Heatforge — Activity Book

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

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

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1. Temperature & Thermal Energy Basics

Circle the correct answer

1. What does a thermometer measure?
(A) How much energy an object can absorb (B) Temperature, which is a measure of the average kinetic energy of particles in a substance (C) The total amount of heat in an object (D) The weight of particles inside a substance

2. What is the freezing point of water on the Celsius scale?
(A) 32 degrees Celsius (B) 0 degrees Celsius (C) 100 degrees Celsius (D) −10 degrees Celsius

3. What is thermal energy?
(A) Energy stored in chemical bonds (B) The temperature reading on a thermometer (C) The total kinetic energy of all the moving particles in a substance (D) The amount of light an object gives off

4. On the Fahrenheit scale, what temperature does water boil at under normal conditions?
(A) 212 degrees Fahrenheit (B) 100 degrees Fahrenheit (C) 250 degrees Fahrenheit (D) 180 degrees Fahrenheit

5. What is the Kelvin scale used for?
(A) Measuring absolute temperature starting from absolute zero, where all particle motion would stop (B) Measuring the brightness of light, as this directly follows from the underlying principles (C) Measuring the weight of gases, and this is the standard approach used in most cases (D) Measuring heat in cooking recipes, and this is the standard approach used in most cases

6. Why does a large pot of boiling water have more thermal energy than a small cup of boiling water, even though they are at the same temperature?
(A) Because the large pot has heavier particles (B) Because the stove adds extra energy to larger containers (C) Because the large pot is hotter than the cup (D) Because the large pot has more water particles, so the total kinetic energy of all particles is greater

Write the answer

7. How do particles in a hot solid behave differently from particles in a cold solid?
Answer: _____

8. If you place a metal spoon in a cup of hot cocoa, why does the spoon handle eventually feel warm?
Answer: _____

9. Why does a swimming pool feel cooler than the air on a hot summer day, even though both have been in the sun?
Answer: _____

10. What happens to particle motion when a gas is cooled down?
Answer: _____

Match each question to its answer

1. You have two identical cups: one with 200 mL of water at 80°C and one with 200 mL of water at 20°C. If you mix them, approximately what temperature will the mixture be? →
2. A student wants to keep a drink cold for lunch. Which container should they choose? →
3. A weather report says tomorrow will be 95°F. What is this temperature approximately in Celsius? (Use: °C = (°F − 32) × 5/9) →
4. You place an ice cube on a wooden cutting board and another on a metal baking sheet. Both are at room temperature. Which melts faster and why? →
5. If you are feeling cold outside and put on a winter coat, does the coat add heat to your body? →

(A) No, the coat traps your body heat and slows down heat loss to the cold air, making you feel warmer
(B) The ice cube on the metal baking sheet melts faster because metal conducts heat to the ice more quickly than wood does
(C) About 35°C
(D) About 50°C, because the thermal energy averages out between the two equal amounts
(E) An insulated thermos, because it slows down heat transfer between the drink and the warmer surroundings

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2. Heat Transfer Methods

Circle the correct answer

11. What are the three main methods of heat transfer?
(A) Conduction, convection, and radiation (B) Evaporation, condensation, and precipitation (C) Friction, gravity, and magnetism (D) Absorption, reflection, and refraction

12. Which heat transfer method requires direct physical contact between particles?
(A) Convection (B) Evaporation (C) Conduction (D) Radiation

13. How does the Sun's energy reach Earth through the vacuum of space?
(A) Through convection currents in the solar wind (B) Through conduction by particles in space (C) Through sound waves between planets (D) Through radiation — electromagnetic waves that do not require matter to travel

14. What is convection?
(A) The transfer of heat through solid materials, and this principle applies across similar situations (B) The transfer of heat by electromagnetic waves, which is why this approach is recommended by experts (C) The transfer of heat through the bulk movement of fluids as warmer, less dense portions rise and cooler, denser portions sink (D) The transfer of heat by chemical reactions, which is why this approach is recommended by experts

15. Which heat transfer type makes warm air from a heater rise to the ceiling?
(A) Conduction, because air particles touch each other (B) Radiation, because the heater emits infrared waves (C) Convection, because heated air becomes less dense and rises (D) Evaporation, because the heater vaporizes moisture

16. Why can you feel warmth from a campfire several meters away with no wind?
(A) Invisible sparks fly from fire and hit your skin (B) The fire emits infrared radiation — electromagnetic waves that travel through air and warm your skin directly (C) Hot air particles travel in a straight line from fire to you (D) Sound waves from the fire carry heat energy

Write the answer

17. Why do cooking pots have metal bodies but plastic or wooden handles?
Answer: _____

18. Why does the second floor of a house tend to be warmer than the first?
Answer: _____

19. Why does layered clothing keep you warmer than a single thick layer?
Answer: _____

20. How does a thermos minimize all three types of heat transfer?
Answer: _____

Match each question to its answer

1. A homeowner paints their roof white to save on cooling costs. Which heat transfer method does this primarily address? →
2. You want to cool hot soup quickly. Which strategy is most effective? →
3. A student places a heater at the top of a fish tank. Will the water heat evenly? →
4. A car dashboard reaches 170°F (77°C) when outside is only 90°F (32°C) on a sunny day. What combination of heat transfer causes this? →
5. An engineer wraps a hot pipe with fiberglass insulation then covers it with aluminum foil. What does each layer primarily reduce? →

(A) Fiberglass reduces conduction and convection by trapping still air; aluminum foil reduces radiation by reflecting infrared energy
(B) Blow across the surface, increasing convective heat loss and evaporation
(C) Radiation passes through glass and heats the dashboard; glass traps heated air inside by reducing convection — the greenhouse effect
(D) Radiation — white reflects more sunlight and absorbs less thermal energy than a dark roof
(E) No — heated water at the top stays there since it is already less dense, preventing efficient convection currents

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3. Conduction in Solids

Circle the correct answer

21. How does thermal energy transfer through a solid by conduction?
(A) Fast-vibrating particles in the hotter region collide with slower neighbors, passing kinetic energy along through the material (B) Heat waves travel through empty spaces between atoms, and this has been consistently demonstrated in practice (C) Particles physically move from hot end to cold end, and this is the standard approach used in most cases (D) The solid melts slightly and flows carry heat, which is why this approach is recommended by experts

22. What is a thermal conductor?
(A) A material that allows thermal energy to pass through it easily and quickly, such as metals (B) A material that generates its own heat (C) A material that blocks all heat transfer (D) A material that only transfers heat in one direction

23. What is a thermal insulator?
(A) A material that only exists in cold environments (B) A material that converts heat into light (C) A material that resists the flow of thermal energy, such as wood, plastic, or rubber (D) A material that absorbs all heat permanently

24. Which metal is the best thermal conductor?
(A) Silver, followed closely by copper and aluminum (B) Iron, because it is the strongest metal (C) Lead, because it is the heaviest common metal (D) Titanium, because it is used in aerospace

25. What is thermal conductivity?
(A) A measure of how well a material conducts heat, expressed as the amount of heat that flows through a given thickness per unit time per degree of temperature difference (B) The temperature at which a material begins to conduct heat, as this directly follows from the underlying principles (C) The speed at which a material changes temperature, and this is the standard approach used in most cases (D) The amount of heat a material can store before getting hot, making this the most widely accepted explanation

26. Why are metals generally better thermal conductors than nonmetals?
(A) Metals are shinier, so they absorb more heat (B) Metals are harder, so heat bounces through faster (C) Metals have free electrons that carry thermal energy much faster than vibrations alone (D) Metals are heavier, so they hold more heat

Write the answer

27. If you heat one end of a copper rod, why does the other end eventually get hot?
Answer: _____

28. Why does a tile bathroom floor feel colder on bare feet than carpet, even though both are at the same temperature?
Answer: _____

29. Why do diamonds conduct heat even better than most metals, despite lacking free electrons?
Answer: _____

30. Why is fiberglass a good insulator even though glass itself is a moderate conductor?
Answer: _____

Match each question to its answer

1. A chef needs a baking sheet with even heat distribution. Should they choose aluminum, glass, or ceramic? →
2. An overheating circuit board gets a copper heat sink with aluminum fins. Why is this combination effective? →
3. You are camping with a thin aluminum pot and a thick cast iron pot. Which boils water faster on a campfire? →
4. Metal studs are installed in wall frames instead of wood studs. How does this affect energy efficiency? →
5. You need to cool a hot laptop quickly. Would placing it on a wooden desk or a marble countertop help more? →

(A) Copper quickly conducts heat away from the chip, and aluminum fins provide large surface area to dissipate heat to the air
(B) A marble countertop — marble conducts heat away from the laptop faster than wood, acting as a heat sink
(C) Aluminum — its high thermal conductivity distributes heat evenly, reducing hot spots
(D) Metal studs create thermal bridges that conduct heat through the wall faster, reducing insulation effectiveness and increasing energy costs
(E) The thin aluminum pot — aluminum conducts heat faster than iron and thin walls transfer heat more quickly

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4. Convection in Fluids

Circle the correct answer

31. What causes convection currents in a fluid?
(A) Magnetic fields push fluid particles in circles, and this is the standard approach used in most cases (B) Pressure from container walls pushes fluid around, and this has been consistently demonstrated in practice (C) Gravity pulls all fluid downward at the same rate, which is the most common explanation for this phenomenon (D) Differences in temperature cause differences in density — warmer, less dense fluid rises while cooler, denser fluid sinks, creating circular flow

32. What is the difference between natural and forced convection?
(A) Natural convection is faster, and this has been consistently demonstrated in practice (B) Natural moves heat up, forced moves it down, and this is the standard approach used in most cases (C) Natural convection only happens in gases, as this is what research and standard practice suggests (D) Natural convection occurs from density differences alone; forced convection uses external force like a fan or pump

33. In which states of matter can convection occur?
(A) Only in liquids because they are denser (B) All three states: solids, liquids, and gases (C) Only in gases because they are lightest (D) Liquids and gases (fluids), because particles must be free to move and flow in bulk

34. What is a convection cell?
(A) A container for storing heated fluids, as this is what research and standard practice suggests (B) A battery converting heat to electricity, and this principle applies across similar situations (C) A single molecule that carries heat upward, which is why this approach is recommended by experts (D) A circular flow pattern where warm fluid rises, travels across, cools and sinks, then returns along the bottom

35. Why does smoke from a candle rise upward?
(A) Gravity repels hot particles upward, and this is the standard approach used in most cases (B) The flame heats surrounding air, making it less dense than cooler air above, so warm air carrying smoke rises by buoyancy (C) Smoke particles are lighter than air molecules, which is the most common explanation for this phenomenon (D) The flame pushes smoke upward with its energy, making this the most widely accepted explanation

36. Why do hot air balloons float?
(A) Wind pushes the balloon upward from below, and this principle applies across similar situations (B) The burner heats air inside the balloon, making it less dense than surrounding cooler air, creating upward buoyant force (C) The flame produces a naturally lighter gas, and this has been consistently demonstrated in practice (D) The fabric is lighter than air, which is the most common explanation for this phenomenon

Write the answer

37. Why does a pot heated from the bottom boil more effectively than one heated from the top?
Answer: _____

38. How do ocean currents act as a global heat conveyor belt?
Answer: _____

39. How does a lava lamp demonstrate convection?
Answer: _____

40. Why does Earth's mantle undergo convection even though it is solid rock?
Answer: _____

Match each question to its answer

1. A room has a radiator on one wall. Where should you place a desk fan to warm the room most effectively? →
2. Should you put a hot pot of soup directly in the fridge or cool it first in an ice bath? →
3. During a house fire, why are people told to crawl low to the ground? →
4. Why do you stir a pot of soup while heating it on the stove? →
5. How does a convection oven cook food differently from a conventional oven? →

(A) Hot toxic smoke rises by convection and collects near the ceiling, so air nearest the floor is cooler, cleaner, and more breathable
(B) Cool it first in an ice bath — the ice bath provides much faster convective cooling and avoids warming other food in the fridge
(C) Stirring creates forced convection that distributes heat evenly, preventing the bottom from overheating while the top stays cool
(D) A built-in fan circulates hot air, creating forced convection that transfers heat more evenly and about 25-30% more efficiently
(E) Near the floor pointing toward the radiator, pushing cool floor-level air toward the heater to accelerate the natural convection cycle

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5. Radiation & Electromagnetic Energy

Circle the correct answer

41. What is thermal radiation?
(A) Energy that requires air molecules to transfer, and this principle applies across similar situations (B) Sound waves that carry thermal energy, and this is the standard approach used in most cases (C) Heat that travels only through solids, which is the most common explanation for this phenomenon (D) The transfer of energy through electromagnetic waves, primarily infrared, that can travel through empty space without needing matter

42. What part of the electromagnetic spectrum is most associated with thermal energy?
(A) Visible light (B) Radio waves (C) X-rays (D) Infrared radiation

43. What is emissivity?
(A) The speed at which radiation travels, as this directly follows from the underlying principles (B) The color of an object, which is why this approach is recommended by experts (C) The temperature at which an object starts to glow, which is why this approach is recommended by experts (D) A measure of how efficiently a surface emits thermal radiation compared to a perfect black body, ranging from 0 to 1

44. What is the Stefan-Boltzmann law in simple terms?
(A) Energy radiated is proportional to the object's mass, making this the most widely accepted explanation (B) Radiation energy depends only on the object's color, and this principle applies across similar situations (C) Hotter objects always radiate less energy, as this is what research and standard practice suggests (D) The total energy radiated by an object increases rapidly with temperature — specifically, it is proportional to the fourth power of the object's absolute temperature

45. What is a black body in physics?
(A) A body that only emits visible light, and this principle applies across similar situations (B) An object that absorbs no radiation, making this the most widely accepted explanation (C) An idealized object that absorbs all incoming electromagnetic radiation and emits the maximum possible radiation at every wavelength for its temperature (D) A body that is painted black, and this is the standard approach used in most cases

46. Why do we feel warmth from the Sun even though space between us is a vacuum?
(A) Solar wind pushes warm gases toward Earth, and this principle applies across similar situations (B) Hot particles from the Sun fly through space to reach us, and this principle applies across similar situations (C) The Sun emits electromagnetic radiation (including infrared and visible light) that travels through the vacuum at the speed of light and is absorbed by our skin, converting to thermal energy (D) Sound waves from the Sun vibrate air molecules on Earth, which is the most common explanation for this phenomenon

Write the answer

47. Why do objects glow different colors as they get hotter (red, then orange, then white)?
Answer: _____

48. Why does a silver or shiny surface stay cooler in sunlight than a dark matte surface?
Answer: _____

49. Why can you get sunburned on a cloudy day?
Answer: _____

50. Why does Earth's atmosphere act like a greenhouse, trapping heat?
Answer: _____

Match each question to its answer

1. A homeowner installs a radiant barrier (reflective foil) in their attic. How does this reduce cooling costs? →
2. An infrared thermometer measures surface temperature by detecting emitted infrared radiation. Why might it give an inaccurate reading on a shiny stainless steel surface? →
3. Firefighters wear reflective silver-colored suits when approaching intense fires. How does this protect them? →
4. Why do climate scientists use satellites to measure Earth's radiation budget? →
5. Desert peoples traditionally wear dark robes despite intense sun. Wouldn't white clothing be cooler? →

(A) The highly reflective surface reflects most of the intense infrared radiation emitted by the fire, reducing radiant heat absorption
(B) The reflective foil reflects infrared radiation from the hot roof back outward instead of allowing it to radiate down into the attic space, keeping the attic cooler
(C) Shiny metal has very low emissivity, so it emits much less infrared than its temperature would suggest, making the thermometer read too low
(D) Satellites can measure both incoming solar radiation and outgoing infrared radiation from Earth, revealing whether the planet is gaining or losing energy overall
(E) Research shows dark robes absorb more solar radiation, but this heats the outer fabric which then drives stronger convection between the robe and body, pulling cool air upward through the loose garment — the net effect is similar to white robes

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6. Insulation & Thermal Design

Circle the correct answer

51. What is R-value in building insulation?
(A) The weight of insulation per square meter (B) The temperature at which insulation melts (C) A measure of a material's resistance to heat flow — higher R-values mean better insulation (D) The rate at which heat passes through a material

52. What is U-value and how does it relate to R-value?
(A) U-value measures ultraviolet light transmission, as this is what research and standard practice suggests (B) U-value measures how quickly a material heats up, as this is what research and standard practice suggests (C) U-value is the same as R-value but in metric units, making this the most widely accepted explanation (D) U-value measures how easily heat passes through a material — it is the inverse of R-value (U = 1/R), so lower U-values mean better insulation

53. What is a thermal bridge?
(A) A device that connects two heat sources, and this has been consistently demonstrated in practice (B) A bridge made of heat-resistant materials, as this is what research and standard practice suggests (C) A path of high thermal conductivity in an insulated building envelope that allows heat to bypass the insulation (D) A type of thermometer used in construction, and this principle applies across similar situations

54. Name three common types of building insulation materials.
(A) Fiberglass batts, spray foam, and cellulose (or mineral wool, rigid foam board) (B) Plastic bags, cardboard, and newspaper, as this is what research and standard practice suggests (C) Aluminum, copper, and brass, and this has been consistently demonstrated in practice (D) Concrete, steel, and glass, as this directly follows from the underlying principles

55. What makes air a good insulator?
(A) Air has no mass so heat cannot exist in it, which is why this approach is recommended by experts (B) Air has very low thermal conductivity (0.025 W/m•K), about 1000 times less than metals, because gas molecules are far apart and collide infrequently (C) Air blocks radiation completely, and this has been consistently demonstrated in practice (D) Air is actually a poor insulator, as this is what research and standard practice suggests

56. Why does spray foam insulation have a higher R-value per inch than fiberglass?
(A) Spray foam is a darker color that absorbs less heat, making this the most widely accepted explanation (B) Spray foam has metal particles that reflect radiation, and this principle applies across similar situations (C) Spray foam is heavier than fiberglass, which is the most common explanation for this phenomenon (D) Spray foam traps gas in closed cells that are smaller and more uniformly distributed than fiberglass air pockets, and the trapped gas (often HFC or CO_2) has lower conductivity than air

Write the answer

57. How do double-pane windows reduce heat loss compared to single-pane windows?
Answer: _____

58. Why are passive house designs oriented to maximize south-facing windows in the Northern Hemisphere?
Answer: _____

59. Why is thermal mass important in building design?
Answer: _____

60. What is a vapor barrier and why is it important in insulated walls?
Answer: _____

Match each question to its answer

1. An older house has R-11 wall insulation. Adding rigid foam board (R-5 per inch) on the exterior would cost $3,000. How much insulation should be added to reach R-19, and why is continuous exterior insulation effective? →
2. A homeowner in Arizona wants to reduce summer cooling costs. Should they prioritize attic insulation or wall insulation? →
3. You are designing a portable cooler for a camping trip. Which combination of materials would keep ice frozen longest? →
4. A building inspector recommends adding weather stripping to doors and windows. How does this improve energy efficiency? →
5. You need to insulate a hot water pipe in an unheated basement. What combination of materials and design would be most effective? →

(A) Attic insulation, because the roof receives the most direct solar radiation and hot air rises, making the attic the largest source of heat gain in summer
(B) Weather stripping seals air gaps that allow warm indoor air to escape and cold outdoor air to infiltrate, reducing heat loss from air leakage which can account for 25-40% of heating and cooling costs
(C) Wrap with tubular foam insulation (for conduction resistance), cover with reflective tape or foil (for radiation resistance), and ensure no gaps at joints (to prevent convection through exposed pipe)
(D) Need R-8 more, so about 1.6 inches of rigid foam. Exterior insulation is effective because it covers studs and other thermal bridges that interior insulation cannot address
(E) Thick Styrofoam walls (for low conductivity), reflective foil lining (to reduce radiation), and a tight-sealing lid (to prevent convection and moisture exchange)

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7. Phase Changes & Latent Heat

Circle the correct answer

61. What is the term for the process where a solid changes directly into a gas without becoming a liquid first?
(A) Deposition (B) Evaporation (C) Condensation (D) Sublimation

62. What are the three common states of matter?
(A) Solid, liquid, and plasma (B) Gas, plasma, and liquid (C) Solid, liquid, and gas (D) Solid, gas, and plasma

63. What is the phase change called when a gas turns into a liquid?
(A) Condensation (B) Evaporation (C) Freezing (D) Melting

64. What is the name for the energy absorbed or released during a phase change?
(A) Kinetic energy (B) Thermal energy (C) Specific heat (D) Latent heat

65. At what temperature does pure water freeze at standard atmospheric pressure?
(A) -10 degrees Celsius (B) 100 degrees Celsius (C) 32 degrees Fahrenheit only (D) 0 degrees Celsius

66. Why does the temperature of water stay at 100 degrees Celsius while it is boiling, even though heat is still being added?
(A) The added energy is used to break intermolecular bonds rather than increase temperature (B) The thermometer stops working at boiling point (C) The water cannot absorb any more heat (D) The energy escapes into the air immediately

Write the answer

67. How does adding salt to ice lower the freezing point of water?
Answer: _____

68. Why does sweating help cool your body?
Answer: _____

69. What happens to the arrangement of molecules when a solid melts into a liquid?
Answer: _____

70. Why does water expand when it freezes, unlike most other substances?
Answer: _____

Match each question to its answer

1. A pot of water is heated from 20 degrees Celsius to 100 degrees Celsius and then continues to boil. During which part of this process is latent heat being absorbed? →
2. If the latent heat of fusion for water is 334 joules per gram, how much energy is needed to melt 10 grams of ice at 0 degrees Celsius? →
3. You place a glass of ice water outside on a humid summer day. Why do water droplets form on the outside of the glass? →
4. A student heats a block of ice steadily and records the temperature over time. The graph shows a flat section at 0 degrees Celsius. What is happening during this flat section? →
5. Mountain climbers notice that water boils at a lower temperature at high altitudes. How does this affect cooking time? →

(A) During the boiling phase when the temperature stays at 100 degrees Celsius
(B) The ice is melting and absorbing latent heat without a temperature increase
(C) 3,340 joules
(D) Food takes longer to cook because the boiling water is at a lower temperature
(E) Water vapor in the warm air condenses when it contacts the cold glass surface

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8. Thermodynamics Laws & Applications

Circle the correct answer

71. What does the first law of thermodynamics state?
(A) Heat always flows from cold to hot objects (B) Energy is always lost as friction in any process (C) Energy cannot be created or destroyed, only transferred or transformed (D) All systems eventually reach absolute zero

72. What does the second law of thermodynamics describe?
(A) Energy can be created from nothing under certain conditions (B) Heat naturally flows from hotter objects to cooler objects, and entropy tends to increase (C) Cold objects spontaneously become hotter over time (D) All energy transformations are 100 percent efficient

73. What is entropy?
(A) The total amount of heat in a substance (B) The speed at which molecules move (C) A measure of the disorder or randomness in a system (D) The pressure inside a closed container

74. What is the zeroth law of thermodynamics?
(A) If two systems are each in thermal equilibrium with a third system, they are in thermal equilibrium with each other (B) Heat always flows from hot to cold, and this is the standard approach used in most cases (C) Energy cannot be created or destroyed, as this is what research and standard practice suggests (D) Absolute zero cannot be reached in a finite number of steps, which is the most common explanation for this phenomenon

75. What is thermal equilibrium?
(A) When two objects have the same mass (B) When all molecular motion stops completely (C) The state when two objects in contact reach the same temperature and no net heat flows between them (D) When an object reaches its maximum possible temperature

76. Why is it impossible to build a machine that converts 100 percent of heat energy into useful work?

(A) The first law of thermodynamics prohibits energy conversion (B) The second law of thermodynamics requires that some energy is always lost as waste heat to a cooler reservoir (C) Friction can be completely eliminated with better materials (D) We lack the technology to build precise enough machines

Write the answer

77. How does a refrigerator appear to violate the second law of thermodynamics by moving heat from a cold interior to a warmer room?

Answer: _____

78. Why does a cup of hot coffee eventually cool to room temperature but never spontaneously reheat itself?

Answer: _____

79. What is the relationship between the first law of thermodynamics and the law of conservation of energy?

Answer: _____

80. Why does blowing on hot soup cool it down?

Answer: _____

Match each question to its answer

1. A heat engine absorbs 500 joules of heat from a hot source and exhausts 350 joules to a cold sink. What is the efficiency of this engine? →
2. A 200-gram block of aluminum at 80 degrees Celsius is placed in 300 grams of water at 20 degrees Celsius in an insulated container. Using the first law of thermodynamics, what can you predict about the final temperature? →
3. You rub your hands together vigorously on a cold day and they feel warmer. Explain this using the first law of thermodynamics. →
4. A car engine operates between combustion temperatures of about 2,000 degrees Celsius and an exhaust temperature of about 500 degrees Celsius. Using the Carnot efficiency formula, what is the maximum theoretical efficiency? →
5. An insulated thermos contains hot coffee. Over several hours, the coffee cools slightly. Does this violate the first law of thermodynamics? →

(A) 30 percent

(B) No, the energy is not destroyed — it slowly leaks through the imperfect insulation to the surroundings

(C) Approximately 66 percent

(D) Mechanical work from friction is converted into thermal energy, increasing the

internal energy of your hands
(E) The final temperature will be between 20 and 80 degrees Celsius, closer to 20 because water has a higher specific heat and greater mass

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9. Heat & Energy

Circle the correct answer

81. What are the three common states of matter?
(A) Solid, vapor, and plasma (B) Solid, liquid, and gas (C) Solid, liquid, and plasma (D) Gas, plasma, and liquid

82. What is the process called when a solid changes directly into a gas without becoming a liquid first?
(A) Condensation (B) Deposition (C) Sublimation (D) Evaporation

83. At what temperature does pure water boil at standard atmospheric pressure?
(A) 100°C (212°F) (B) 110°C (230°F) (C) 80°C (176°F) (D) 90°C (194°F)

84. What is the term for the heat energy required to change a substance from solid to liquid at its melting point?
(A) Specific heat capacity (B) Thermal conductivity (C) Latent heat of vaporization (D) Latent heat of fusion

85. What is the reverse process of sublimation, when a gas changes directly into a solid?
(A) Freezing (B) Condensation (C) Deposition (D) Crystallization

86. What is the name for the temperature at which a solid begins to melt?
(A) Dew point (B) Flash point (C) Boiling point (D) Melting point

Write the answer

87. Why does the temperature of water stay at 100°C while it is boiling, even though heat is still being added?
Answer: _____

88. How does the arrangement of particles differ between a solid and a gas?
Answer: _____

89. Why does sweating help cool your body down?
Answer: _____

90. Why does adding salt to ice lower the melting point of the ice?
Answer: _____

Match each question to its answer

1. What happens to the volume of most substances when they change from liquid to gas? →
2. A puddle of water disappears on a warm, sunny day even though the temperature never reaches 100°C. What process explains this? →
3. You take a cold glass of lemonade outside on a humid summer day and water droplets form on the outside of the glass. What phase change is occurring? →
4. A scientist heats 500 grams of ice at 0°C. If the latent heat of fusion for water is 334 J/g, how much energy is needed to melt all the ice? →
5. A metal spoon left in a hot cup of soup quickly becomes too hot to touch, while a wooden spoon stays cool. Which property of the metal explains this? →

(A) Evaporation
(B) Condensation
(C) 167,000 J
(D) High thermal conductivity
(E) The volume increases significantly

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10. Heat & Energy

Circle the correct answer

91. What does the R-value of an insulation material measure?
(A) Its moisture absorption rate (B) Its flammability rating (C) Its weight per square foot (D) Its resistance to heat flow

92. What does HVAC stand for?
(A) Heating, Ventilation, and Air Conditioning (B) Heat, Vacuum, and Air Control (C) Home Ventilation and Air Circulation (D) Hydraulic Ventilation and Cooling

93. Which type of material is the best conductor of heat: metal, wood, or plastic?
(A) Metal (B) Wood (C) Plastic (D) They all conduct heat equally

94. What is a thermostat used for in a building?
(A) To generate electricity for the building (B) To monitor and regulate indoor temperature by controlling the heating or cooling system (C) To purify the air inside a building (D) To measure outdoor weather conditions

95. What is the term for heat transfer through direct contact between materials?
(A) Insulation (B) Convection (C) Radiation (D) Conduction

96. What common household material is used as insulation in many home walls?
(A) Aluminum foil (B) Concrete (C) Fiberglass (D) Steel beams

Write the answer

97. Why do double-pane windows insulate better than single-pane windows?
Answer: _____

98. Why are many hot water pipes wrapped in foam insulation?
Answer: _____

99. How does a thermos (vacuum flask) keep drinks hot or cold for hours?
Answer: _____

100. Why do builders place insulation in the attic of a house rather than only in the walls?
Answer: _____

Match each question to its answer

1. What role does color play in how much heat a surface absorbs from sunlight? →
2. A homeowner wants to reduce their heating bill. Their house has R-11 insulation in the walls and R-19 in the attic. An energy auditor recommends upgrading the attic to R-38. Why would the attic upgrade save more energy than upgrading the walls? →
3. An engineer is designing a portable cooler. She chooses white plastic for the exterior and lines the inside with reflective foil and thick foam. Explain how each material helps keep the contents cold. →
4. During winter, you notice that a metal doorknob feels much colder than the wooden door, even though both are at the same room temperature. Using your knowledge of thermal conductivity, explain why. →
5. A student wraps one cup of hot water in aluminum foil and another in a wool sock. After 30 minutes, the water in the wool sock is warmer. Explain why wool was the better insulator. →

(A) Dark colors absorb more radiant heat than light colors, which reflect more sunlight
(B) Wool traps air in its fibers, which resists heat transfer by conduction and convection; aluminum foil conducts heat quickly
(C) The attic loses the most heat because hot air rises, so improving attic insulation has the greatest impact on reducing overall heat loss
(D) Metal has high thermal conductivity, so it rapidly draws heat away from your

hand, making it feel cold; wood conducts heat slowly
(E) White exterior reflects solar radiation; reflective foil reduces radiant heat transfer inward; foam slows conduction from warm outside air

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11. Heat & Energy

Circle the correct answer

101. What does the First Law of Thermodynamics state?
(A) All energy eventually becomes useless (B) Energy always flows from cold to hot (C) Energy cannot be created or destroyed, only transferred or transformed (D) Heat always moves in a circle

102. What is entropy?
(A) A measure of the disorder or randomness in a system (B) A measure of the temperature of a system (C) The total energy in a system (D) The speed at which heat flows

103. What does the Second Law of Thermodynamics state about the direction of heat flow?
(A) Heat naturally flows from hot objects to cold objects, never the reverse without external energy input (B) Heat flows from cold to hot naturally, as this directly follows from the underlying principles (C) Heat only flows when pushed by gravity, which is why this approach is recommended by experts (D) Heat flows equally in all directions, which is why this approach is recommended by experts

104. What is a heat engine?
(A) A device that converts thermal energy into mechanical work (B) A device that only transfers heat without doing work (C) A machine that creates heat from nothing (D) A tool used to measure temperature

105. What is the term for a process where no heat enters or leaves the system?
(A) Isochoric process (B) Isobaric process (C) Adiabatic process (D) Isothermal process

106. What is thermal equilibrium?
(A) The state when two objects in contact reach the same temperature and heat stops flowing between them (B) When an object reaches its maximum possible temperature (C) When all heat in a system disappears (D) When two objects are the same size

Write the answer

107. Why can no heat engine ever be 100% efficient?
Answer: _____

108. When you rub your hands together, they feel warm. Explain this in terms of the First Law of Thermodynamics.
Answer: _____

109. Why does an ice cube melt when placed on a warm countertop, and why doesn't the countertop freeze instead?
Answer: _____

110. How does a refrigerator seem to violate the Second Law by moving heat from a cold interior to a warm room?
Answer: _____

Match each question to its answer

1. Why does a brand-new deck of cards (sorted by suit and number) represent low entropy, while a shuffled deck represents high entropy? →
2. A car engine burns gasoline and converts about 25% of the fuel's chemical energy into motion. What happens to the other 75%? →
3. You mix hot water (80°C) with cold water (20°C) in an insulated container. Using the concept of thermal equilibrium, predict what will happen. →
4. A steam power plant heats water to 500°C and exhausts waste heat at 100°C. Using these temperatures, explain why the plant cannot be 100% efficient. →
5. An inventor claims to have built a machine that runs forever without any energy input. Using the laws of thermodynamics, explain why this is impossible. →

(A) It is converted to waste heat released through the exhaust and cooling system, consistent with the Second Law of Thermodynamics
(B) The First Law says you cannot create energy from nothing, and the Second Law says some energy is always lost as waste heat — so the machine must eventually stop
(C) The Second Law requires that some heat be rejected to the cold reservoir; the maximum theoretical efficiency depends on the temperature ratio and will always be less than 100%
(D) Heat will flow from the hot water to the cold water until both reach the same intermediate temperature (close to 50°C if equal volumes), and then heat flow stops
(E) The sorted deck has one specific arrangement (high order), while the shuffled deck could be in any of billions of possible arrangements (high disorder)

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12. Heat & Energy

Circle the correct answer

111. What is the greenhouse effect?
(A) The process by which certain gases in Earth's atmosphere trap heat from the Sun, keeping the planet warm enough to support life (B) The process of heat escaping from Earth into space (C) The cooling effect of clouds reflecting sunlight (D) The effect of growing plants in greenhouses on global temperature

112. What is geothermal energy?
(A) Heat energy from inside the Earth, generated by radioactive decay and residual heat from the planet's formation (B) Energy stored in ocean waves, which is why this approach is recommended by experts (C) Energy produced by earthquakes, and this principle applies across similar situations (D) Energy from the Sun reflected off the ground, making this the most widely accepted explanation

113. Which gas is the most abundant greenhouse gas produced by human activities?
(A) Methane (CH_4) (B) Carbon dioxide (CO_2) (C) Ozone (O_3) (D) Nitrous oxide (N_2O)

114. What is the primary source of energy that drives Earth's climate system?
(A) Heat from volcanic activity (B) Energy from ocean tides (C) Geothermal energy from Earth's core (D) The Sun

115. What are the three main greenhouse gases in Earth's atmosphere?
(A) Carbon dioxide (CO_2), methane (CH_4), and water vapor (H_2O) (B) Oxygen, nitrogen, and argon (C) Ozone, carbon monoxide, and sulfur dioxide (D) Hydrogen, helium, and neon

116. What happens to most of the solar energy that reaches Earth's surface?
(A) It is permanently stored in rocks (B) It is immediately reflected back to space (C) It passes through the Earth and exits the other side (D) It is absorbed by land and oceans, which then re-emit it as infrared radiation (heat)

Write the answer

117. Why do oceans play such an important role in regulating Earth's climate?
Answer: _____

118. How does the greenhouse effect become a problem when it is enhanced by human activities?
Answer: _____

119. Why does Earth's surface temperature vary so much between day and night in a desert but very little near the ocean?
Answer: _____

120. How do ocean currents help distribute heat around the planet?
Answer: _____

Match each question to its answer

1. Why does adding more CO_2 to the atmosphere increase the amount of heat trapped near Earth's surface? →
2. Iceland uses geothermal energy to heat nearly 90% of its homes. Given that Iceland sits on a tectonic boundary, explain why geothermal energy is especially accessible there. →
3. A coastal city and an inland city are at the same latitude. Predict which city will have hotter summers and colder winters, and explain using specific heat capacity. →
4. Scientists measure that Earth absorbs 240 watts per square meter of solar energy on average. If greenhouse gases cause Earth to temporarily radiate less than 240 W/m^2 back to space, what happens to Earth's temperature? →
5. A city plans to reduce urban heat by replacing dark asphalt parking lots with light-colored concrete and planting trees. Explain how each change reduces heat using heat transfer principles. →

(A) Iceland sits on the Mid-Atlantic Ridge where tectonic plates are pulling apart, bringing hot magma close to the surface and heating underground water that can be pumped up for heating
(B) Light-colored concrete reflects more solar radiation (reducing absorption); trees provide shade (blocking radiation) and cool the air through evapotranspiration (evaporative cooling)
(C) Earth's temperature increases because more energy is being absorbed than radiated away, creating an energy imbalance
(D) More CO_2 molecules absorb and re-emit more infrared radiation, reducing the amount of heat that escapes to space
(E) The inland city will have hotter summers and colder winters because land has lower specific heat capacity and changes temperature more quickly than ocean water near the coastal city

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13. Temperature & Thermal Energy Basics

Circle the correct answer

121. A student touches a metal railing and a rubber grip on the same railing on a cold morning. Both have been outside all night. Which feels colder and why?
(A) The metal part feels colder because it conducts heat away from your hand faster, even though both are the same temperature — our touch senses heat flow rate, not

true temperature (B) Both feel exactly the same because they are the same temperature (C) The rubber grip feels colder because rubber stores more cold energy (D) The metal is actually at a lower temperature because metals cool faster

122. Why does layered clothing keep you warmer than a single thick layer?
(A) Multiple layers weigh more, generating more body heat (B) Layers trap pockets of still air that act as insulation, reducing heat loss by convection and conduction (C) Each layer reflects heat like a mirror (D) Layers compress air so tightly particles cannot move

123. What is thermal conductivity?
(A) The amount of heat a material can store before getting hot, making this the most widely accepted explanation (B) The speed at which a material changes temperature, and this is the standard approach used in most cases (C) The temperature at which a material begins to conduct heat, as this directly follows from the underlying principles (D) A measure of how well a material conducts heat, expressed as the amount of heat that flows through a given thickness per unit time per degree of temperature difference

124. A low-pressure system forms over warm ocean. Using convection, explain how it can intensify into a tropical storm.
(A) Warm ocean heats air above it, which rises rapidly creating low pressure. Surrounding air rushes in, gets heated and moist, rises, and releases latent heat when moisture condenses — this strengthens the convective cycle (B) Ocean waves create low pressure, making this the most widely accepted explanation (C) Cold polar air collides with warm ocean air, which is the most common explanation for this phenomenon (D) Underwater volcanic activity creates surface winds, as this directly follows from the underlying principles

125. Why does Earth's atmosphere act like a greenhouse, trapping heat?
(A) Certain gases (CO_2, methane, water vapor) are transparent to incoming visible solar radiation but absorb and re-emit outgoing infrared radiation from Earth's surface, trapping heat (B) The atmosphere is made of glass-like material, and this principle applies across similar situations (C) The ozone layer reflects all heat back to the surface, and this is the standard approach used in most cases (D) Gravity prevents heat from escaping into space, and this principle applies across similar situations

126. How do double-pane windows reduce heat loss compared to single-pane windows?
(A) The sealed air or gas gap between two panes creates a low-conductivity barrier that reduces conduction and prevents convection between the glass layers (B) The space between panes creates a vacuum, and this is the standard approach used in most cases (C) Two layers of glass are harder for heat to conduct through, and this

has been consistently demonstrated in practice (D) The inner pane reflects all heat back inside, and this is the standard approach used in most cases

Write the answer

127. Propose a design for a thermal energy storage system that uses phase change materials to store heat during the day and release it at night for home heating. What properties should the phase change material have?
Answer: _____

128. A car engine operates between combustion temperatures of about 2,000 degrees Celsius and an exhaust temperature of about 500 degrees Celsius. Using the Carnot efficiency formula, what is the maximum theoretical efficiency?
Answer: _____

129. Design a simple experiment to show that dark-colored objects absorb more thermal energy from sunlight than light-colored objects.
Answer: _____

130. How does a thermos minimize all three types of heat transfer?
Answer: _____

Match each question to its answer

1. You need to cool a hot laptop quickly. Would placing it on a wooden desk or a marble countertop help more? →
2. Why does a pot heated from the bottom boil more effectively than one heated from the top? →
3. Earth emits infrared radiation continuously but does not cool down to the temperature of space (−270°C). Why does our planet maintain a relatively stable temperature? →
4. What is a vapor barrier and why is it important in insulated walls? →
5. Mountain climbers notice that water boils at a lower temperature at high altitudes. How does this affect cooking time? →

(A) Earth receives a continuous supply of solar radiation that balances its infrared emissions, and greenhouse gases trap some outgoing radiation, maintaining equilibrium at about 15°C
(B) Food takes longer to cook because the boiling water is at a lower temperature
(C) A marble countertop — marble conducts heat away from the laptop faster than wood, acting as a heat sink
(D) Bottom heating allows warm water to rise and cool water to sink naturally, creating efficient convection throughout
(E) A moisture-resistant layer that prevents warm humid indoor air from reaching

cold surfaces inside the wall where it would condense, potentially causing mold and degrading insulation

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14. Temperature & Thermal Energy Basics

Circle the correct answer

131. In an experiment, equal amounts of water and vegetable oil are heated with the same source. The oil reaches 60°C while water only reaches 40°C. What explains this?
(A) Oil is hotter because it is thicker than water (B) Water has a higher specific heat capacity than oil, meaning it requires more energy to increase in temperature by the same amount (C) Water lost more heat to the air than oil did, which is the most common explanation for this phenomenon (D) The heat source gave more energy to the oil, as this directly follows from the underlying principles

132. A blanket advertises it 'reflects body heat back to you using NASA technology.' Evaluate this claim's scientific basis.
(A) The claim is completely false because blankets only use conduction (B) The claim is perfectly true because all body heat is radiation (C) The reflective material addresses convection by bouncing air back, and this has been consistently demonstrated in practice (D) The reflective material does reduce radiative heat loss, which is valid, but radiation is only a fraction of body heat loss — conduction and convection are not addressed by reflection alone

133. Stainless steel cookware often has an aluminum or copper core. Why use this layered approach instead of all aluminum?
(A) The layers generate extra heat from friction, as this directly follows from the underlying principles (B) Stainless steel provides durability and a non-reactive cooking surface, while the core provides rapid even heat distribution — combining the best of each (C) Aluminum is too expensive for entire pans, and this principle applies across similar situations (D) Stainless steel makes pans lighter, which is why this approach is recommended by experts

134. In which states of matter can convection occur?
(A) Only in liquids because they are denser (B) Only in gases because they are lightest (C) All three states: solids, liquids, and gases (D) Liquids and gases (fluids), because particles must be free to move and flow in bulk

135. What is a black body in physics?
(A) An object that absorbs no radiation, making this the most widely accepted explanation (B) A body that only emits visible light, and this principle applies across similar situations (C) An idealized object that absorbs all incoming electromagnetic

radiation and emits the maximum possible radiation at every wavelength for its temperature (D) A body that is painted black, and this is the standard approach used in most cases

136. Design an energy-efficient window system for a house in a climate with hot summers and cold winters.
(A) Use single-pane glass with heavy curtains, which is why this approach is recommended by experts (B) Use triple-pane clear glass with no coatings, and this has been consistently demonstrated in practice (C) Use double-pane windows with low-E coating optimized for both seasons: spectrally selective coating transmits visible light but reflects infrared in both directions. Add external overhangs sized so summer sun is blocked but winter sun enters. Use argon gas fill for lower conductivity than air (D) Use small windows on all sides to minimize glass area, and this is the standard approach used in most cases

Write the answer

137. Design an experiment to measure the latent heat of fusion of ice using a calorimeter, a thermometer, warm water, and ice cubes. Describe the procedure and the key measurements you would take.
Answer: _____

138. Analyze why the overall efficiency of a coal power plant is typically only about 33 percent, even though the combustion process releases enormous amounts of energy.
Answer: _____

139. Two metal blocks of the same size and temperature are heated by the same flame for the same time. Block A (aluminum) reaches a higher temperature than Block B (iron). What can you conclude?
Answer: _____

140. Which metal is the best thermal conductor?
Answer: _____

Match each question to its answer

1. A room has a radiator on one wall. Where should you place a desk fan to warm the room most effectively? →
2. Design an experiment to measure whether dark or light colored roofs absorb more solar radiation, using common materials. →
3. Some builders promote 'insulating concrete forms' (ICFs) — concrete poured between foam layers — as having thermal performance equivalent to R-50 walls due to thermal mass effects. Evaluate this claim. →
4. Why does a large pot of boiling water have more thermal energy than a small cup of

boiling water, even though they are at the same temperature? →
5. How does the Sun's energy reach Earth through the vacuum of space? →

(A) Through radiation — electromagnetic waves that do not require matter to travel
(B) Near the floor pointing toward the radiator, pushing cool floor-level air toward the heater to accelerate the natural convection cycle
(C) Because the large pot has more water particles, so the total kinetic energy of all particles is greater
(D) Place identical containers of water under two identical cardboard roofs — one painted black, one white — in direct sunlight. Measure water temperature every 10 minutes for an hour. The darker roof should result in warmer water, demonstrating greater solar radiation absorption
(E) Misleading — ICFs have static R-values of about R-23 to R-26. Thermal mass improves effective performance by moderating temperature swings, but the equivalent R-value in cold climates is closer to R-30, not R-50. The claim exaggerates the thermal mass benefit

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15. Temperature & Thermal Energy Basics

Circle the correct answer

141. Create a temperature scale called 'Student Degrees' where 0 is freezing and 50 is boiling for water. What would body temperature (37°C) be?
(A) 74 Student Degrees because you double the Celsius value (B) 18.5 Student Degrees, because 37°C is 37% of the way from 0 to 100°C, and 37% of 50 is 18.5 (C) 37 Student Degrees because it is the same number (D) 25 Student Degrees because body temperature is about halfway

142. Students debate keeping ice cream frozen during transport. Student A says aluminum foil. Student B says Styrofoam cooler. Who is right?
(A) Both are equally effective, and this has been consistently demonstrated in practice (B) Student A because foil reflects heat away (C) Student A because foil blocks radiation, the main heat source (D) Student B — Styrofoam insulates against all three methods, while aluminum is a conductor that would speed up heat transfer to the ice cream

143. Why do diamonds conduct heat even better than most metals, despite lacking free electrons?
(A) Diamonds are transparent so heat passes through like light, which is why this approach is recommended by experts (B) Diamonds have hidden metallic properties, making this the most widely accepted explanation (C) Diamond has an extremely rigid crystal structure with strong carbon-carbon bonds that transmit vibrations with

very little energy loss (D) Diamonds are so hard that heat cannot escape, and this principle applies across similar situations

144. Why do we feel warmth from the Sun even though space between us is a vacuum? (A) Solar wind pushes warm gases toward Earth, and this principle applies across similar situations (B) The Sun emits electromagnetic radiation (including infrared and visible light) that travels through the vacuum at the speed of light and is absorbed by our skin, converting to thermal energy (C) Sound waves from the Sun vibrate air molecules on Earth, which is the most common explanation for this phenomenon (D) Hot particles from the Sun fly through space to reach us, and this principle applies across similar situations

145. Why are passive house designs oriented to maximize south-facing windows in the Northern Hemisphere?
(A) Southern exposure has lower humidity, which is the most common explanation for this phenomenon (B) The south side receives more wind for natural ventilation, and this principle applies across similar situations (C) South-facing walls are thicker and better insulated, which is the most common explanation for this phenomenon (D) South-facing windows receive maximum solar radiation in winter when the sun is low, providing free heat, while the roof overhang blocks the high summer sun to prevent overheating

146. A company claims its new 'instant ice pack' works by using a chemical that absorbs heat during dissolution. Is this an example of a phase change, and does the principle of latent heat apply?
(A) No, because chemical reactions cannot absorb heat (B) Yes, because any process that absorbs heat involves latent heat (C) Yes, dissolving is a phase change and latent heat applies directly (D) It is not a true phase change but uses an endothermic dissolving process; latent heat specifically applies to changes of state, not dissolution

Write the answer

147. You rub your hands together vigorously on a cold day and they feel warmer. Explain this using the first law of thermodynamics.
Answer: _____

148. Why does a swimming pool feel cooler than the air on a hot summer day, even though both have been in the sun?
Answer: _____

149. What is convection?
Answer: _____

150. Metal studs are installed in wall frames instead of wood studs. How does this affect energy efficiency?
Answer: _____

Match each question to its answer

1. Dense fog over a lake on a cool morning disappears by midday. A student says 'the sun burns it off by evaporation.' Evaluate this explanation. →
2. Why can you get sunburned on a cloudy day? →
3. A thermal image of a house shows bright yellow areas at stud locations behind the siding, but cooler blue areas between studs. What does this pattern reveal about the wall's thermal performance? →
4. A student observes that a puddle of water evaporates on a warm day even though the temperature is well below 100 degrees Celsius. How is this possible? →
5. A student claims that entropy is always bad because it means energy is wasted. Evaluate this statement. →

(A) Some surface molecules have enough kinetic energy to escape the liquid even below the boiling point
(B) Partially correct but incomplete — sunlight heats the ground creating convection currents that mix foggy air with warmer drier air above, dispersing the fog. Direct evaporation plays a secondary role
(C) This is an oversimplification; entropy increase is essential for all natural processes including life, and 'waste' heat often drives important processes like weather and ocean circulation
(D) Ultraviolet radiation from the Sun can penetrate through clouds because clouds primarily block visible light and infrared but allow significant UV to pass through
(E) The studs are thermal bridges — wood has lower R-value than the insulation between studs, so more heat escapes through the framing, appearing warmer on the exterior thermal image

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16. Temperature & Thermal Energy Basics

Circle the correct answer

151. A weather report says tomorrow will be 95°F. What is this temperature approximately in Celsius? (Use: °C = (°F − 32) × 5/9)
(A) About 50°C (B) About 35°C (C) About 25°C (D) About 63°C

152. An overheating circuit board gets a copper heat sink with aluminum fins. Why is this combination effective?
(A) Copper reflects heat while aluminum absorbs it, and this principle applies across

similar situations (B) Copper quickly conducts heat away from the chip, and aluminum fins provide large surface area to dissipate heat to the air (C) Copper absorbs heat and aluminum freezes it, which is why this approach is recommended by experts (D) Two metals create a cooling electric current, as this is what research and standard practice suggests

153. What causes convection currents in a fluid?
(A) Differences in temperature cause differences in density — warmer, less dense fluid rises while cooler, denser fluid sinks, creating circular flow (B) Pressure from container walls pushes fluid around, and this has been consistently demonstrated in practice (C) Gravity pulls all fluid downward at the same rate, which is the most common explanation for this phenomenon (D) Magnetic fields push fluid particles in circles, and this is the standard approach used in most cases

154. What is the relationship between the first law of thermodynamics and the law of conservation of energy?
(A) The first law of thermodynamics replaced the conservation of energy in modern physics (B) They are completely unrelated laws from different branches of science (C) The first law of thermodynamics is the conservation of energy applied specifically to thermal systems and heat transfer (D) The conservation of energy only applies to mechanical systems, not thermal ones

155. A classmate suggests using a standard mercury thermometer to measure the temperature inside a pizza oven at 500°F. Evaluate this idea.
(A) This would work perfectly since 500°F is well below mercury's boiling point (B) This is fine because mercury can measure any temperature (C) This is a great idea because mercury thermometers are the most accurate (D) This is not safe — the glass thermometer would likely crack at oven temperatures, and it is approaching mercury's practical limits; an infrared thermometer or thermocouple would be more appropriate

156. A neighbor insulated their walls but not the attic, and their heating bill barely changed. They conclude 'insulation does not work.' Evaluate this conclusion.
(A) The conclusion is wrong — heat rises and escapes primarily through the ceiling/attic in most houses. Insulating walls while leaving the attic uninsulated allows the dominant heat loss path to remain. The insulation works but was applied to the wrong priority area (B) Wrong because wall insulation needs 5 years to start working, which is consistent with the fundamental principles of this field (C) Correct — insulation is generally ineffective, which is the most common explanation for this phenomenon (D) Wrong because the insulation was probably installed incorrectly, based on the typical behavior observed in controlled experiments

Write the answer

157. A student wants to keep a drink cold for lunch. Which container should they choose?
Answer: _____

158. Why do cooking pots have metal bodies but plastic or wooden handles?
Answer: _____

159. Why does Earth's mantle undergo convection even though it is solid rock?
Answer: _____

160. You need to insulate a hot water pipe in an unheated basement. What combination of materials and design would be most effective?
Answer: _____

Match each question to its answer

1. A student argues that since ice floats on water, all solids must float on their liquid form. Evaluate this claim. →
2. What is the freezing point of water on the Celsius scale? →
3. A building inspector recommends adding weather stripping to doors and windows. How does this improve energy efficiency? →
4. Design a solar oven using household materials that maximizes all three heat transfer methods. →
5. At what temperature does pure water freeze at standard atmospheric pressure? →

(A) Line a cardboard box with aluminum foil to reflect and concentrate radiation, use clear plastic wrap as a lid to trap convection (greenhouse effect), and place black paper on the bottom to absorb radiation and conduct heat to food
(B) 0 degrees Celsius
(C) 0 degrees Celsius
(D) Weather stripping seals air gaps that allow warm indoor air to escape and cold outdoor air to infiltrate, reducing heat loss from air leakage which can account for 25-40% of heating and cooling costs
(E) This claim is incorrect; water is an unusual exception because most solids are denser than their liquid form and would sink

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Riddle & Joke Break

Guess the answer, then check the key!

161. Why was the thermometer so smart?

162. What did the ice cube say to the boiling water?

163. Why did the metal spoon complain at dinner?

164. What did one molecule say to the other at the party?

165. Why did the convection current go in circles?

166. What's the Sun's favorite way to transfer heat?

Answer Key

1. B — Temperature, which is a measure of the average kinetic energy of particles in a substance
2. B — 0 degrees Celsius
3. C — The total kinetic energy of all the moving particles in a substance
4. A — 212 degrees Fahrenheit
5. A — Measuring absolute temperature starting from absolute zero, where all particle motion would stop
6. D — Because the large pot has more water particles, so the total kinetic energy of all particles is greater
7. Particles in a hot solid vibrate faster and with more energy than particles in a cold solid
8. Thermal energy transfers from the hot cocoa through the metal spoon to your hand because heat flows from warmer to cooler objects
9. Water has a higher specific heat capacity than air, so it absorbs more energy without its temperature rising as much
10. The gas particles slow down and move with less kinetic energy
    Matching (Temperature & Thermal Energy Basics): 1→D, 2→E, 3→C, 4→B, 5→A
11. A — Conduction, convection, and radiation
12. C — Conduction
13. D — Through radiation — electromagnetic waves that do not require matter to travel
14. C — The transfer of heat through the bulk movement of fluids as warmer, less dense portions rise and cooler, denser portions sink
15. C — Convection, because heated air becomes less dense and rises

16. B — The fire emits infrared radiation — electromagnetic waves that travel through air and warm your skin directly
17. Metal conducts heat well for cooking, while plastic or wood are poor conductors that protect your hand
18. Warm air is less dense than cool air, so it rises by convection to upper floors
19. Layers trap pockets of still air that act as insulation, reducing heat loss by convection and conduction
20. A vacuum between double walls stops conduction and convection, while reflective inner walls reduce radiation
    Matching (Heat Transfer Methods): 1→D, 2→B, 3→E, 4→C, 5→A
21. A — Fast-vibrating particles in the hotter region collide with slower neighbors, passing kinetic energy along through the material
22. A — A material that allows thermal energy to pass through it easily and quickly, such as metals
23. C — A material that resists the flow of thermal energy, such as wood, plastic, or rubber
24. A — Silver, followed closely by copper and aluminum
25. A — A measure of how well a material conducts heat, expressed as the amount of heat that flows through a given thickness per unit time per degree of temperature difference
26. C — Metals have free electrons that carry thermal energy much faster than vibrations alone
27. Vibrating atoms pass energy to neighbors through collisions, and free electrons rapidly transport energy along the rod
28. Tile conducts heat away from your feet much faster than carpet, so your feet lose heat more rapidly
29. Diamond has an extremely rigid crystal structure with strong carbon-carbon bonds that transmit vibrations with very little energy loss
30. The thin glass fibers trap large amounts of still air between them, and the trapped air is the actual insulator
    Matching (Conduction in Solids): 1→C, 2→A, 3→E, 4→D, 5→B
31. D — Differences in temperature cause differences in density — warmer, less dense fluid rises while cooler, denser fluid sinks, creating circular flow

32. D — Natural convection occurs from density differences alone; forced convection uses external force like a fan or pump
33. D — Liquids and gases (fluids), because particles must be free to move and flow in bulk
34. D — A circular flow pattern where warm fluid rises, travels across, cools and sinks, then returns along the bottom
35. B — The flame heats surrounding air, making it less dense than cooler air above, so warm air carrying smoke rises by buoyancy
36. B — The burner heats air inside the balloon, making it less dense than surrounding cooler air, creating upward buoyant force
37. Bottom heating allows warm water to rise and cool water to sink naturally, creating efficient convection throughout
38. Warm surface water flows toward poles, cools, becomes denser, sinks deep, and flows back toward the equator, redistributing thermal energy worldwide
39. The bulb heats wax making it less dense so it rises; at the top it cools, becomes denser, and sinks — creating a continuous cycle
40. Under enormous pressure and temperature, the mantle behaves like an extremely slow-moving fluid over millions of years — radioactive heating causes warmer rock to rise and cooler rock to sink
    Matching (Convection in Fluids): 1→E, 2→B, 3→A, 4→C, 5→D
41. D — The transfer of energy through electromagnetic waves, primarily infrared, that can travel through empty space without needing matter
42. D — Infrared radiation
43. D — A measure of how efficiently a surface emits thermal radiation compared to a perfect black body, ranging from 0 to 1
44. D — The total energy radiated by an object increases rapidly with temperature — specifically, it is proportional to the fourth power of the object's absolute temperature
45. C — An idealized object that absorbs all incoming electromagnetic radiation and emits the maximum possible radiation at every wavelength for its temperature
46. C — The Sun emits electromagnetic radiation (including infrared and visible light) that travels through the vacuum at the speed of light and is absorbed by our skin, converting to thermal energy

47. As temperature increases, the peak wavelength of emitted radiation shifts to shorter wavelengths — from infrared to red to orange to white (a mix of all visible colors)
48. Shiny surfaces have low emissivity and high reflectivity — they reflect most incoming radiation rather than absorbing it, so less energy converts to heat
49. Ultraviolet radiation from the Sun can penetrate through clouds because clouds primarily block visible light and infrared but allow significant UV to pass through
50. Certain gases (CO2, methane, water vapor) are transparent to incoming visible solar radiation but absorb and re-emit outgoing infrared radiation from Earth's surface, trapping heat
    Matching (Radiation & Electromagnetic Energy): 1→B, 2→C, 3→A, 4→D, 5→E
51. C — A measure of a material's resistance to heat flow — higher R-values mean better insulation
52. D — U-value measures how easily heat passes through a material — it is the inverse of R-value (U = 1/R), so lower U-values mean better insulation
53. C — A path of high thermal conductivity in an insulated building envelope that allows heat to bypass the insulation
54. A — Fiberglass batts, spray foam, and cellulose (or mineral wool, rigid foam board)
55. B — Air has very low thermal conductivity (0.025 W/m•K), about 1000 times less than metals, because gas molecules are far apart and collide infrequently
56. D — Spray foam traps gas in closed cells that are smaller and more uniformly distributed than fiberglass air pockets, and the trapped gas (often HFC or CO2) has lower conductivity than air
57. The sealed air or gas gap between two panes creates a low-conductivity barrier that reduces conduction and prevents convection between the glass layers
58. South-facing windows receive maximum solar radiation in winter when the sun is low, providing free heat, while the roof overhang blocks the high summer sun to prevent overheating
59. Dense materials like concrete and stone absorb heat slowly during the day and release it slowly at night, smoothing temperature swings and reducing heating/cooling needs
60. A moisture-resistant layer that prevents warm humid indoor air from reaching cold surfaces inside the wall where it would condense, potentially causing mold

and degrading insulation
Matching (Insulation & Thermal Design): 1→D, 2→A, 3→E, 4→B, 5→C

61. D — Sublimation
62. C — Solid, liquid, and gas
63. A — Condensation
64. D — Latent heat
65. D — 0 degrees Celsius
66. A — The added energy is used to break intermolecular bonds rather than increase temperature
67. Salt disrupts the formation of ice crystals by interfering with water molecule bonding
68. Evaporating sweat absorbs latent heat from your skin
69. Molecules move from a fixed, orderly arrangement to a more random, flowing arrangement
70. Water molecules form a hexagonal crystal structure with open spaces that take up more volume
Matching (Phase Changes & Latent Heat): 1→A, 2→C, 3→E, 4→B, 5→D
71. C — Energy cannot be created or destroyed, only transferred or transformed
72. B — Heat naturally flows from hotter objects to cooler objects, and entropy tends to increase
73. C — A measure of the disorder or randomness in a system
74. A — If two systems are each in thermal equilibrium with a third system, they are in thermal equilibrium with each other
75. C — The state when two objects in contact reach the same temperature and no net heat flows between them
76. B — The second law of thermodynamics requires that some energy is always lost as waste heat to a cooler reservoir
77. It does not violate the law because external work (electricity) is used to pump heat against the natural direction
78. The second law of thermodynamics dictates that heat flows from hot to cold, increasing overall entropy

79. The first law of thermodynamics is the conservation of energy applied specifically to thermal systems and heat transfer
80. Blowing removes the warm, saturated air layer above the soup and promotes faster evaporation, which absorbs latent heat
    Matching (Thermodynamics Laws & Applications): 1→A, 2→E, 3→D, 4→C, 5→B
81. B — Solid, liquid, and gas
82. C — Sublimation
83. A — 100°C (212°F)
84. D — Latent heat of fusion
85. C — Deposition
86. D — Melting point
87. The added energy is used to break bonds between water molecules rather than raise the temperature
88. Solid particles are tightly packed in fixed positions, while gas particles are far apart and move freely
89. Evaporating sweat absorbs heat energy from your skin
90. Salt disrupts the crystal structure of ice, making it harder for water molecules to stay frozen
    Matching (Heat & Energy): 1→E, 2→A, 3→B, 4→C, 5→D
91. D — Its resistance to heat flow
92. A — Heating, Ventilation, and Air Conditioning
93. A — Metal
94. B — To monitor and regulate indoor temperature by controlling the heating or cooling system
95. D — Conduction
96. C — Fiberglass
97. The layer of air or gas trapped between the two panes acts as an insulator that slows heat transfer
98. To reduce heat loss from the hot water as it travels through the pipes
99. A vacuum between two walls eliminates conduction and convection, and

reflective surfaces reduce radiation

100. Hot air rises, so the most heat escapes through the roof; attic insulation prevents this major heat loss
Matching (Heat & Energy): 1→A, 2→C, 3→E, 4→D, 5→B
101. C — Energy cannot be created or destroyed, only transferred or transformed
102. A — A measure of the disorder or randomness in a system
103. A — Heat naturally flows from hot objects to cold objects, never the reverse without external energy input
104. A — A device that converts thermal energy into mechanical work
105. C — Adiabatic process
106. A — The state when two objects in contact reach the same temperature and heat stops flowing between them
107. The Second Law of Thermodynamics requires that some heat must always be released to a cold reservoir — not all heat can be converted to work
108. The mechanical energy of your moving hands is converted into thermal energy (heat) through friction, conserving total energy
109. Heat naturally flows from the warmer countertop to the colder ice, not the reverse, as dictated by the Second Law of Thermodynamics
110. It uses external energy (electricity) to do work, so it does not violate the Second Law — energy is added to force heat to flow against its natural direction
Matching (Heat & Energy): 1→E, 2→A, 3→D, 4→C, 5→B
111. A — The process by which certain gases in Earth's atmosphere trap heat from the Sun, keeping the planet warm enough to support life
112. A — Heat energy from inside the Earth, generated by radioactive decay and residual heat from the planet's formation
113. B — Carbon dioxide (CO_2)
114. D — The Sun
115. A — Carbon dioxide (CO_2), methane (CH_4), and water vapor (H_2O)
116. D — It is absorbed by land and oceans, which then re-emit it as infrared radiation (heat)
117. Water has a very high specific heat capacity, so oceans absorb and store enormous amounts of thermal energy, moderating temperature changes on land

118. Burning fossil fuels adds extra greenhouse gases, trapping more heat and causing global temperatures to rise beyond natural levels

119. Land in deserts has low specific heat capacity and heats/cools quickly, while ocean water has high specific heat capacity and changes temperature slowly, moderating nearby temperatures

120. Warm water from the tropics flows toward the poles and cold water flows toward the equator, transferring thermal energy and moderating global temperatures
Matching (Heat & Energy): 1→D, 2→A, 3→E, 4→C, 5→B

121. A — The metal part feels colder because it conducts heat away from your hand faster, even though both are the same temperature — our touch senses heat flow rate, not true temperature

122. B — Layers trap pockets of still air that act as insulation, reducing heat loss by convection and conduction

123. D — A measure of how well a material conducts heat, expressed as the amount of heat that flows through a given thickness per unit time per degree of temperature difference

124. A — Warm ocean heats air above it, which rises rapidly creating low pressure. Surrounding air rushes in, gets heated and moist, rises, and releases latent heat when moisture condenses — this strengthens the convective cycle

125. A — Certain gases (CO_2, methane, water vapor) are transparent to incoming visible solar radiation but absorb and re-emit outgoing infrared radiation from Earth's surface, trapping heat

126. A — The sealed air or gas gap between two panes creates a low-conductivity barrier that reduces conduction and prevents convection between the glass layers

127. Use a material with a melting point near room temperature, high latent heat capacity, and good thermal conductivity, stored in panels that absorb daytime heat and release it as the material solidifies at night

128. Approximately 66 percent

129. Place thermometers inside identical containers, one wrapped in black paper and one in white paper, set them in sunlight for 30 minutes, and compare final temperatures

130. A vacuum between double walls stops conduction and convection, while reflective inner walls reduce radiation
Matching (Temperature & Thermal Energy Basics): 1→C, 2→D, 3→A, 4→E, 5→B

131. B — Water has a higher specific heat capacity than oil, meaning it requires more energy to increase in temperature by the same amount
132. D — The reflective material does reduce radiative heat loss, which is valid, but radiation is only a fraction of body heat loss — conduction and convection are not addressed by reflection alone
133. B — Stainless steel provides durability and a non-reactive cooking surface, while the core provides rapid even heat distribution — combining the best of each
134. D — Liquids and gases (fluids), because particles must be free to move and flow in bulk
135. C — An idealized object that absorbs all incoming electromagnetic radiation and emits the maximum possible radiation at every wavelength for its temperature
136. C — Use double-pane windows with low-E coating optimized for both seasons: spectrally selective coating transmits visible light but reflects infrared in both directions. Add external overhangs sized so summer sun is blocked but winter sun enters. Use argon gas fill for lower conductivity than air
137. Measure the mass and temperature of warm water in the calorimeter, add a known mass of ice at 0°C, stir until melted, record the final temperature, and calculate latent heat using energy conservation
138. Most energy is lost as waste heat in the condenser and cooling towers, as required by the second law, plus additional losses from friction and heat leaks
139. Aluminum has a lower specific heat capacity than iron, so it heats up faster with the same energy input
140. Silver, followed closely by copper and aluminum
    Matching (Temperature & Thermal Energy Basics): 1→B, 2→D, 3→E, 4→C, 5→A
141. B — 18.5 Student Degrees, because 37°C is 37% of the way from 0 to 100°C, and 37% of 50 is 18.5
142. D — Student B — Styrofoam insulates against all three methods, while aluminum is a conductor that would speed up heat transfer to the ice cream
143. C — Diamond has an extremely rigid crystal structure with strong carbon-carbon bonds that transmit vibrations with very little energy loss
144. B — The Sun emits electromagnetic radiation (including infrared and visible light) that travels through the vacuum at the speed of light and is absorbed by our skin, converting to thermal energy
145. D — South-facing windows receive maximum solar radiation in winter when the

sun is low, providing free heat, while the roof overhang blocks the high summer sun to prevent overheating

146. D — It is not a true phase change but uses an endothermic dissolving process; latent heat specifically applies to changes of state, not dissolution
147. Mechanical work from friction is converted into thermal energy, increasing the internal energy of your hands
148. Water has a higher specific heat capacity than air, so it absorbs more energy without its temperature rising as much
149. The transfer of heat through the bulk movement of fluids as warmer, less dense portions rise and cooler, denser portions sink
150. Metal studs create thermal bridges that conduct heat through the wall faster, reducing insulation effectiveness and increasing energy costs
Matching (Temperature & Thermal Energy Basics): 1→B, 2→D, 3→E, 4→A, 5→C
151. B — About 35°C
152. B — Copper quickly conducts heat away from the chip, and aluminum fins provide large surface area to dissipate heat to the air
153. A — Differences in temperature cause differences in density — warmer, less dense fluid rises while cooler, denser fluid sinks, creating circular flow
154. C — The first law of thermodynamics is the conservation of energy applied specifically to thermal systems and heat transfer
155. D — This is not safe — the glass thermometer would likely crack at oven temperatures, and it is approaching mercury's practical limits; an infrared thermometer or thermocouple would be more appropriate
156. A — The conclusion is wrong — heat rises and escapes primarily through the ceiling/attic in most houses. Insulating walls while leaving the attic uninsulated allows the dominant heat loss path to remain. The insulation works but was applied to the wrong priority area
157. An insulated thermos, because it slows down heat transfer between the drink and the warmer surroundings
158. Metal conducts heat well for cooking, while plastic or wood are poor conductors that protect your hand
159. Under enormous pressure and temperature, the mantle behaves like an extremely slow-moving fluid over millions of years — radioactive heating causes warmer rock to rise and cooler rock to sink

160. Wrap with tubular foam insulation (for conduction resistance), cover with reflective tape or foil (for radiation resistance), and ensure no gaps at joints (to prevent convection through exposed pipe)
Matching (Temperature & Thermal Energy Basics): 1→E, 2→B, 3→D, 4→A, 5→B
161. It had a lot of degrees!
162. "You're making quite a scene -- I mean, a phase change!"
163. It was conducting too much heat from the soup!
164. "Is it hot in here, or is it just our thermal energy?"
165. Because it always comes back around!
166. Radiation -- it doesn't even need to touch you!
