Circuitforge — Activity Book

A Spark & Anvil activity book — puzzles, questions, and fun from Circuitforge.

Write in the book, circle your answers, and check the Answer Key at the back.

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1. Electricity Basics

Circle the correct answer

1. What is the tiny particle inside an atom that carries a negative electric charge?
(A) Neutron (B) Electron (C) Proton (D) Photon

2. What do we call a material that allows electricity to flow through it easily?
(A) Resistor (B) Conductor (C) Insulator (D) Magnet

3. What type of electricity builds up on the surface of objects when they are rubbed together?
(A) Magnetic energy (B) Static electricity (C) Current electricity (D) Solar energy

4. Which of these is a natural example of static electricity being discharged?
(A) Lightning (B) Earthquakes (C) Wind (D) Rainbows

5. When you rub a balloon on your hair, electrons move from your hair to the balloon. Why does the balloon then stick to a wall?
(A) The balloon becomes magnetic (B) The balloon has a negative charge that attracts the positive charges in the wall (C) The wall creates its own electricity (D) The balloon gets heavier from extra electrons

6. Why do metals like copper make good conductors of electricity?
(A) They are heavier than other materials (B) Their electrons can move freely between atoms (C) They are shiny and smooth (D) They contain more protons than other materials

Write the answer

7. Why does rubber coating on a wire help keep you safe from electric shock?
Answer: _____

8. How is lightning similar to the shock you feel when you touch a metal doorknob after walking on carpet?
Answer: _____

9. Why do you sometimes get a small shock when you touch a metal doorknob but NOT when you touch a wooden door?
Answer: _____

10. If a negatively charged balloon is brought near another negatively charged balloon, what happens?
Answer: _____

Match each question to its answer

1. You have a collection of materials: a copper penny, a rubber band, a paper clip, and a glass marble. Which TWO would you expect to conduct electricity? →
2. You are building a circuit and need to connect two parts with a material that conducts electricity. Which would you choose from your toolbox? →
3. Your wool sweater keeps giving you small shocks today. How could you reduce the static buildup? →
4. You rub a plastic comb on a wool cloth and then hold it near tiny pieces of paper. The paper jumps up to the comb. How would you use this knowledge to pick up small bits of aluminum foil? →
5. During a thunderstorm, lightning usually strikes tall metal objects like towers. Using what you know about conductors and insulators, how would you apply this to design a safe building? →

(A) Touch a metal object slowly to discharge the static before it builds up too much
(B) Attach a metal rod to the top of the building connected by wire to the ground, so lightning follows the conductor safely
(C) The copper penny and the paper clip
(D) Rub the comb on wool again and hold it near the foil, since static charge attracts lightweight objects
(E) Copper wire

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2. Simple Circuits & Components

Circle the correct answer

11. What are the three basic parts that every simple circuit must have to work?
(A) A power source, a conductor, and a load (B) A switch, a wire, and a fuse (C) A plug, a motor, and a computer (D) A battery, a magnet, and a light

12. What is the name of the path that electricity follows to travel from a power source, through a device, and back again?
(A) A conductor (B) A voltage (C) A circuit (D) A current

13. What happens to a light bulb in a circuit when the circuit is broken or has a gap in it?
(A) The light bulb turns off because electricity cannot flow (B) The light bulb gets brighter (C) The light bulb flickers rapidly (D) The light bulb changes color

14. A circuit where the path is complete and electricity can flow without interruption is called what?
(A) A broken circuit (B) A short circuit (C) An open circuit (D) A closed circuit

15. Why does a battery have both a positive (+) and a negative (–) end?
(A) To prevent the battery from overheating (B) To make the battery last longer (C) To create a difference in charge that pushes electricity through a circuit (D) So you know which end to put in first

16. What unit is used to measure how much push a battery gives to electricity in a circuit?
(A) Ohms (B) Volts (C) Watts (D) Amps

Write the answer

17. If you connect a 1.5-volt battery to a small light bulb and the bulb glows dimly, what could you do to make it glow brighter?
Answer: _____

18. Inside a light bulb, what thin piece of metal glows white-hot when electricity flows through it?
Answer: _____

19. Why does a light bulb produce light when electricity flows through it?
Answer: _____

20. You have a battery, a light bulb, and wires. When you connect them and the bulb does not light up, which of the following is the most likely reason?
Answer: _____

Match each question to its answer

1. What is the job of a switch in an electrical circuit? →
2. When a light switch on the wall is turned OFF, the circuit is in what state? →
3. Design a simple circuit that includes a battery, a switch, and a buzzer. Describe the order of the components and how the switch controls the buzzer. →
4. A student builds a circuit with a battery and two light bulbs, but only one bulb lights up. What should the student check first to troubleshoot the problem? →
5. A battery has a voltage rating of 9V and another battery has a rating of 1.5V. If you use each one separately in the same circuit with the same light bulb, what difference

would you observe? →

(A) Check whether the dark bulb is properly connected with no loose wires
(B) Connect the positive end of the battery to one terminal of the switch with a wire, connect the other terminal of the switch to the buzzer, and connect the buzzer back to the negative end of the battery. Flipping the switch opens or closes the circuit to turn the buzzer on or off.
(C) The bulb would glow much brighter with the 9V battery because it provides more electrical push
(D) Open
(E) To open or close the circuit, controlling whether electricity flows

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3. Series & Parallel Circuits

Circle the correct answer

21. In a series circuit, how are the components arranged?
(A) Side by side with separate paths for each component (B) In a stack with components on top of each other (C) In a single path, one after another, so electricity flows through each component in order (D) In a random arrangement with wires crossing over

22. What happens to all the other light bulbs in a series circuit if one bulb burns out?
(A) Nothing changes for the other bulbs (B) All the other bulbs go out because the single path is broken (C) The remaining bulbs get brighter (D) The other bulbs start to flicker

23. How are components arranged in a parallel circuit?
(A) Components are connected only to the switch, not the battery (B) Each component is connected on its own separate branch, giving electricity multiple paths to follow (C) Components are stacked on top of each other (D) All components are on a single path in a straight line

24. A 12-volt battery is connected to three identical light bulbs in a series circuit. Approximately how much voltage does each bulb receive?
(A) 12 volts each, because each bulb gets the full battery voltage (B) 0 volts, because the bulbs cancel out the voltage (C) 36 volts each, because the voltage multiplies with each bulb (D) 4 volts each, because voltage is divided equally among identical components in series

25. In a series circuit with three light bulbs, the current flowing through the first bulb is 0.5 amps. What is the current flowing through the second and third bulbs?
(A) Less than 0.5 amps because each bulb uses up some current (B) Zero amps because the first bulb absorbs all the current (C) More than 0.5 amps because the current builds up (D) 0.5 amps through each, because current is the same at every point in a series circuit

26. Why do the light bulbs in a parallel circuit each glow at full brightness, while bulbs in a series circuit glow dimmer as you add more?
(A) In parallel, each bulb receives the full battery voltage on its own branch; in series, bulbs must share the voltage (B) Parallel bulbs are made of better materials than series bulbs (C) Parallel bulbs are closer to the battery so they get more power (D) Series circuits have weaker batteries than parallel circuits

Write the answer

27. If one light bulb burns out in a parallel circuit with three bulbs, what happens to the other two?
Answer: _____

28. A 6-volt battery is connected to two identical bulbs in a parallel circuit. What voltage does each bulb receive?
Answer: _____

29. In a parallel circuit with three branches, the battery supplies a total of 3 amps. If each branch has an identical light bulb, how much current flows through each branch?
Answer: _____

30. Compare the total resistance of three identical 10-ohm resistors connected in series versus the same three resistors connected in parallel. Which arrangement has greater total resistance?
Answer: _____

Match each question to its answer

1. Why are the electrical outlets in your home wired in parallel rather than in series? →
2. A student claims that adding more light bulbs in parallel to a battery will make the battery die faster. Evaluate whether this claim is correct. →
3. In a series circuit containing a 9-volt battery, a 2-ohm resistor, and a 4-ohm resistor, what is the total current flowing through the circuit? (Use Ohm's Law: I = V/R) →
4. What is the key difference between how voltage behaves in a series circuit versus a parallel circuit? →
5. What is the key difference between how current behaves in a series circuit versus a

parallel circuit? →

(A) In series, current is the same through all components; in parallel, current splits among the branches
(B) The claim is correct because each additional parallel branch draws more current from the battery, draining it faster
(C) 1.5 amps (9V divided by the total resistance of 6 ohms)
(D) So each outlet receives full voltage independently, and one device turning off or failing does not affect the others
(E) In series, voltage divides among components; in parallel, every component gets the full source voltage

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4. Digital Logic & Binary

Circle the correct answer

31. What two digits does the binary number system use to represent all numbers?
(A) 1 and 2 (B) 0 and 9 (C) 0 and 1 (D) A and B

32. What is the decimal (base-10) value of the binary number 1010?
(A) 1010 (B) 10 (C) 5 (D) 20

33. What is a logic gate in digital electronics?
(A) A basic building block that takes one or more binary inputs and produces a single binary output based on a specific rule (B) A device that converts electricity to light (C) A physical gate that opens and closes to let electricity through (D) A lock on a computer that requires a password

34. An AND gate has two inputs. When does it output a 1?
(A) When the inputs are different (B) When both inputs are 0 (C) When either input is 1 (D) Only when BOTH inputs are 1

35. What does a truth table show for a logic gate?
(A) Whether the gate is working correctly or is broken (B) The temperature of the gate during operation (C) All possible combinations of inputs and the corresponding output for each combination (D) How fast the gate processes information

36. What is the main difference between a digital signal and an analog signal?
(A) A digital signal has only two distinct levels (ON/OFF), while an analog signal can be any value along a continuous range (B) Digital signals use letters and analog signals use numbers (C) Digital signals are faster than analog signals (D) Analog signals only exist in nature, not in electronics

Write the answer

37. Convert the decimal number 13 to binary.
Answer: _____

38. An OR gate has two inputs. When does it output a 1?
Answer: _____

39. A NOT gate has one input. What does it do to the input signal?
Answer: _____

40. Complete this truth table for an AND gate: Input A = 1, Input B = 0. What is the output?
Answer: _____

Match each question to its answer

1. Why do computers use binary (base-2) instead of decimal (base-10)? →
2. What is the largest decimal number you can represent with 4 binary digits (4 bits)? →
3. You need to design a circuit that triggers an alarm ONLY when both the front door sensor AND the window sensor detect an intruder. Which logic gate should you use? →
4. A system uses an OR gate to control a greenhouse fan. Sensor A detects high temperature and Sensor B detects high humidity. Analyze what happens when it is cool but very humid (Sensor A = 0, Sensor B = 1). →
5. What is the binary representation of the decimal number 7? →

(A) The fan turns ON because the OR gate outputs 1 when at least one input is 1
(B) Because electronic circuits can easily represent two states (ON and OFF), which map directly to 1 and 0
(C) 111
(D) An AND gate, because it outputs 1 only when both inputs are 1
(E) 15 (binary 1111 = 8+4+2+1)

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5. Sensors, Inputs & Outputs

Circle the correct answer

41. What is a sensor in an electronic system?
(A) A device that stores electricity for later use (B) A device that detects changes in the environment and converts them into electrical signals (C) A device that connects to the internet (D) A device that displays information on a screen

42. Which type of sensor detects the amount of light in the environment?
(A) A light sensor (photoresistor or photodiode) (B) An accelerometer, based on the typical behavior observed in controlled experiments (C) A thermistor, according to the standard scientific model for this phenomenon (D) A microphone, which is what the experimental evidence consistently shows

43. What is the difference between an input device and an output device in a circuit?
(A) Input devices use more power than output devices, which is why this approach is recommended by experts (B) An input device sends information INTO the system (like a button or sensor), while an output device receives information FROM the system and produces a result (like a light or speaker) (C) Input devices are bigger and output devices are smaller, and this has been consistently demonstrated in practice (D) There is no real difference — the terms are interchangeable, and this is the standard approach used in most cases

44. Which of the following is an output device?
(A) A push button (B) A light sensor (C) A buzzer that makes sound when activated (D) A temperature sensor

45. What is a feedback loop in an electronic system?
(A) When an output from the system is measured by a sensor and used as input to adjust the system's behavior (B) When two systems share the same power supply (C) When a user gives a review about the system (D) When a system plays back recorded audio

46. A motion sensor detects movement and turns on a porch light. Identify which part is the input, which is the output, and what role the circuit plays.
(A) Both the sensor and the light are outputs because they both use electricity (B) The circuit is the input and the motion sensor is the output (C) The motion sensor is the input, the porch light is the output, and the circuit is the processor that decides to turn on the light when motion is detected (D) The porch light is the input and the motion sensor is the output

Write the answer

47. A temperature sensor in a greenhouse reads 35°C. The system is set to turn on a fan when the temperature exceeds 30°C. What signal should the system send to the fan?
Answer: _____

48. Name three different types of sensors and what each one detects.
Answer: _____

49. How does a piezoelectric buzzer convert an electrical signal into sound?
Answer: _____

50. A home heating system uses a thermostat with a temperature sensor, a processing unit, and a furnace. Explain how this system uses a feedback loop to maintain a comfortable temperature.
Answer: _____

Match each question to its answer

1. What is signal processing in the context of a sensor-based system? →
2. An ultrasonic distance sensor sends out a sound pulse and listens for the echo. If the echo returns in 0.006 seconds and sound travels at about 343 meters per second, approximately how far away is the object? →
3. A student builds a nightlight that turns on when it gets dark. They use a light sensor and an LED. But the LED stays on all the time, even in bright light. Analyze what might be wrong. →
4. Compare a push button and a sensor as input devices. What is a key difference in how they provide input to a circuit? →
5. List three examples of output devices and describe what type of energy each one converts electrical energy into. →

(A) About 1 meter away (sound travels 2.058m total round trip, so the object is half that distance: ~1.03m)
(B) A push button requires direct human action to send a signal, while a sensor automatically detects environmental changes without human intervention
(C) The step where a circuit or microcontroller analyzes the raw sensor data and makes decisions about what action to take
(D) An LED converts electrical energy into light energy, a motor converts electrical energy into mechanical (motion) energy, and a speaker converts electrical energy into sound energy
(E) The circuit logic is likely inverted — the LED turns on when the sensor reads HIGH (bright) instead of LOW (dark). The student needs to add a NOT gate or adjust the circuit logic.

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6. Engineering Design Process

Circle the correct answer

51. What is the first step of the engineering design process?
(A) Choose the best materials available, and this principle applies across similar situations (B) Test the finished product, which is why this approach is recommended by experts (C) Build a prototype as quickly as possible, and this has been consistently demonstrated in practice (D) Define the problem by identifying what needs to be solved, who it is for, and what constraints exist

52. What is a design constraint?
(A) A tool used to measure the quality of a design, as this is what research and standard practice suggests (B) A decoration added to make a product look better, which is why this approach is recommended by experts (C) A limitation or requirement that the design solution must meet, such as budget, size, weight, time, or safety standards (D) A type of building material used in prototypes, as this directly follows from the underlying principles

53. Why is it important to research existing solutions before designing your own?
(A) To make sure your design looks similar to others, which is why this approach is recommended by experts (B) Because the teacher requires it for a grade (C) To learn from what others have already tried, understand what works and what doesn't, and avoid reinventing something that already exists (D) To copy someone else's design exactly, which is the most common explanation for this phenomenon

54. What is brainstorming, and why is it useful during the design phase?
(A) Brainstorming is researching what competitors have built, as this directly follows from the underlying principles (B) Brainstorming is choosing the best idea from a list, as this is what research and standard practice suggests (C) Brainstorming is generating many ideas without judging them, which encourages creative thinking and produces a wider range of potential solutions (D) Brainstorming is testing a prototype to see if it works, as this is what research and standard practice suggests

55. What is a prototype in the engineering design process?
(A) A drawing of the design on paper, which is why this approach is recommended by experts (B) A preliminary model or version of a design built to test whether the concept works before creating the final product (C) A list of materials needed to build the product, making this the most widely accepted explanation (D) The final, polished version of a product ready for sale, making this the most widely accepted explanation

56. You are asked to design a device that reminds students to drink water throughout the school day. What are three specific constraints you should identify before designing?
(A) The device must be invisible, weigh nothing, and last forever (B) There are no constraints because any design will work (C) The device must be made of gold, play loud music, and cost at least $100 (D) The device must be small enough to fit in a

backpack, quiet enough to not disrupt class, and affordable for students (under $10)

Write the answer

57. Why should engineers test their prototypes under conditions similar to real-world use?
Answer: _____

58. What does it mean to 'iterate' on a design?
Answer: _____

59. You built a prototype of a solar-powered phone charger, but during testing it charges the phone much slower than expected. Describe three specific changes you might test in the next iteration.
Answer: _____

60. What is a trade-off in engineering design?
Answer: _____

Match each question to its answer

1. You are designing a wearable fitness tracker for kids. Create a list of at least three design criteria (requirements the design must meet) and three design constraints (limitations you must work within). →
2. Why is a breadboard useful for prototyping electronic circuits? →
3. A team designs a flashlight for camping. Prototype A uses a single powerful LED (bright but battery dies in 2 hours). Prototype B uses three dim LEDs (less bright but lasts 8 hours). Which prototype better meets the needs of campers, and why? →
4. What is the purpose of keeping a design notebook or engineering journal throughout a project? →
5. During testing, your circuit prototype works perfectly on the lab bench but fails when you demonstrate it in the gymnasium. What environmental factor likely caused the failure, and how would you investigate? →

(A) To document ideas, designs, test results, changes, and reasoning so you can track progress, learn from mistakes, and communicate your process to others
(B) It allows you to build and test circuits quickly without soldering, and you can easily rearrange components to try different designs
(C) The gymnasium likely has different lighting, temperature, vibration, or electrical interference. You would investigate by systematically changing one environmental variable at a time to identify the cause.
(D) Criteria: must accurately count steps, must be comfortable to wear all day, must display data clearly. Constraints: must cost under $15 to manufacture, must weigh less than 30 grams, must be water-resistant for hand washing.

(E) Prototype B better meets campers' needs because camping trips last many hours and a longer battery life is more important than extreme brightness for most camping activities

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7. Microcontrollers & Programming

Circle the correct answer

61. What is a microcontroller?
(A) A microscope used to look at computer chips (B) A tiny remote control for a television (C) A small, programmable computer on a single chip that can read inputs, make decisions, and control outputs (D) A controller that can only be seen under a microscope

62. What is the Arduino Uno, and why is it popular for learning electronics?
(A) A video game console designed for young children, as this is what research and standard practice suggests (B) An open-source microcontroller board with digital and analog pins, popular because it is affordable, beginner-friendly, and supported by a large community with many tutorials (C) A professional-grade computer used only in factories, and this principle applies across similar situations (D) A type of battery that powers electronic projects, and this has been consistently demonstrated in practice

63. What is a program (also called a sketch in Arduino)?
(A) A list of materials needed to build a project (B) A drawing of the circuit that shows where components go (C) A set of step-by-step instructions written in a programming language that tells the microcontroller exactly what to do (D) The brand name printed on the Arduino board

64. In Arduino programming, what is a variable?
(A) The speed at which the Arduino processes instructions (B) A named container in memory that stores a value which can change as the program runs (C) A type of wire that connects components on a breadboard (D) A physical knob on the Arduino board that adjusts settings

65. How does a light sensor (photoresistor) communicate with an Arduino microcontroller?
(A) The photoresistor sends text messages to the Arduino via Wi-Fi, as this directly follows from the underlying principles (B) The photoresistor changes its electrical resistance based on light levels, and the Arduino reads this changing voltage through an analog input pin as a number between 0 and 1023 (C) The photoresistor plugs into the USB port and sends binary code, and this has been consistently demonstrated in

practice (D) The photoresistor makes a sound that the Arduino's microphone picks up, which is the most common explanation for this phenomenon

66. What are the two main functions that every Arduino sketch must contain? (A) begin() and end(), and this is the standard approach used in most cases (B) start() and stop(), which is the most common explanation for this phenomenon (C) on() and off(), and this is the standard approach used in most cases (D) setup() which runs once when the Arduino starts, and loop() which runs repeatedly forever

Write the answer

67. What does the following line of Arduino code do? digitalWrite(13, HIGH);
Answer: _____

68. What is a loop in programming, and why is it useful?
Answer: _____

69. You want to make an LED connected to pin 9 blink on for 1 second, then off for 1 second, repeating forever. Write the logic for the loop() function in plain language (pseudocode).
Answer: _____

70. You connect a temperature sensor to an Arduino and write code to read it. The sensor reads 78 when you hold it in your hand. But 78 what? What does the raw number from analogRead() actually represent?
Answer: _____

Match each question to its answer

1. What is the purpose of the Serial Monitor in the Arduino IDE? →
2. Write the pseudocode logic for a program that reads a temperature sensor and turns on a fan when the temperature exceeds 30 degrees. →
3. What is an if-else statement in programming, and how does it help a microcontroller make decisions? →
4. A student writes code for an Arduino nightlight. The light sensor reads values 0-1023 (low numbers = dark, high numbers = bright). They write: if(sensorValue > 500) { turn on LED; }. But the LED turns on in bright light instead of dark. What is the bug? →
5. What are the key differences between a digital pin and an analog pin on an Arduino? →

(A) Read the temperature sensor value, convert it to degrees, if the temperature is greater than 30 then turn the fan ON, otherwise turn the fan OFF
(B) It displays text and data sent from the Arduino to the computer over USB, allowing you to see sensor readings, debug code, and monitor program behavior

(C) An if-else statement checks a condition: if the condition is true, it runs one block of code; if false, it runs a different block. This lets the microcontroller choose different actions based on sensor data.
(D) The comparison operator is backward. Since low values mean dark, the code should be if(sensorValue < 500) to turn on the LED when it is dark
(E) A digital pin can only read or send two states (HIGH/LOW, or 1/0), while an analog input pin can read a range of values from 0 to 1023, representing different voltage levels

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8. Robotics & Integrated Systems

Circle the correct answer

71. What are the three fundamental components that every robot must have?
(A) Bluetooth, Wi-Fi, and a battery, making this the most widely accepted explanation (B) Sensors (to perceive the environment), a controller/processor (to make decisions), and actuators (to take physical action) (C) A keyboard, a monitor, and a mouse, and this is the standard approach used in most cases (D) Wheels, arms, and a head, making this the most widely accepted explanation

72. What is the difference between a DC motor and a servo motor?
(A) A DC motor is large and a servo motor is always small (B) A DC motor uses direct current and a servo motor uses alternating current (C) A DC motor spins continuously at variable speed, while a servo motor moves to a precise angle position (usually 0-180 degrees) and holds it (D) There is no real difference — they are different names for the same thing

73. What does it mean for a robot to be 'autonomous'?
(A) The robot is powered by solar energy and does not need batteries, as this directly follows from the underlying principles (B) The robot can operate and make decisions on its own without direct human control, using its sensors and programming to navigate and respond to its environment (C) The robot is controlled by a remote control with no delay, which is why this approach is recommended by experts (D) The robot can repair itself when damaged, making this the most widely accepted explanation

74. What is artificial intelligence (AI) in the context of robotics?
(A) A computer program that can feel emotions like humans, which is the most common explanation for this phenomenon (B) Any electronic device that uses electricity to function, and this principle applies across similar situations (C) The ability of a robot's software to learn from experience, recognize patterns, and make decisions that were not explicitly programmed for every possible situation (D) A

robot that looks and acts exactly like a human being, and this has been consistently demonstrated in practice

75. Name two ethical concerns related to the use of robots and AI in society.
(A) Robots using too much electricity and robots being too expensive (B) Robots taking up too much physical space and robots being too heavy (C) Job displacement (robots replacing human workers) and privacy concerns (robots with cameras and microphones collecting personal data) (D) Robots being painted the wrong color and robots being too noisy

76. Explain how a line-following robot uses sensors to stay on a path.
(A) It uses a camera to read text printed next to the line, making this the most widely accepted explanation (B) It uses a magnetic sensor to follow a magnet hidden under the floor, as this is what research and standard practice suggests (C) It uses GPS to navigate like a car's navigation system, and this principle applies across similar situations (D) It uses infrared sensors on the bottom that detect the difference between a dark line and a light surface. If the left sensor sees the line, the robot steers left; if the right sensor sees it, the robot steers right, keeping the line between the sensors.

Write the answer

77. What is a stepper motor, and when would you choose it over a regular DC motor for a robot?
Answer: _____

78. A robot navigates a room using ultrasonic distance sensors. It detects an obstacle 30 cm ahead on the right side but clear space on the left. What should its navigation algorithm do?
Answer: _____

79. How does machine learning differ from traditional programming in how a robot learns to recognize objects?
Answer: _____

80. A factory wants to introduce robots to package products on an assembly line, replacing 50 human workers. Analyze both the potential benefits and drawbacks of this decision.
Answer: _____

Match each question to its answer

1. What is a robot chassis, and why is its design important? →
2. What is a pneumatic actuator, and in what type of robot might you find one? →
3. You are designing a robot to explore a collapsed building and search for survivors. What sensors would you include, and why? →
4. Explain the difference between teleoperation and full autonomy in robotics. What is a situation where teleoperation is preferred over autonomy? →
5. A self-driving car's AI must decide between two unavoidable outcomes: swerving left into a wall (injuring the passenger) or continuing straight (hitting a pedestrian). This is an example of what ethical challenge in AI? →

(A) The trolley problem — a moral dilemma where AI must be programmed to make life-or-death decisions with no good outcome, raising questions about who decides the rules and who is responsible
(B) A pneumatic actuator uses compressed air to create linear (pushing/pulling) or rotary motion. You would find them in industrial robots that need powerful, fast movements for tasks like gripping, stamping, or lifting heavy objects.
(C) The chassis is the robot's frame or body structure that supports all components. Its design affects stability, weight distribution, maneuverability, and how easily components can be mounted and accessed.
(D) Teleoperation means a human controls the robot remotely in real-time, while full autonomy means the robot decides and acts on its own. Teleoperation is preferred for bomb disposal, where the consequences of a wrong autonomous decision could be fatal.
(E) A thermal camera (to detect body heat of survivors), an ultrasonic or LIDAR sensor (to map obstacles and navigate rubble), a microphone (to detect voices or tapping), and a gas sensor (to detect dangerous gas leaks)

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9. Electronics & Circuits

Circle the correct answer

81. What are the two digits used in the binary number system?
(A) 1 and 2 (B) 0 and 9 (C) 0 and 2 (D) 0 and 1

82. What does the acronym LED stand for?
(A) Low Emission Diode (B) Light Energy Device (C) Laser Emitting Device (D) Light Emitting Diode

83. What logic gate outputs TRUE only when both inputs are TRUE?
(A) AND gate (B) XOR gate (C) NOT gate (D) OR gate

84. How many bits are in one byte?
(A) 2 (B) 4 (C) 8 (D) 16

85. What is the binary representation of the decimal number 5?
(A) 110 (B) 101 (C) 100 (D) 111

86. What logic gate inverts its input, turning 1 to 0 and 0 to 1?
(A) NAND gate (B) AND gate (C) NOT gate (D) OR gate

Write the answer

87. Why do computers use binary instead of decimal?
Answer: _____

88. What happens to the output of an OR gate when at least one input is TRUE?
Answer: _____

89. How does a truth table help you understand a logic gate?
Answer: _____

90. What is the difference between an AND gate and a NAND gate?
Answer: _____

Match each question to its answer

1. Why is hexadecimal (base 16) often used alongside binary in computing? →
2. Convert the binary number 1010 to decimal. →
3. An AND gate has inputs A=1 and B=0. What is the output? →
4. You need a circuit that turns on a light only when EITHER switch A OR switch B is pressed. Which gate do you use? →
5. What is the decimal value of the binary number 11001? →

(A) 10
(B) 0
(C) It provides a compact way to represent groups of 4 binary digits
(D) 25
(E) OR gate

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10. Electronics & Circuits

Circle the correct answer

91. What is a sensor?
(A) A device that stores electricity, making this the most widely accepted explanation (B) A device that creates motion, and this is the standard approach used in most cases (C) A type of battery, which is the most common explanation for this phenomenon (D) A device that detects changes in the environment and converts them to electrical signals

92. What does a thermistor measure?
(A) Sound volume (B) Light intensity (C) Temperature (D) Pressure

93. What type of sensor detects light levels?
(A) Potentiometer (B) Piezoelectric sensor (C) Photoresistor (LDR) (D) Thermistor

94. What does a microphone convert?
(A) Sound waves into electrical signals (B) Electrical signals into sound (C) Heat into motion (D) Light into electricity

95. What is a transducer?
(A) A device that amplifies signals (B) A circuit protection device (C) A type of resistor (D) A device that converts one form of energy to another

96. What does a PIR sensor detect?
(A) Visible light from lamps (B) Sound waves from speakers (C) Infrared radiation from warm objects like people (D) Magnetic fields from magnets

Write the answer

97. Why does an LDR's resistance decrease in bright light?
Answer: _____

98. How does a piezoelectric sensor generate electricity?
Answer: _____

99. What is the difference between an analog sensor and a digital sensor?
Answer: _____

100. Why do many sensor circuits use a voltage divider?
Answer: _____

Match each question to its answer

1. How does an ultrasonic distance sensor measure distance? →
2. You want to build a circuit that turns on a fan when the room gets too hot. Which sensor would you use? →
3. Design a nightlight circuit: what sensor should detect darkness, and what output device should produce light? →

4. An ultrasonic sensor reads a round-trip echo time of 0.006 seconds. If sound travels at 340 m/s, what is the distance to the object? →
5. You are building a plant-watering system. Which sensor should detect soil moisture? →

(A) LDR (photoresistor) for input, LED for output
(B) A moisture sensor (two probes measuring soil conductivity)
(C) Thermistor or temperature sensor
(D) 1.02 meters
(E) It sends out a sound pulse and measures how long the echo takes to return

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11. Electronics & Circuits

Circle the correct answer

101. What instrument is used to measure voltage in a circuit?
(A) Ohmmeter (B) Wattmeter (C) Ammeter (D) Voltmeter

102. What is a short circuit?
(A) A circuit with high resistance (B) A circuit that is physically small (C) A circuit with very few components (D) An unintended low-resistance path that allows excessive current to flow

103. What component protects a circuit by melting when too much current flows?
(A) Diode (B) Transistor (C) Capacitor (D) Fuse

104. What does a circuit schematic diagram show?
(A) A photograph of the circuit, which is why this approach is recommended by experts (B) The components in a circuit and how they are electrically connected using standard symbols (C) The physical size of components, and this principle applies across similar situations (D) The cost of each part, and this is the standard approach used in most cases

105. What color bands on a resistor indicate its resistance value?
(A) The brand name written on it (B) The temperature of the resistor (C) Color-coded bands painted around the resistor body (D) The size of the resistor

106. What is the purpose of a breadboard in circuit prototyping?
(A) To generate power for circuits, which is why this approach is recommended by experts (B) To permanently mount circuits, and this has been consistently demonstrated in practice (C) To measure resistance, and this has been consistently demonstrated in practice (D) To build and test circuits without soldering, using plug-in connections

Write the answer

107. Why should a voltmeter be connected in parallel, not in series?
Answer: _____

108. Why do circuit designers add decoupling capacitors near integrated circuits?
Answer: _____

109. What is the difference between a series circuit and a parallel circuit?
Answer: _____

110. How does a pull-up resistor prevent a floating input on a digital circuit?
Answer: _____

Match each question to its answer

1. Why is it important to match the voltage rating of components in a circuit? →
2. A circuit with three LEDs in series doesn't light up. Your voltmeter shows full battery voltage across the first LED. What is the most likely problem? →
3. You need to limit current through an LED to 20 mA using a 9V battery. The LED drops 2V. What resistor value do you need? →
4. Your circuit has a buzzing noise in the audio output. What troubleshooting step should you try first? →
5. You are building a circuit on a breadboard and it doesn't work. List three things to check. →

(A) Check for loose connections and add decoupling capacitors to filter noise
(B) 350 ohms
(C) Exceeding a component's voltage rating can cause damage, overheating, or failure
(D) The first LED is open (burned out or disconnected), blocking all current flow
(E) Check power connections, verify component orientation (LED polarity, IC pin 1), and look for accidental short circuits between adjacent rows

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12. Electronics & Circuits

Circle the correct answer

111. What does IC stand for in electronics?
(A) Integrated Circuit (B) Internal Capacitor (C) Insulated Connector (D) Intelligent Controller

112. What popular microcontroller board is widely used for beginner electronics

projects?
(A) PlayStation (B) Router (C) Arduino (D) Calculator

113. What does PWM stand for, and what does it do?
(A) Permanent Wire Module — it connects wires (B) Power Watt Meter — it measures power (C) Passive Wireless Mode — it sends signals wirelessly (D) Pulse Width Modulation — it controls the average power by rapidly switching on and off

114. What is a printed circuit board (PCB)?
(A) A computer program for circuits, and this principle applies across similar situations (B) A board with copper traces that connect electronic components without wires (C) A circuit drawn on paper, making this the most widely accepted explanation (D) A type of battery, which is the most common explanation for this phenomenon

115. What is the main function of a transistor in a circuit?
(A) To measure temperature (B) To store electrical energy (C) To convert AC to DC (D) To switch or amplify electrical signals

116. What programming language is most commonly used with Arduino?
(A) C/C++ (Arduino language based on C++) (B) Java, according to the standard scientific model for this phenomenon (C) Python, which is consistent with the fundamental principles of this field (D) HTML, since this follows from the basic laws governing this process

Write the answer

117. Why are microcontrollers important in modern electronics?
Answer: _____

118. How does a servo motor differ from a regular DC motor?
Answer: _____

119. What is the role of a voltage regulator in a circuit?
Answer: _____

120. Why do many electronic devices use both 3.3V and 5V power rails?
Answer: _____

Match each question to its answer

1. How does an H-bridge circuit control a motor's direction? →
2. Write pseudocode to make an LED blink on and off every second using a microcontroller. →
3. You want a microcontroller to read a potentiometer and control LED brightness.

What type of input/output do you need? →
4. Calculate the power consumed by a 5V circuit drawing 200 mA of current. →
5. You're building a line-following robot. What sensors would you place on the bottom, and how would they work? →

(A) By switching which pair of transistors is active, it reverses the current direction through the motor
(B) Set LED pin as output; Loop: turn LED on, wait 1 second, turn LED off, wait 1 second, repeat
(C) 1 watt
(D) Analog input to read the potentiometer, PWM output to control LED brightness
(E) IR reflectance sensors — they emit infrared light and measure how much reflects back from the surface

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13. Electricity Basics

Circle the correct answer

121. What do we call a material that allows electricity to flow through it easily?
(A) Resistor (B) Conductor (C) Magnet (D) Insulator

122. A teacher asks you to judge which is safer: plugging a nightlight into a wall outlet or connecting an LED to a 3-volt battery. Which is safer for a student to experiment with, and why?
(A) The battery is less safe because it could explode (B) The 3-volt battery is much safer because wall outlets carry 120 volts, which is dangerous and can cause serious electric shock (C) Both are equally safe because electricity is electricity (D) The wall outlet is safer because it has built-in safety features

123. Compare the total resistance of three identical 10-ohm resistors connected in series versus the same three resistors connected in parallel. Which arrangement has greater total resistance?
(A) Neither arrangement has any resistance because resistors cancel each other (B) Both arrangements have the same total resistance of 10 ohms (C) The series arrangement has greater total resistance (30 ohms) compared to the parallel arrangement (about 3.3 ohms) (D) The parallel arrangement has greater total resistance

124. A system uses an OR gate to control a greenhouse fan. Sensor A detects high temperature and Sensor B detects high humidity. Analyze what happens when it is cool but very humid (Sensor A = 0, Sensor B = 1).
(A) The fan turns ON because the OR gate outputs 1 when at least one input is 1 (B)

The fan stays OFF because Sensor A is 0 (C) The fan turns on at half speed because only one sensor is active (D) The fan turns OFF because OR requires both inputs to be 1

125. Which of the following is an output device?
(A) A temperature sensor (B) A push button (C) A light sensor (D) A buzzer that makes sound when activated

126. You are asked to design a device that reminds students to drink water throughout the school day. What are three specific constraints you should identify before designing?
(A) There are no constraints because any design will work (B) The device must be made of gold, play loud music, and cost at least $100 (C) The device must be invisible, weigh nothing, and last forever (D) The device must be small enough to fit in a backpack, quiet enough to not disrupt class, and affordable for students (under $10)

Write the answer

127. What is a loop in programming, and why is it useful?
Answer: _____

128. Explain how a line-following robot uses sensors to stay on a path.
Answer: _____

129. How is lightning similar to the shock you feel when you touch a metal doorknob after walking on carpet?
Answer: _____

130. What happens to a light bulb in a circuit when the circuit is broken or has a gap in it?
Answer: _____

Match each question to its answer

1. A 12-volt battery is connected to three identical light bulbs in a series circuit. Approximately how much voltage does each bulb receive? →
2. Design a simple binary counting system using light bulbs that can display the numbers 0 through 7. How many light bulbs do you need and what does each represent? →
3. What is a feedback loop in an electronic system? →
4. What is a fair test in engineering, and why is it important when comparing two designs? →
5. How does a light sensor (photoresistor) communicate with an Arduino

microcontroller? →

(A) You need 3 light bulbs representing the values 4, 2, and 1. Each bulb being ON (1) or OFF (0) creates binary numbers from 000 (0) to 111 (7).
(B) When an output from the system is measured by a sensor and used as input to adjust the system's behavior
(C) The photoresistor changes its electrical resistance based on light levels, and the Arduino reads this changing voltage through an analog input pin as a number between 0 and 1023
(D) A fair test changes only one variable at a time while keeping everything else the same, so you can accurately determine which change caused any difference in performance
(E) 4 volts each, because voltage is divided equally among identical components in series

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14. Electricity Basics

Circle the correct answer

131. Your wool sweater keeps giving you small shocks today. How could you reduce the static buildup?
(A) Stand on a rubber mat all day, which is why this approach is recommended by experts (B) Rub your hands together faster, which is why this approach is recommended by experts (C) Touch a metal object slowly to discharge the static before it builds up too much (D) Wear more layers of wool on top, and this has been consistently demonstrated in practice

132. Your flashlight stops working. You open it and see the batteries are in correctly and the bulb looks fine. What else could be preventing the circuit from working?
(A) The batteries are too cold to produce electricity (B) The bulb needs to be screwed in tighter to increase voltage (C) Corrosion on the battery contacts could be blocking the flow of electricity (D) The flashlight needs to be charged by sunlight first

133. How many rows would a truth table have for a logic gate with 3 inputs?
(A) 8 rows, because each input can be 0 or 1, giving 2×2×2 = 8 combinations (B) 6 rows, because 3 inputs × 2 states = 6 (C) 3 rows, one for each input (D) 16 rows, because 8 doubled is 16

134. Which type of sensor detects the amount of light in the environment?
(A) A thermistor, which is consistent with the fundamental principles of this field (B) A light sensor (photoresistor or photodiode) (C) A microphone, which is what the experimental evidence consistently shows (D) An accelerometer, since this follows

from the basic laws governing this process

135. Your team must choose between two design solutions for a rain alert system. Design A uses a rain sensor and buzzer (simple, reliable, $5). Design B uses a rain sensor, LCD screen, Wi-Fi module, and phone app ($35). For an elementary school garden project, which should you recommend?
(A) Design B because more features are always better (B) Design A, because it meets the core need (rain alert) within appropriate constraints for an elementary school project — simpler, cheaper, and more reliable (C) Neither — rain alerts are not useful for gardens, and this has been consistently demonstrated in practice (D) Design B because the LCD screen looks more impressive

136. An Arduino program uses the variable 'int count = 0;' and then runs 'count = count + 1;' inside loop(). What does this code accomplish?
(A) It creates a counter that increases by 1 each time the loop() function repeats, tracking how many times the loop has run (B) It stores the number 1 permanently in memory, which is the most common explanation for this phenomenon (C) It counts down from infinity to zero, and this is the standard approach used in most cases (D) It resets the counter to 0 every time the loop runs, as this is what research and standard practice suggests

Write the answer

137. What is the difference between a robot's end effector and its actuators?
Answer: _____

138. Your friend says, 'If I wear rubber-soled shoes, I can never get shocked by lightning because rubber is an insulator.' Evaluate whether this reasoning is correct.
Answer: _____

139. Why does a battery have both a positive (+) and a negative (−) end?
Answer: _____

140. In a series circuit with three light bulbs, the current flowing through the first bulb is 0.5 amps. What is the current flowing through the second and third bulbs?
Answer: _____

Match each question to its answer

1. List three examples of output devices and describe what type of energy each one converts electrical energy into. →
2. A team's prototype scored 70/100 on their testing rubric. Team member A says they should start over with a new design. Team member B says they should iterate on the current prototype. Who has the better approach, and why? →

3. What is a program (also called a sketch in Arduino)? →
4. What is a pneumatic actuator, and in what type of robot might you find one? →
5. If a negatively charged balloon is brought near another negatively charged balloon, what happens? →

(A) They push away from each other
(B) A set of step-by-step instructions written in a programming language that tells the microcontroller exactly what to do
(C) A pneumatic actuator uses compressed air to create linear (pushing/pulling) or rotary motion. You would find them in industrial robots that need powerful, fast movements for tasks like gripping, stamping, or lifting heavy objects.
(D) Team member B has the better approach because 70/100 means the design is mostly working and iterative improvements will be faster and more efficient than starting from scratch
(E) An LED converts electrical energy into light energy, a motor converts electrical energy into mechanical (motion) energy, and a speaker converts electrical energy into sound energy

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15. Electricity Basics

Circle the correct answer

141. A student says, 'Insulators destroy electricity.' What is wrong with this statement, and what do insulators actually do?
(A) Insulators convert electricity into heat, so the statement is correct (B) Insulators only slow electricity down by half (C) Insulators do not destroy electricity; they block its flow by not allowing electrons to pass through easily (D) Nothing is wrong; insulators do destroy electricity

142. Convert the decimal number 13 to binary.
(A) 1011 (B) 1110 (C) 1101 (D) 1001

143. What are the key differences between a digital pin and an analog pin on an Arduino?
(A) There is no difference — they can be used interchangeably, which is the most common explanation for this phenomenon (B) A digital pin can only read or send two states (HIGH/LOW, or 1/0), while an analog input pin can read a range of values from 0 to 1023, representing different voltage levels (C) Digital pins are for inputs only and analog pins are for outputs only, as this is what research and standard practice suggests (D) Digital pins are faster and analog pins are slower, which is why this approach is recommended by experts

144. You are designing a robot to explore a collapsed building and search for survivors. What sensors would you include, and why?
(A) Only a regular camera because seeing is the most important sense (B) A taste sensor and a smell sensor to detect food and perfume, and this has been consistently demonstrated in practice (C) No sensors — just drive forward and hope for the best, which is why this approach is recommended by experts (D) A thermal camera (to detect body heat of survivors), an ultrasonic or LIDAR sensor (to map obstacles and navigate rubble), a microphone (to detect voices or tapping), and a gas sensor (to detect dangerous gas leaks)

145. Why do you sometimes get a small shock when you touch a metal doorknob but NOT when you touch a wooden door?
(A) Wooden doors absorb your body heat first (B) Metal is colder, which creates the shock (C) Metal is a conductor that lets the charge jump to it, while wood is an insulator (D) Metal doorknobs create their own electricity

146. You are given a battery, three wires, a switch, and a motor. Apply your knowledge of circuits to explain the correct steps to connect these components so the switch controls the motor.
(A) Connect one wire from the battery's positive terminal to one side of the switch, a second wire from the other side of the switch to the motor, and a third wire from the motor back to the battery's negative terminal (B) Connect all three wires to the battery and then touch them to the motor, and this has been consistently demonstrated in practice (C) Connect the motor directly to the battery and place the switch on top of the motor, which is the most common explanation for this phenomenon (D) Wrap all three wires around the switch and connect the ends to the battery, as this is what research and standard practice suggests

Write the answer

147. You have a 12V battery, three 6-ohm resistors, and wires. Calculate the total current drawn from the battery if the resistors are connected in parallel. (Hint: 1/Rtotal = 1/R1 + 1/R2 + 1/R3)
Answer: _____

148. A student claims, 'A motor is both an input and an output device because it uses electricity (input) and produces motion (output).' Evaluate whether this classification is correct.
Answer: _____

149. Explain why engineers often build low-fidelity prototypes (rough, simple models) before building high-fidelity prototypes (detailed, functional models).
Answer: _____

150. Before starting to write code for your Arduino project, what planning steps should you take?

Answer: _____

Match each question to its answer

1. Two students disagree about what causes a static shock from a doorknob. One says 'the doorknob sends electricity into you' and the other says 'your body sends electricity into the doorknob.' How would you figure out who is right? →
2. A student says, 'A dead battery means there is no electricity inside it.' Evaluate whether this explanation is scientifically accurate. →
3. A student measures the voltage across each of four identical bulbs in a series circuit connected to a 20-volt battery. The readings are: 5V, 5V, 5V, and 3V. What can you conclude? →
4. A student claims that an analog thermometer is better than a digital thermometer because analog gives 'more precise' readings. Evaluate this claim. →
5. What is the difference between an input device and an output device in a circuit? →

(A) The fourth bulb likely has a measurement error or different resistance, because identical bulbs in series should each receive 5V

(B) The claim is debatable; analog thermometers show continuous readings but are harder to read precisely, while digital thermometers show exact numbers but with limited decimal places determined by the sensor

(C) Check which object has extra electrons. If you built up charge on carpet, YOUR electrons jump to the doorknob, so the second student is right

(D) It is not fully accurate; a dead battery still has chemicals inside, but they have reacted completely and can no longer create the charge difference needed to push electrons

(E) An input device sends information INTO the system (like a button or sensor), while an output device receives information FROM the system and produces a result (like a light or speaker)

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16. Electricity Basics

Circle the correct answer

151. Design a simple experiment to test which household materials are the best conductors and which are insulators. Describe what you would need and what you would do.

(A) Heat each material and measure which one gets hot fastest (B) Rub each material on a balloon and see which one creates the most static (C) Put each

material in water and see which one dissolves fastest (D) Build a simple circuit with a battery, wires, and a light bulb, then place each material in a gap in the circuit to see if the bulb lights up

152. You need to build a circuit to test whether different materials conduct electricity. Which setup would work best?
(A) Connect a battery, a light bulb, and two wires with a gap between them where you can place test materials (B) Place materials on top of a battery and see if they get warm (C) Rub materials together and check if sparks appear (D) Hold materials near a light bulb to see if they glow

153. Why do the light bulbs in a parallel circuit each glow at full brightness, while bulbs in a series circuit glow dimmer as you add more?
(A) In parallel, each bulb receives the full battery voltage on its own branch; in series, bulbs must share the voltage (B) Parallel bulbs are made of better materials than series bulbs (C) Series circuits have weaker batteries than parallel circuits (D) Parallel bulbs are closer to the battery so they get more power

154. A student says, 'Since 10 in binary equals 2 in decimal, then 100 in binary must equal 3 in decimal.' Is this correct?
(A) Yes, binary numbers increase by 1 each time just like decimal (B) No, binary 100 equals 100 in decimal (C) Yes, because you just count up from the previous number (D) No, binary 100 equals 4 in decimal. Each position in binary doubles in value (1, 2, 4, 8...), it does not increase by 1

155. What is a trade-off in engineering design?
(A) A situation where improving one aspect of a design requires accepting a compromise in another aspect (B) When two engineers swap their designs with each other (C) When a design is so perfect that no compromises are needed (D) When a company sells a design to another company

156. A student argues that learning to code an Arduino is a waste of time because 'there are apps for everything now.' Evaluate this argument.
(A) The argument is completely correct because phones can do everything microcontrollers can, since this follows from the basic laws governing this process (B) The argument is correct because Arduino is outdated technology, which is what the experimental evidence consistently shows (C) The argument is flawed only because Arduino is cheaper than a phone, according to the standard scientific model for this phenomenon (D) The argument is flawed because learning microcontroller programming teaches computational thinking, problem-solving, and hardware-software integration skills that apps cannot replace. Many real-world systems (medical devices, vehicles, factories) run on microcontrollers, not phone apps.

Write the answer

157. A plastic ruler rubbed with cloth can pick up small pieces of paper. But when the same experiment is done on a very humid day, it does not work as well. What is the most likely reason?

Answer: _____

158. Design a simple circuit that includes a battery, a switch, and a buzzer. Describe the order of the components and how the switch controls the buzzer.

Answer: _____

159. A 6-volt battery is connected to two identical bulbs in a parallel circuit. What voltage does each bulb receive?

Answer: _____

160. You need to design a circuit that triggers an alarm ONLY when both the front door sensor AND the window sensor detect an intruder. Which logic gate should you use?

Answer: _____

Match each question to its answer

1. How does a piezoelectric buzzer convert an electrical signal into sound? →
2. Why should engineers test their prototypes under conditions similar to real-world use? →
3. A student notices that adding a fourth bulb in series to a three-bulb series circuit makes all bulbs noticeably dimmer, but adding a fourth bulb in parallel to a three-bulb parallel circuit does not change the brightness of the original three. Explain why. →
4. Examine this scenario: A student's Arduino program checks a temperature sensor every 100 milliseconds (10 times per second) and immediately turns a heater on or off based on each reading. They notice the heater switches on and off rapidly, making clicking noises. What is causing this, and how could they fix it? →
5. What does it mean for a robot to be 'autonomous'? →

(A) In series, the fourth bulb increases total resistance and each bulb gets less voltage (now 1/4 instead of 1/3); in parallel, each bulb still gets full battery voltage regardless of how many branches exist

(B) It uses a special crystal that vibrates when electricity flows through it, and these vibrations push air to create sound waves

(C) The robot can operate and make decisions on its own without direct human control, using its sensors and programming to navigate and respond to its environment

(D) Because a prototype that works in ideal conditions may fail under real-world stresses like temperature changes, rough handling, or continuous use

(E) The sensor readings fluctuate slightly around the threshold due to noise, causing rapid switching. Adding hysteresis (using a slightly higher turn-on threshold than

turn-off threshold) or averaging multiple readings would fix this.

Riddle & Joke Break

Guess the answer, then check the key!

161. I'm a complete path that electricity can flow through. If there's a break in me, the current stops. What am I?

162. I'm measured in volts and I push electrons through a circuit. Without me, nothing flows. I'm like the pressure in a water pipe. What am I?

163. I'm a component with two long legs -- one longer than the other. I only let current flow in one direction, and I glow when electricity passes through me. What am I?

164. I'm the flow of electrons through a conductor. I'm measured in amperes (amps). Without voltage to push me, I don't move. What am I?

165. V equals I times R. I'm a law that relates voltage, current, and resistance. A German physicist discovered me in 1827. What law am I?

166. I'm a circuit where all the components are connected end-to-end in a single loop. If one bulb burns out, they all go dark. What type of circuit am I?

167. I'm a circuit where components are connected in separate branches. Each branch gets the full voltage. If one bulb burns out, the others stay lit. What type of circuit am I?

168. I slow down the flow of current. I'm measured in ohms. I have colored bands that tell you my value. I protect components from getting too much current. What am I?

169. Why was the capacitor always getting into trouble?

170. What did the resistor say to the current?

171. Why did the LED break up with the circuit?

172. What's a circuit's favorite type of music?

173. Why did the wire refuse to carry the current?

174. What did the switch say to the light bulb?

Fun Facts

- Did you know? A bolt of lightning contains enough energy to toast about 100,000 slices of bread! However, each bolt only lasts about 1-2 milliseconds, so

harnessing that energy is basically impossible with current technology.

- Did you know? The first battery was invented around 1800 by Alessandro Volta. He stacked discs of zinc and copper separated by cardboard soaked in saltwater. This "voltaic pile" is why we measure electrical pressure in volts!
- Did you know? Electric eels aren't actually eels -- they're a type of knifefish! They can generate up to 860 volts of electricity, which they use to stun prey. That's about 7 times the voltage in a US wall outlet.
- Did you know? The world's first programmable computer, Colossus, was built in 1943 to crack Nazi codes during World War II. It used 1,500 vacuum tubes and was so secret that its existence wasn't revealed until the 1970s!
- Did you know? Copper is used for most electrical wiring because it's an excellent conductor and relatively affordable. Silver is actually a better conductor, but it costs about 75 times more than copper -- not exactly practical for wiring your house!
- Did you know? The International Space Station runs on about 75-90 kilowatts of solar power -- roughly the same as 30-40 average American homes. Its solar panels span an area larger than a football field!
- Did you know? The first LED was created in 1962, and it could only glow in dim red. Blue LEDs weren't invented until the 1990s, and they were so important for enabling white LED light that their inventors won the Nobel Prize in Physics in 2014!
- Did you know? A microchip the size of your fingernail can contain more transistors than there are stars in the Milky Way! Modern chips pack over 100 billion transistors, while our galaxy has an estimated 100-400 billion stars.

Answer Key

1. B — Electron
2. B — Conductor
3. B — Static electricity
4. A — Lightning
5. B — The balloon has a negative charge that attracts the positive charges in the wall
6. B — Their electrons can move freely between atoms
7. Rubber is an insulator that blocks the flow of electricity

8. Both are caused by a buildup of static charge that is suddenly released
9. Metal is a conductor that lets the charge jump to it, while wood is an insulator
10. They push away from each other
    Matching (Electricity Basics): 1→C, 2→E, 3→A, 4→D, 5→B
11. A — A power source, a conductor, and a load
12. C — A circuit
13. A — The light bulb turns off because electricity cannot flow
14. D — A closed circuit
15. C — To create a difference in charge that pushes electricity through a circuit
16. B — Volts
17. Add another 1.5-volt battery in series to increase the voltage
18. The filament
19. Electrical energy is converted into light and heat energy by the filament
20. One of the wire connections is loose, creating an open circuit
    Matching (Simple Circuits & Components): 1→E, 2→D, 3→B, 4→A, 5→C
21. C — In a single path, one after another, so electricity flows through each component in order
22. B — All the other bulbs go out because the single path is broken
23. B — Each component is connected on its own separate branch, giving electricity multiple paths to follow
24. D — 4 volts each, because voltage is divided equally among identical components in series
25. D — 0.5 amps through each, because current is the same at every point in a series circuit
26. A — In parallel, each bulb receives the full battery voltage on its own branch; in series, bulbs must share the voltage
27. The other two continue working normally because each has its own independent path
28. 6 volts each, because every branch in a parallel circuit receives the full source voltage

29. 1 amp through each branch, because the total current divides equally among identical branches
30. The series arrangement has greater total resistance (30 ohms) compared to the parallel arrangement (about 3.3 ohms)
    Matching (Series & Parallel Circuits): 1→D, 2→B, 3→C, 4→E, 5→A
31. C — 0 and 1
32. B — 10
33. A — A basic building block that takes one or more binary inputs and produces a single binary output based on a specific rule
34. D — Only when BOTH inputs are 1
35. C — All possible combinations of inputs and the corresponding output for each combination
36. A — A digital signal has only two distinct levels (ON/OFF), while an analog signal can be any value along a continuous range
37. 1101
38. When at least one input is 1 (or both are 1)
39. It inverts the input: if the input is 1, the output is 0; if the input is 0, the output is 1
40. 0, because AND requires both inputs to be 1
    Matching (Digital Logic & Binary): 1→B, 2→E, 3→D, 4→A, 5→C
41. B — A device that detects changes in the environment and converts them into electrical signals
42. A — A light sensor (photoresistor or photodiode)
43. B — An input device sends information INTO the system (like a button or sensor), while an output device receives information FROM the system and produces a result (like a light or speaker)
44. C — A buzzer that makes sound when activated
45. A — When an output from the system is measured by a sensor and used as input to adjust the system's behavior
46. C — The motion sensor is the input, the porch light is the output, and the circuit is the processor that decides to turn on the light when motion is detected
47. An ON signal, because 35°C exceeds the 30°C threshold

48. Temperature sensor (detects heat/cold), ultrasonic sensor (detects distance using sound waves), and humidity sensor (detects moisture in the air)
49. It uses a special crystal that vibrates when electricity flows through it, and these vibrations push air to create sound waves
50. The sensor measures room temperature (input), the processor compares it to the set temperature and turns the furnace on or off (process/output), the furnace changes the room temperature, and the sensor measures again, continuously adjusting
    Matching (Sensors, Inputs & Outputs): 1→C, 2→A, 3→E, 4→B, 5→D
51. D — Define the problem by identifying what needs to be solved, who it is for, and what constraints exist
52. C — A limitation or requirement that the design solution must meet, such as budget, size, weight, time, or safety standards
53. C — To learn from what others have already tried, understand what works and what doesn't, and avoid reinventing something that already exists
54. C — Brainstorming is generating many ideas without judging them, which encourages creative thinking and produces a wider range of potential solutions
55. B — A preliminary model or version of a design built to test whether the concept works before creating the final product
56. D — The device must be small enough to fit in a backpack, quiet enough to not disrupt class, and affordable for students (under $10)
57. Because a prototype that works in ideal conditions may fail under real-world stresses like temperature changes, rough handling, or continuous use
58. To repeat the cycle of testing, evaluating results, making improvements, and testing again until the design meets its goals
59. Try a larger solar panel to capture more light, use a more efficient voltage converter circuit, or angle the panel to face the sun more directly
60. A situation where improving one aspect of a design requires accepting a compromise in another aspect
    Matching (Engineering Design Process): 1→D, 2→B, 3→E, 4→A, 5→C
61. C — A small, programmable computer on a single chip that can read inputs, make decisions, and control outputs
62. B — An open-source microcontroller board with digital and analog pins, popular

because it is affordable, beginner-friendly, and supported by a large community with many tutorials

63. C — A set of step-by-step instructions written in a programming language that tells the microcontroller exactly what to do
64. B — A named container in memory that stores a value which can change as the program runs
65. B — The photoresistor changes its electrical resistance based on light levels, and the Arduino reads this changing voltage through an analog input pin as a number between 0 and 1023
66. D — setup() which runs once when the Arduino starts, and loop() which runs repeatedly forever
67. It turns ON the component connected to digital pin 13 by sending a HIGH (5V) signal to that pin
68. A loop is a programming structure that repeats a block of code multiple times, which is useful for tasks that need to happen over and over without writing the same code repeatedly
69. Turn pin 9 ON, wait 1000 milliseconds, turn pin 9 OFF, wait 1000 milliseconds (this repeats forever because it is inside loop())
70. It represents a voltage level converted to a number between 0 and 1023 — not a temperature in degrees. You need a mathematical formula to convert this number to actual temperature.
    Matching (Microcontrollers & Programming): 1→B, 2→A, 3→C, 4→D, 5→E
71. B — Sensors (to perceive the environment), a controller/processor (to make decisions), and actuators (to take physical action)
72. C — A DC motor spins continuously at variable speed, while a servo motor moves to a precise angle position (usually 0-180 degrees) and holds it
73. B — The robot can operate and make decisions on its own without direct human control, using its sensors and programming to navigate and respond to its environment
74. C — The ability of a robot's software to learn from experience, recognize patterns, and make decisions that were not explicitly programmed for every possible situation
75. C — Job displacement (robots replacing human workers) and privacy concerns (robots with cameras and microphones collecting personal data)

76. D — It uses infrared sensors on the bottom that detect the difference between a dark line and a light surface. If the left sensor sees the line, the robot steers left; if the right sensor sees it, the robot steers right, keeping the line between the sensors.
77. A stepper motor moves in precise, discrete steps (like 1.8 degrees per step), giving exact position control without a feedback sensor. Choose it when you need precise positioning, like in a 3D printer's print head.
78. Steer left to avoid the obstacle, continue forward, and keep monitoring sensors to detect new obstacles and adjust course
79. In traditional programming, a human writes specific rules for each object. In machine learning, the system is shown thousands of example images and automatically discovers patterns to distinguish objects on its own.
80. Benefits: increased speed, consistency, 24/7 operation, reduced injury risk.
    Drawbacks: 50 workers lose jobs, high initial investment, maintenance costs, lack of flexibility for new product types, reduced human skill development.
    Matching (Robotics & Integrated Systems): 1→C, 2→B, 3→E, 4→D, 5→A
81. D — 0 and 1
82. D — Light Emitting Diode
83. A — AND gate
84. C — 8
85. B — 101
86. C — NOT gate
87. Electronic switches have two states: on and off
88. The output is TRUE
89. It shows all possible input combinations and their outputs
90. A NAND gate is an AND gate followed by a NOT gate
    Matching (Electronics & Circuits): 1→C, 2→A, 3→B, 4→E, 5→D
91. D — A device that detects changes in the environment and converts them to electrical signals
92. C — Temperature
93. C — Photoresistor (LDR)
94. A — Sound waves into electrical signals

95. D — A device that converts one form of energy to another
96. C — Infrared radiation from warm objects like people
97. Light energy frees more electrons in the semiconductor material, allowing more current to flow
98. Mechanical pressure on certain crystals produces a voltage across the crystal
99. Analog sensors output a continuous range of values; digital sensors output discrete on/off states
100. To convert the sensor's resistance change into a measurable voltage change
Matching (Electronics & Circuits): 1→E, 2→C, 3→A, 4→D, 5→B
101. D — Voltmeter
102. D — An unintended low-resistance path that allows excessive current to flow
103. D — Fuse
104. B — The components in a circuit and how they are electrically connected using standard symbols
105. C — Color-coded bands painted around the resistor body
106. D — To build and test circuits without soldering, using plug-in connections
107. A voltmeter has very high resistance; connecting it in series would block current flow
108. To filter out high-frequency noise and provide stable local power supply
109. In series, components share one current path; in parallel, each component has its own path
110. It connects the input to a defined high voltage when no other signal is present
Matching (Electronics & Circuits): 1→C, 2→D, 3→B, 4→A, 5→E
111. A — Integrated Circuit
112. C — Arduino
113. D — Pulse Width Modulation — it controls the average power by rapidly switching on and off
114. B — A board with copper traces that connect electronic components without wires
115. D — To switch or amplify electrical signals

116. A — C/C++ (Arduino language based on C++)
117. They provide programmable control, allowing one chip to replace many discrete components and perform complex logic
118. A servo motor can rotate to a specific angle and hold its position, while a DC motor spins continuously
119. To maintain a constant output voltage regardless of changes in input voltage or load current
120. Different components require different voltages — newer ICs use 3.3V while legacy components use 5V
    Matching (Electronics & Circuits): 1→A, 2→B, 3→D, 4→C, 5→E
121. B — Conductor
122. B — The 3-volt battery is much safer because wall outlets carry 120 volts, which is dangerous and can cause serious electric shock
123. C — The series arrangement has greater total resistance (30 ohms) compared to the parallel arrangement (about 3.3 ohms)
124. A — The fan turns ON because the OR gate outputs 1 when at least one input is 1
125. D — A buzzer that makes sound when activated
126. D — The device must be small enough to fit in a backpack, quiet enough to not disrupt class, and affordable for students (under $10)
127. A loop is a programming structure that repeats a block of code multiple times, which is useful for tasks that need to happen over and over without writing the same code repeatedly
128. It uses infrared sensors on the bottom that detect the difference between a dark line and a light surface. If the left sensor sees the line, the robot steers left; if the right sensor sees it, the robot steers right, keeping the line between the sensors.
129. Both are caused by a buildup of static charge that is suddenly released
130. The light bulb turns off because electricity cannot flow
    Matching (Electricity Basics): 1→E, 2→A, 3→B, 4→D, 5→C
131. C — Touch a metal object slowly to discharge the static before it builds up too much
132. C — Corrosion on the battery contacts could be blocking the flow of electricity
133. A — 8 rows, because each input can be 0 or 1, giving 2×2×2 = 8 combinations

134. B — A light sensor (photoresistor or photodiode)
135. B — Design A, because it meets the core need (rain alert) within appropriate constraints for an elementary school project — simpler, cheaper, and more reliable
136. A — It creates a counter that increases by 1 each time the loop() function repeats, tracking how many times the loop has run
137. Actuators are the motors and mechanisms that create movement throughout the robot (wheels, arm joints). An end effector is the specific tool at the end of a robot arm that interacts with objects (gripper, welding torch, suction cup).
138. This reasoning is wrong because lightning has enough energy to pass through rubber soles; thin rubber cannot stop millions of volts
139. To create a difference in charge that pushes electricity through a circuit
140. 0.5 amps through each, because current is the same at every point in a series circuit
    Matching (Electricity Basics): 1→E, 2→D, 3→B, 4→C, 5→A
141. C — Insulators do not destroy electricity; they block its flow by not allowing electrons to pass through easily
142. C — 1101
143. B — A digital pin can only read or send two states (HIGH/LOW, or 1/0), while an analog input pin can read a range of values from 0 to 1023, representing different voltage levels
144. D — A thermal camera (to detect body heat of survivors), an ultrasonic or LIDAR sensor (to map obstacles and navigate rubble), a microphone (to detect voices or tapping), and a gas sensor (to detect dangerous gas leaks)
145. C — Metal is a conductor that lets the charge jump to it, while wood is an insulator
146. A — Connect one wire from the battery's positive terminal to one side of the switch, a second wire from the other side of the switch to the motor, and a third wire from the motor back to the battery's negative terminal
147. 6 amps (total resistance is 2 ohms, so I = 12V ÷ 2Ω = 6A)
148. The classification is incorrect. In circuit terminology, 'input' and 'output' refer to information flow, not energy flow. A motor is an output device because it receives a control signal from the system and produces a physical result.

149. Low-fidelity prototypes are cheap, fast to build, and let you test basic concepts early. It is better to discover major problems in a cardboard model than in an expensive functional prototype.

150. Define what the project should do, list all inputs (sensors/buttons) and outputs (LEDs/motors), draw a circuit diagram, and outline the program logic in pseudocode or a flowchart
Matching (Electricity Basics): 1→C, 2→D, 3→A, 4→B, 5→E

151. D — Build a simple circuit with a battery, wires, and a light bulb, then place each material in a gap in the circuit to see if the bulb lights up

152. A — Connect a battery, a light bulb, and two wires with a gap between them where you can place test materials

153. A — In parallel, each bulb receives the full battery voltage on its own branch; in series, bulbs must share the voltage

154. D — No, binary 100 equals 4 in decimal. Each position in binary doubles in value (1, 2, 4, 8...), it does not increase by 1

155. A — A situation where improving one aspect of a design requires accepting a compromise in another aspect

156. D — The argument is flawed because learning microcontroller programming teaches computational thinking, problem-solving, and hardware-software integration skills that apps cannot replace. Many real-world systems (medical devices, vehicles, factories) run on microcontrollers, not phone apps.

157. Moisture in the air conducts the static charge away before it can build up

158. Connect the positive end of the battery to one terminal of the switch with a wire, connect the other terminal of the switch to the buzzer, and connect the buzzer back to the negative end of the battery. Flipping the switch opens or closes the circuit to turn the buzzer on or off.

159. 6 volts each, because every branch in a parallel circuit receives the full source voltage

160. An AND gate, because it outputs 1 only when both inputs are 1
Matching (Electricity Basics): 1→B, 2→D, 3→A, 4→E, 5→C

161. A closed circuit! An open circuit has a break that stops the flow of electricity.

162. Voltage! It's the electrical potential difference between two points.

163. An LED (light-emitting diode)! The longer leg is the positive side (anode).

164. Electric current! One amp equals about 6.24 quintillion electrons passing a point per second.
165. Ohm's law! If you know any two values, you can calculate the third.
166. A series circuit! The current has only one path to follow.
167. A parallel circuit! Current has multiple paths to follow.
168. A resistor! The colored bands are a code for the resistance value.
169. It couldn't stop charging into situations!
170. "You shall not pass! ...well, not all of you, anyway."
171. It felt like the relationship had no spark!
172. Heavy metal -- it's a great conductor!
173. It just didn't have the capacity -- it was too thin and had too much resistance!
174. "I'm the one who turns you on!"
