller the more thrust in generated.

Big Idea

Think of all the amazing things we have because humans learned how to make a flying machine. Propellers opened up a whole new frontier for human civilization.

In-Class Activity

In the Engineering Wonder show Peter uses a toy propeller to demonstrate how to generate thrust from a propeller. These are common toys and can be purchased...or made! Here is a great video on how your students can make or 3d print their own toy propellers that really fly.

Essential Questions

- What might happen to the flight of propeller if you changed the size of the dowel?
- What might happen to the flight of the propeller if you changed the size of the propeller?
- What might happen if the shape of the propeller was changed?
- What happens if the propeller is spun in the opposite direction?
- Is there an optimal design that goes the fastest or farthest? Test your designs against other students to see which design goes higher or faster.
- What causes the propeller to fall to the earth if it's not creating thrust?

Vocabulary

- Thrust: The force that causes an object to move forward.

Science Standards

Maine: **Elementary**: K-2-ETS-1, K-2-ETS1-2, K-2-ETS1-3, 4-PS3-1, 5-PS2-1**Middle**: MS-PS2-2

Massachusetts: **Elementary**: K-2-ETS1-1, K-2-ETS1-2, K-2-ETS1-3, 4-PS3-1, 5-PS2-1

MIddle: MS-PS2-2 **High:** HS-ETS3-6

NGSS: **Elementary**: K-2-ETS1-1, K-2-ETS1-2, K-2-ETS1-3, 4-PS3-1, 5-PS2-1 **Middle:** MS-PS2-2

Scientific History

Knowledge

All the technology we use today goes back hundreds and sometimes thousands of years. It's important to appreciate that when we invent and make things we are not starting from scratch and we draw on the collective knowledge of human civilization for our inventions today. Maybe if we are lucky and work hard enough we can add to that knowledge. The electronics/maker community is such a wonderful and generous place to learn from and share the things we learn. Science and inventions are discovered and made with teamwork.

Essential Questions

- What is the most important invention in the last 300 years?
- How can studying the past change the future?
- What would the world be like if we didn't invent ways to store our knowledge for future generations?
- What invention (that hasn't been invented yet) would have the greatest positive impact on society right now?
- If you could go back in time what modern invention would you give to the past?

Science Standards

Massachusetts: **Elementary**: 3-5-ETS3-1

The Three C's of Learning

Peter's three C's of learning are curiosity, creativity and commitment. Curiosity is truly at the root of all learning. Sometimes people have a natural curiosity, and sometimes teachers or mentors and help cultivate curiosity. When that curiosity is quenched it is a satisfying experience, and that experience is addictive! Which leads to more curiosity.

To be creative is about adding a piece of you into what you are creating. When you first learn something you will mimic your teacher, which is normal. As you learn you will discover

more unanswered questions which you get to bring your own creativity to as you try and find the answers and build off of established knowledge or inventions.

Commitment is about self discipline. Being self disciplined is about creating habits and habits are formed through repetition. Whatever your goal is you must devote time and brainpower to it. Creating habits for learning or being creative is probably the biggest "secret" of smart, successful and/or creative people. Set aside the time to focus on learning something new and/or being creative everyday. It could be as little as 15-30 minutes. It might be hard to do for the first couple weeks or months, but soon the habit will be formed and if you miss one day you will feel like you forgot to do something, which you did!

Essential Questions

- What everyday practices can be done to generate more curiosity about the world around us?
- What forces can destroy curiosity in people?
- How does creativity affect science?
- What is something that is unique to you that you want to share with the world?
- How would you start a new everyday habit?
- How would your life change if you committed 20 minutes a day to just learning about stuff YOU are curious about?

Review

Basic summaries of the most important lessons from the Engineering Wonder program are:

- Electricity is negatively charged electrons that travel over a conductor that is connected in a circuit, which is a closed loop that electrons travel on.
- Batteries work by a chemical reaction that releases electrons when connected in a circuit.
- Electric motors work by magnets and electromagnets.
- Radio waves are electromagnetic radiation. Binary code is sent over radio ways by modifying the wave to signal a 1 or 0 to the receiver.
- Propellers create thrust by pushing air through it.
- The technology of today has a long history of discovery and invention by the great scientists and inventors of the past. We never invent by ourselves, even if our only partners are from the past.
- Be curious. Be creative. Be committed, and you will never stop learning new and amazing things throughout your entire life!

Final Thoughts

First off, great job! You are a teacher which is the most important job in the world. You get to impact young people everyday. I hope this program can help add a spark of excitement for science and creativity into your classroom.

If you would like to continue to get fun electronic and 3d printing project ideas for your students I would suggest subscribing to my YouTube channel. I am constantly making videos with the hope of inspiring young and old to start making cool stuff for themselves and the world!

If I can be of any help in the future, answer any questions, or if you would like to share your student's projects with me you can always email me at peter@engineeringwonder.show

Thank you again and remember a curious mind is a mind ready to learn!
-Peter

Vocabulary Word Search Grades 5+

Engineering Wonder Word Search

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

Electromagnet	Electrolyte	Conductor
Insulator	Amplitude	Radiation
Frequency	Electron	Cathode
Magnet	Circuit	Binary
Thrust	Anode	Rotor

Vocabulary Word Search Grades K-4

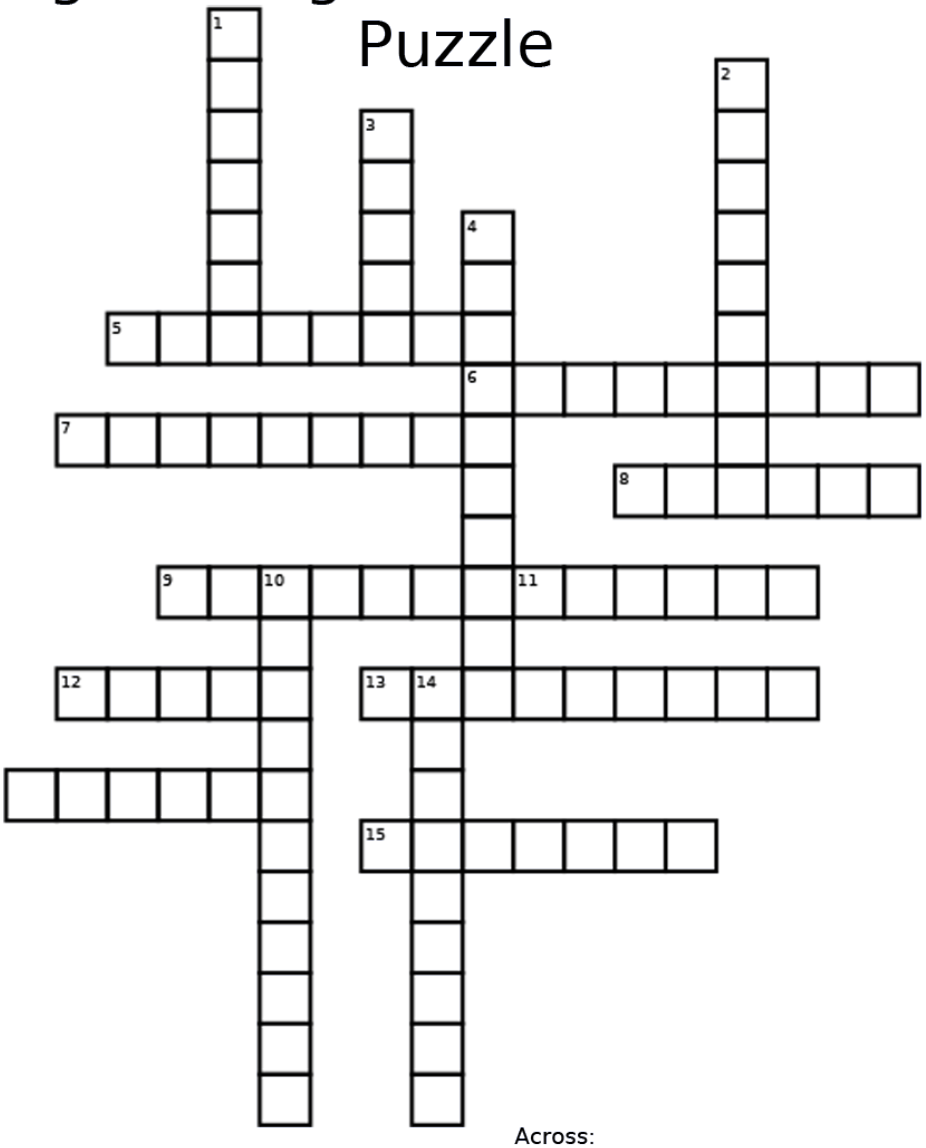
Engineering Wonder Word Search

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

Electromagnet	Electrolyte	Insulator
Radiation	Conductor	Amplitude
Frequency	Circuit	Magnet
Binary	Thrust	Electron
Cathode	Anode	Rotor

Vocabulary Crossword Puzzle Grades 5+

Engineering Wonder Crossword Puzzle



Down:

1. Negative end of a battery or electronic device
2. Material that electricity travels over
3. Part that spins in or connected to a part that does not move
4. Computer instructions that only use 1s and 0s
10. A solution that allows charged particles to pass between the anode and cathode of a battery
14. Emission of energy like electromagnetic waves

Across:

5. Negatively charged particle
6. Height of a radio wave
7. Material that electricity can not travel over
8. Force that causes an object to move forward
9. Magnetic field that is produced by an electric current
11. Metal that can attract or repel certain types of metal
12. Positive end of a battery or electronic device
13. Number of waves that pass a fixed point in a unit of time
15. Closed loop that electrons travel in

Binary Code Activity

Here are the binary codes for capital letters, lowercase letters and numbers. Every character is represented by 8 digits that are either a 1 or a 0. Notice that the capital letters start with 001, and the lowercase letters start with 011, and the rest of the binary code is the same for each letter. Also notice that the 5 digits to the right of the first three digits in the letters are the binary code for the number that corresponds to the letter's position in the alphabet.

Numbers

0	00000000
1	00000001
2	00000010
3	00000011
4	00000100
5	00000110
6	00000111
7	00001000
8	00001001
9	00001010

Capital Letters

A	00100001
B	01000010
C	00100011
D	01000100
E	01000101
F	01000110
G	01000111
H	01001000
I	01001001
J	01001010
K	01001011
L	01001100
M	01001101
N	01001110
O	01001111
P	01010000
Q	01010001
R	01010010
S	01010011
T	01010100
U	01010101
V	01010110
W	01010111
X	01011000
Y	01011001
Z	01011010

Lowercase Letters

a	01100001
b	01100010
c	01100011
d	01100100
e	01100101
f	01100110
g	01100111
h	01101000
i	01101001
j	01101010
k	01101011
l	01101100
m	01101101
n	01101110
o	01101111
p	01110000
q	01110001
r	01110010
s	01110011
t	01110100
u	01110101
v	01110110
w	01110111
x	01111000
y	01111001
z	01111010

Write your name in binary! Write your name vertically in the shaded column on the left, then use the tables with the binary codes for letters to find the binary code for each letter and write them in the boxes to the right of each letter. Viola! You can write in binary code!
