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**M/J Physical Science Adv.: Thermal Energy Study Guide**

1. **Heat**
	1. ***Thermal Energy***
		1. Explain the relationship between “thermal energy”, “temperature”, and “heat".

***Temperature measures the AVERAGE kinetic energy of the particles in a substance; in other words, the speed of the particles. Thermal energy refers to the TOTAL energy of all of the particles in a substance. Therefore, the thermal energy of a substance depends on the amount, while the temperature does not. Heat is the transfer of thermal energy from one object/substance to another, which results in a temperature change.***

* + 1. How could two objects have the same thermal energy but different temperatures? Give an example.

***Because temperature is an average of the kinetic energy of the molecules, it does not depend on the amount of the substance. Thermal energy, however, does depend on the amount. So if one object has few molecules with a high temperature, it may have the same thermal energy as another object that has many molecules at a lower temperature. An example might be a lit match and an ice sculpture.***

* + 1. How could two objects have the same temperature but different thermal energy? Give an example.

***Like the above question, it will depend on the amount of the substance to determine the thermal energy. If you have two samples of a substance at the same temperature, the sample with more particles (greater volume) will have more thermal energy. An example might be 50 mL of water at room temperature and 100 mL of water at room temperature.***

* 1. ***Temperature Scales***
1. Which temperature scales are considered metric and which are not?

***The Celsius and Kelvin scales are metric measures of temperature while Fahrenheit is not metric.***

1. Compare the boiling and freezing point of water on each of the three temperature scales.

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| ***Temperature Scale*** | ***Fahrenheit*** | ***Celsius*** | ***Kelvin*** |
| ***F.P. of water*** | ***32⁰F*** | ***0⁰C*** | ***273 K*** |
| ***B.P. of water*** | ***212⁰F*** | ***100⁰C*** | ***373 K*** |

1. Why was the Kelvin scale developed? How is it related to Celsius?

***The Kelvin scale was developed to take advantage of the idea of “absolute zero”. Temperature measures the speed of the particles in a substance. If absolute zero occurs when there is no particle motion, it makes sense for zero temperature to be at this point. So the Kelvin scale was developed by shifting the Celsius scale down to account for absolute zero, which occurs at -273⁰C.***

* 1. ***Temperature & Phases***
1. How does the kinetic energy of the molecules in a substance relate to the temperature/phases?

***When you measure the temperature of a substance, you are measuring its average kinetic energy. In other words, you’re measuring how fast the particles are moving. As molecules move faster, the temperature increases; as they move slower, the temperature decreases. As the particles in the substance gain or lose enough energy, their physical state may transition from one phase to another.***

1. Describe how adding thermal energy to a substance over time will affect its temperature/phase. Draw a diagram to illustrate your thoughts.

***Adding or removing thermal energy in a substance will either change its temperature or its physical state (phase). Adding thermal energy to a solid will increase its temperature up to its melting point, where the temperature will level out while the substance undergoes a phase change from solid to liquid. Continuing to add thermal energy to the liquid will increase its temperature to the boiling point, at which temperature the substance will change from a liquid to a gas.***

* 1. ***Heat***
1. Compare Convection, Conduction, and Radiation

***Convection, Conduction, and Radiation are three forms of heat, which is the transfer of thermal energy between objects. Convection transfers thermal energy within a fluid by means of the convection current which is caused by differences in density when the fluid is heated unevenly. Conduction transfers thermal energy through contact between objects, requiring the particles to bump into one another. Radiation transfers thermal energy by means of electromagnetic waves, or light (especially infrared light); it does not require matter to transmit thermal energy.***

1. Differentiate conductors and insulators. How does density affect thermal conductivity?

***Conductors are materials which allow the flow of thermal energy easily as a result of a high density. The closeness of the particles makes it easier for them to bump into each other and transmit energy through the substance. Insulators are materials which inhibit the flow of thermal energy because they have a lower density. Because their particles are farther apart, it is not as easy for them to bump into one another and transfer the energy.***

1. What causes a convection current? How does density affect this current?

***Convection currents occur in a fluid when it is heated unevenly. The warmer fluid will float (or rise) because it is less dense, while the cooler fluid will sink because it is more dense. This cycle of warming and cooling fluid creates a current which transfers thermal energy throughout the substance.***

1. What evidence do we have that radiation can transfer thermal energy through empty space?

***The Earth receives thermal energy from the Sun in the form of infrared radiation. Because the sunlight traveled through the vacuum of space to reach Earth, we have evidence that thermal energy can be transferred by radiation without the presence of matter.***

1. What type of heat was involved in the “purple ice” lab station? Why did the purple food coloring move through the water in a “circle”?

***The purple ice station illustrated convection. Water near the heat source became warmer and less dense, while water near the ice cube was cooler and denser. As the warm water rose and the cool water sank, this created a current within the dish that was shown by the flow of the purple food coloring.***

1. In the “black blocks” lab station, why did block B feel “cold” when you first observed the blocks, and why did it melt the ice faster? What type of heat was responsible for melting the ice cubes?

***The black blocks station illustrated conduction because heat was transferred between the blocks and the ice by contact between the two substances. Because the room temperature blocks were warmer than the ice cubes, they transferred their thermal energy into the ice cubes causing them to begin melting. The reason block B felt “cold” even though it was the same temperature as block A is because block B was made of metal, which is a good conductor of thermal energy. Your hand, being warmer than the block, transferred thermal energy into the block. Your body perceived this loss of energy as “cold”. This is the same reason block B melted the ice faster. Because it is warmer than the ice, and because it is a conductor and can transfer thermal energy easily, thermal energy flows quickly from the block into the ice cube causing it to melt faster.***

1. In the “heat lamp” lab station, what type of heat was responsible for raising the temperature on the thermometer under the lamp?

***The lamp station illustrated radiation. When the lamp was turned on, the air in the lighted area became warmer, which was measured by an increase in temperature on the thermometer.***

1. At the “hand bath” lab station, explain why your left hand and your right hand perceived different water temperatures when you placed them in the room temperature water (*after removing your left hand from the ice water and your right hand from the warm water*)…even though both hands were feeling the same water.

***The hand bath station illustrated another example of conduction because heat was transferred when your hand contacted the water. Your left hand, after leaving the ice-water bath, was cooler than room temperature, causing the room temperature water to feel warm as thermal energy transferred INTO your hand. Your right hand, after leaving the hot-water bath, was warmer than room temperature, causing the room temperature water to feel cold as thermal energy transferred OUT of your hand. This is why you perceived different temperatures in each hand even though both of them were in the same water.***

1. What does the phrase, “Heat always flows in one direction” mean? When will heat no longer flow between objects?

***Heat will always flow from a warmer substance to a cooler substance. As the thermal energy flows from one object to another, the temperature of the warmer object will decrease and the temperature of the cooler object will increase until both objects are the same temperature. This point is called equilibrium.***

1. Why does your hand feel cold when you hold an ice cube?

***Holding an ice cube is an example of conduction. Your hand is warmer than the ice cube, so thermal energy will flow from your hand into the ice cube. As energy exits your hand where the ice cube sits, your body perceives this loss of energy as “cold”.***

1. Why does a stovetop feel hot if you touch it while it is turned on?

***Touching a hot stovetop is another example of conduction. The stove is warmer than your hand, so thermal energy will flow from the stove into your hand where the two are in contact. Your body perceives this influx of energy as “hot”.***

1. Explain the expression, “There’s no such thing as *cold*.”

***What we feel as “hot” is thermal energy entering our body. When we feel “cold”, it is thermal energy leaving our body. While thermal energy can flow from one object to another, there is no such thing as “cold” flowing between objects. Our perception of “cold” is simply an absence of thermal energy, much the same way that “dark” is simply the absence of light.***