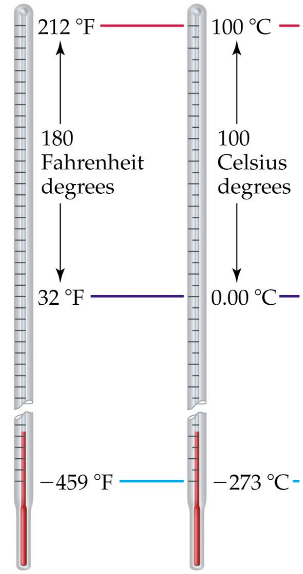
1. How do we know that **heat** is a form of **energy**?
   A) We don't. Anyone who says that it is is just offering up a theory. It may be true or not, but there is no proof of any link between energy and heat.
   B) It isn't. Heat is actually a caloric fluid, permeating all matter. This fluid is colorless, odorless, tasteless, and might be liquid or gas. It is too hard to detect with current technology. But it's definitely a fluid.
   C) It is relatively easy to perform an experiment in which a known amount of energy is transferred to a container of water. Every time the same amount of energy is transferred, the water temperature increases by the same amount.
2. **True or false:** The idea that all matter is composed of tiny, indivisible particles (atoms) was not suggested until late in the 18^{th} century.
3. Distinguish between an **atom** and a **molecule**.
   A) An atom is a single particle (like hydrogen). When two or more atoms are joined, it becomes a molecule (like water = H_2O = 2 hydrogen atoms + 1 oxygen atom).
   B) An atom is the smallest particle of a solid, while a molecule is the smallest particle of a liquid or gas.
   C) An atom is a group of ten particles bonded together. Molecules are larger, and consist of 1 million particles bonded into a single unit.
   D) Technically, answer A is correct. However, for the purposes of Kinetic Theory, we can refer to either atoms or molecules as "molecules."
4. Which of the following is an example of **cohesion**?
   A) Using masking tape to seal a moving box.
   B) Using a weird rubbery material to suspend a car upside down from the ceiling.
   C) Observing dewdrops on the grass in the morning.
   D) Using a magnet to display a photo on the fridge.
   E) All of these, except answer C!
5. Which of the following is an example of **adhesion**?
   A) Dropping a penny in the pool and noticing that it doesn't dissolve.
   B) Using a weird rubbery material to suspend a car upside down from the ceiling.
   C) Observing dewdrops on the grass in the morning.
   D) Stretching a spring and noticing that it returns to its original length and shape.
   E) All of these, except answer B!
6. Of the three phases of matter (solid, liquid, gas), which of them demonstrates the **greatest** cohesive bonding between molecules?
   A) Solids. B) Liquids. C) Gases.
7. Of the three phases of matter (solid, liquid, gas), which of them are considered to be **fluids**?
   A) Solids only. D) Solids & liquids only.
   B) Liquids only. E) Liquids & gases only.
   C) Gases only. F) Solids & gases only.
8. If both liquids and gases are **fluids**, what is the difference between them?
   A) Liquids are made of molecules, while gases are made up of atoms.
   B) A liquid has fixed volume, but variable shape. Gases have both variable volume and variable shape.
   C) A liquid has almost zero cohesive bonding between molecules, while gases have strong cohesive bonds.
   D) All of these answers are accurate!
9. **True or false:** The molecules of a solid material are stationary, and cannot move at all.
10. Which of the following is **not** an example of molecular motion by **diffusion**?
    A) A drop of food coloring gradually turns an entire glass of water red.
    B) You can smell dinner cooking in the kitchen even if you are down the hall and in your bedroom.
    C) Boiling water poured over herb leaves in a mug results in a delicious cup of tea.
    D) You light a candle and the wax melts into a liquid pool surrounding the wick.
11. Briefly summarize the idea of **Kinetic Molecular Theory**.
    A) Because only fluids flow, liquids and gases have kinetic energy. Solids cannot have kinetic energy.
    B) All molecules are moving, always. Solids are the lowest energy phase, and gases have the highest energy.
    C) Individual molecules cannot have kinetic energy, but any object made of the molecules will have KE.
12. **Temperature** is defined as
    A) the average heat of an object.
    B) the average chemical potential energy per molecule of a substance.
    C) the average gravitational potential energy per molecule of a substance.
    D) the average internal kinetic energy per molecule of a substance.
    E) the energy transferred from one substance to another because of a temperature difference.
13. Temperature is
    A) the same as heat.
    B) the measure of the total kinetic energy of a substance.
    C) the measure of the total internal energy of a substance.
    D) the measure of the average kinetic energy per molecule of a substance.
14. Explain **thermal expansion**. When you increase the temperature of a substance, the molecules
    A) move faster, get farther apart, and occupy more space.
    B) move faster, get closer together, and occupy a smaller volume.
    C) move more slowly, get closer together, and occupy less space.
    D) move more slowly, slowly drift apart, occupy a greater volume of space.
15. **True or false:** Most substances shrink, or get smaller, when the temperature is decreased.
16. Consider a cube of metal (like we used in lab) with dimensions length L, width W, and height H. When you put it in boiling water and its temperature increases, it expands
    A) in zero dimensions, or not at all. The cube remains exactly the same size: L, W, and H remain unchanged.
    B) in one dimension only: L gets bigger, while W and H remain constant.
    C) in two dimensions: L and W increase, while H remains constant.
    D) in all three dimensions: L, W, and H all increase at the same rate.
17. The lid on the pickle jar is stuck again, and you can't find that rubber grippy thing to open it. You should run it under
    A) hot water. The lid will expand, the opening will get larger, and the lid will loosen.
    B) cold water. As the lid contracts, the opening will get larger so you can unscrew it easily.

18. A mercury thermometer
    A) depends on gravity to operate. The liquid in the tube is pulled up by the force of gravity, and the force is greater when the temperature is higher.
    B) works on the same principle as a mercury barometer. Higher air pressure forces the mercury farther up the glass tube of the thermometer. This is related to temperature, because higher temperatures create higher pressures.
    C) uses the principle of thermal expansion. The liquid in the glass tube expands when heated. The amount of expansion is proportional to the increase in the temperature, regardless of the scale you use.
    D) is based on the idea that a liquid will expand to fill any closed container. The mercury seeps up the tube, but the air in the end of the tube keeps it from getting all the way to the end. When the air in the tube is cooled, it contracts, which allows the mercury to flow farther up the tube.
19. What is the difference between the **Celsius** and **Kelvin** temperature scales?
    A) Degrees Celsius are larger than degrees Kelvin.
    B) 0°K is much warmer than 0°C.
    C) Celsius is a relative scale is based on the freezing and boiling of water; Kelvin is an absolute scale.
    D) There is no difference whatsoever between them.
20. What is the difference between the **Celsius** and **Fahrenheit** temperature scales?
    A) Degrees Celsius are larger than degrees Fahrenheit.
    B) 100°F is much warmer than 100°C.
    C) Celsius is a relative scale is based on the freezing and boiling of water; Fahrenheit is an absolute scale.
    D) There is no difference whatsoever between them.
21. On which temperature scale will you never see a negative value?
    A) Celsius. 0°C, the freezing point of water, is as cold as anything can possibly get.
    B) Fahrenheit. 0°F is colder than 0°C, but nothing can be colder than 0°F.
    C) Kelvin. The scale is absolute, and 0K is literally as cold as anything can possibly get.
    D) Trick question! There are no negative temperatures possible, no matter what scale you use.
22. The Kelvin scale of temperature
    A) is relative. The degrees are the same size as degrees Celsius, but the scale places 0° at the freezing point of ammonia instead of the freezing point of water.
    B) is relative. the degrees are the same size as degrees Fahrenheit, but the scale uses 100° as the boiling point of water instead of 212°.
    C) is relative. The size of a degree Kelvin is determined by the ratio of boiling temperature to freezing temperature of water, so it is 212/32 = 6.6°.
    D) is absolute. The degrees are the same size as degrees Fahrenheit, but all temperatures are negative. 0K is literally as hot as anything can possibly get.
    E) is absolute. The degrees are the same size as degrees Celsius, but there are no negative temperatures. 0K is literally as cold as anything can possibly get.
23. You have two identical cups of water, both at room temperature. Cup A has a Fahrenheit thermometer in it, which reads 68°F, and Cup B has a Celsius thermometer reading 20°C. You raise the temperature of each cup by 20°, to 88°F and 40°C respectively. Which cup actually feels hotter?



    A) Cup A at 88°F.
    B) Cup B at 40°C.
    C) Trick question! Twenty degrees is 20°, no matter what scale you use.
    D) Trick question! You cannot raise the temperature of either cup!
24. Distinguish between **internal** vs **external** energy.
    A) When you fill a mug of coffee, the internal energy is the individual molecules moving around. External energy would be the kinetic energy of the cup as the barista slides it across the counter to you.
    B) Backwards! Internal energy would be the KE of the cup sliding across the counter, but internal energy would be the molecules moving.
    C) Internal energy would be the KE of the cup sliding across the counter. External energy would be the KE of the barista's hand as he pushes it.
    D) Internal and external are just different ways to say kinetic and potential. KE is always external energy, but PE is always internal.
25. **Heat** is defined as
    A) the average heat of an object.
    B) the average chemical potential energy per molecule of a substance.
    C) the average gravitational potential energy per molecule of a substance.
    D) the average internal kinetic energy per molecule of a substance.
    E) the energy transferred from one substance to another because of a temperature difference.
26. **True or false:** A heat calorie is the same unit as a food calorie.
27. A **calorie** of heat is defined as
    A) the average energy required by the human body to digest 1 gram of food.
    B) the average energy released by 1 gram of food during digestion.
    C) the energy required to raise the temperature of 1 gram of liquid water by 1°C.
    D) the energy required to raise the temperature of 1 pound of liquid water by 1°F.
28. You have two 100 ml beakers of water. One is 20°C and the other is 10°C.
    A) The 20° beaker has twice as much heat as the 10° beaker.
    B) The 20° beaker has half as much heat as the 10° beaker.
    C) The 20° beaker has more heat, but not twice as much, as the the 10° beaker.
    D) Either beaker may have more heat; you don't have enough information to determine.

29. There is more heat in a 5 gallon pail of warm water than in a teacupful of boiling water.
    A) True; there is less energy per molecule in the pail, but there are many more molecules.
    B) True; there is more energy per molecule in the pail, and more molecules as well.
    C) False; there is more energy per molecule in the teacup; the number of molecules doesn't matter.
    D) False; the temperature does not matter. The teacup, being smaller, has a higher "heat density."

30. One beaker holds 1 liter of boiling water; a second beaker holds 2 liters of boiling water.
    A) Because they have the same temperature, they contain the same amount of heat.
    B) The two liter beaker has a higher temperature because it has more heat.
    C) The one liter beaker has half as much heat as the two liter beaker.
    D) The two liter beaker has half as much heat as the one liter beaker.

31. **True or false:** A welding spark, while having a very high temperature, actually contains very little heat.

32. **True or false:** A swimming pool filled with water at 20°C contains much more heat than a welding spark at 5000°.

33. An iron thumbtack and an iron horseshoe are each removed from a 300° oven and dropped into separate pails of water at room temperature.
    A) Each object raises the temperature of its water by the same amount.
    B) The thumbtack raises the temperature of its water more.
    C) The horseshoe raises the temperature of its water more.
    D) Neither raises the water temperature at all.

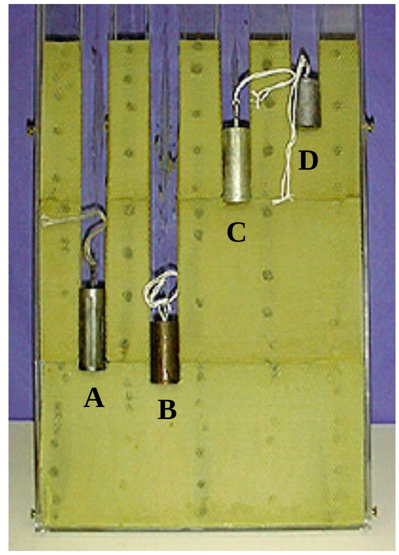
34. Two metal bars are brought into contact, end to end. One bar has a temperature of 0°C, and the other is at 50°C.
    A) Heat is exchanged in both directions, from hot to cold and from cold to hot until both bars reach the same final temperature.
    B) The cold bar gives energy to the hot one until it comes down to 0° to match the cold one.
    C) The hot bar transfers heat to the cold one until both reach a final temperature between 0° and 50°.
    D) No heat is transferred in either direction, since metal is a very poor conductor of heat.

35. **Specific heat** is defined as
    A) the energy required to change the phase of a substance from solid to liquid.
    B) the energy required to change the phase of a substance from a liquid to a vapor.
    C) the energy transferred from one substance to another because of a temperature difference.
    D) the energy required to completely convert mass to energy, using Einstein's famous equation $E = mc^2$.
    E) the energy required to raise the temperature of one gram of a substance by one degree Celsius.

36. **True or false:** Water has a very high specific heat when compared to the specific heats of most metals.

37. How much energy (*Q*, **in calories**) is required to raise the temperature of m = 10g of water (c = 1 cal/g°C) from very cold (T_i = 5°C) to room temperature (T_f = 22°C)?
    A) 5 cal C) 50 cal E) 220 cal
    B) 22 cal D) 170 cal F) 270 cal

38. How much heat energy would an iron (c_{Fe} = 0.113 cal/g°C) coil with m = 250g coil release as it cooled from T_i = 400°C to T_f = 20°C?
    A) None. D) 400 cal
    B) 0.113 cal E) 10,735 cal
    C) 250 cal F) 100,000 cal



The cylinders shown on the right all have precisely the **same mass.** They are all heated to 100°C, then placed on the block of wax as shown. Each cylinder melts the wax until it reaches room temperature (20°C). **Use the multiple choices shown on the figure to answer Questions 54–56.**

39. Which cylinder has the **highest** specific heat?

40. The cylinders shown are **brass, iron, lead,** and **tin**. Identify which cylinder is **lead**. (See the formula sheet for numeric values for the specific heats of various metals.)

41. **None** of the cylinders shown is actually **aluminum**. **True or false:** An aluminum cylinder with the same mass, also raised to 100°C, would melt the same amount of wax as Cylinder B as it cooled.

42. **Conduction** is
    A) the transfer of heat between objects that are not actually touching.
    B) the transfer of heat via bulk motion of the medium.
    C) the transfer of heat by electron and atomic collisions.
    D) the only way to transfer heat from a colder object to a warmer one.

43. An **insulator** is a poor conductor of heat because
    A) it has no electrons to collide.
    B) insulators are too dense to transmit heat effectively.
    C) the electrons are tightly bound to their nuclei, making it hard to move them.
    D) it has a crystal structure that is too closed, and the heat cannot pass through.

44. When you step from the carpet to the tile, the tile feels colder to your bare feet because
    A) its temperature is lower than the temperature of the carpet.
    B) it is a better insulator than carpet, and heat flows from the tile to your feet.
    C) it is a better conductor of heat than carpet, and heat flows from your feet to the floor.
    D) it's a cold, hard world out there, and the tile knows what the fuzzy carpet just doesn't understand

45. **Convection** is
    A) the transfer of heat between objects that are not actually touching.
    B) the transfer of heat via bulk motion of the medium.
    C) the transfer of heat by electron and atomic collisions.
    D) the only way to transfer heat from a colder object to a warmer one.

46. **True or false:** Solids are exceptionally good at heat convection, while fluids tend to be poor convectors.

47. Convection occurs as warmer fluid (liquid or gas) sinks and colder, denser fluid rises.
    A) True; this is why the atmosphere gets colder at higher altitude!
    B) False; warmer fluid is less dense and rises, while colder (and denser) fluid sinks.
    C) True or false; unless you specify what fluid you mean, it could be either way.

48. **Radiation** is
    A) the transmission of energy without the need for a medium of transfer.
    B) the transfer of heat via bulk motion of the medium.
    C) the transfer of heat by electron and atomic collisions.
    D) the only way to transfer heat from a colder object to a warmer one.

49. The frequency of the radiant energy emitted by an object is
    A) inversely proportional to the temperature of the object: higher frequency means lower temperature.
    B) directly proportional to the temperature of the object: lower frequency means lower temperature.
    C) unrelated to the temperature of the object. Not everything radiates energy!
    D) dependent on the station you have tuned in; for me personally, it's 93.1, WXRT.

50. Energy is absorbed by a substance when the phase changes
    A) from liquid to solid or from liquid to gas.
    B) from gas to liquid or from liquid to solid.
    C) from solid to liquid or from liquid to gas.
    D) from gas to solid or from solid to gas.

51. Energy is given up or released by a substance when the phase changes
    A) from liquid to solid or from liquid to gas.
    B) from gas to liquid or from liquid to solid.
    C) from solid to liquid or from liquid to gas.
    D) from gas to solid or from solid to gas.

52. As energy is added to a solid block of ice,
    A) it will melt completely before its temperature can begin to rise.
    B) its temperature will start to rise before any of the ice starts to melt.
    C) the ice starts to melt and the temperature starts to rise simultaneously.
    D) either could happen first, it's totally random.

53. An ice cube tray is filled with liquid water at room temperature (about 20°C) and placed in the freezer.
    A) The temperature won't decrease, staying at 20°C, until all the water has frozen into ice.
    B) The water temperature decreases to the freezing point (0°C) before the phase changes. Once the ice freezes, then the temperature can then be decreased more.
    C) The temperature goes down by half, then half the water freezes. The temperature of the remaining water goes down by half again, then half of the liquid freezes. This pattern repeats until all of the liquid has changed phase.
    D) The process is totally random, so the temperature decreases and phase changes or not. You can't ever predict what will happen, only the final result: solid ice.

54. **Latent heat of fusion** is the amount of energy required to completely change the phase of 1g of a substance
    A) from liquid to solid.
    B) from solid to liquid.
    C) from liquid to gas.
    D) either A or B is correct; the phase change can be in either direction.

55. **Latent heat of vaporization** is the amount of energy required to completely change the phase of 1g of a substance
    A) from liquid to solid.
    B) from solid to liquid.
    C) from liquid to gas.
    D) either A or B is correct; the phase change can be in either direction.

56. Why is the latent heat of vaporization for water (L_v = 540 cal/g) so much larger than the latent heat of fusion for water (L_f = 80 cal/g)?
    A) Because the hot water that is getting ready to boil already has more energy than the cold water that is getting ready to freeze.
    B) To change from the liquid to gas phase, energy is required to break the bonds between water molecules. Then more energy is required to overcome surface tension as the water molecules jump o! the surface.
    C) To change phase from the liquid to solid, bonds are formed between water molecules. From liquid to gas, bonds are broken. It always takes more energy to break bonds than make bonds.
    D) It isn't; 540 cal/g is not correct. The latent heats are the same for either fusion of vaporization, because it does not matter which direction the phase change happens: solid to liquid or liquid to gas, the same amount of energy is required to break the bonds between the molecules.

57. The specific heat of water is c = 1 cal/g·°C, and the the latent heat of fusion is L_f = 80 cal/g. Calculate how much energy must be removed to **completely freeze** m = 100g of liquid water at room temperature (T_i = 20°C).
    A) Q=80 cal/g + (20–0)°C = 100cal
    B) Q=1 cal/g·°C + 80 cal/g + 100 g + 20°C = 201cal
    C) Q=(100g)(1cal/g·°C)(20–0)°C+(100g)(80cal/g) = 10,000cal
    D) Q=(100g)(1cal/g·°C)(100–20)°C+(100g)(80cal/g)=16,000cal

58. The specific heat of water is c = 1 cal/g·°C, and the the latent heat of vaporization is L_v = 540 cal/g. You have 10g of warm water initially at 45°C. How much total energy (Q) must be added to **completely vaporize** the entire 10g of water?
    A) Q = 540 cal/g + (100–45)°C = 595cal
    B) Q = 1 cal/g·°C + 540 cal/g + 10 g + 45°C = 596cal
    C) Q = (10g)(1cal/g·°C)(45°C)+(10g)(540cal/g) = 5850cal
    D) Q = (10g)(1cal/g·°C)(100–45)°C+(10g)(540cal/g)=5950cal

59. Adding 100 calories of heat to 1g of solid ice at 0°C results in
    A) liquid water at 100°C.
    B) liquid water at 80°C.
    C) liquid water at 20°C.
    D) solid ice at 0°C.

60. **Evaporation** of a liquid is a cooling process. This means that
    A) the higher energy liquid molecules escape, leaving the lower energy molecules behind.
    B) the lower energy liquid molecules collide with and stick to a cooler surface, and cool that surface.
    C) the higher energy molecules give their energy to the lower energy molecules, lowering the average energy and thus the temperature of the liquid.
    D) all of the liquid molecules have the same energy; it is a cooling process because you have to put the liquid in the refrigerator (or some kind of cooler) in order to start the evaporation process.