

Measuring Heat Transfer Worksheet **Answers**

Liquid	Specific Heat Capacity (kJ/kg-K)	Mass in 500 ml of Fluid (kg)
A = salt water	3.93	0.51
B = fresh water	4.19	0.50
C = maple syrup	2.10	0.66
D = vegetable oil	1.67	0.46
E = corn syrup	2.72	0.71

Question: Examine the list of unknown liquids in the table above. In the space below, write which of the liquids you think would work best as a radiator fluid to cool the engine. Explain your thinking. *Example answer:* Based on the given specific heat capacities, liquid A or B would be the best because they have the highest values of specific heat capacity. This means that liquids A and B are able to absorb larger amounts of heat energy per unit mass and therefore would work the best to remove heat from an engine.

Instructions

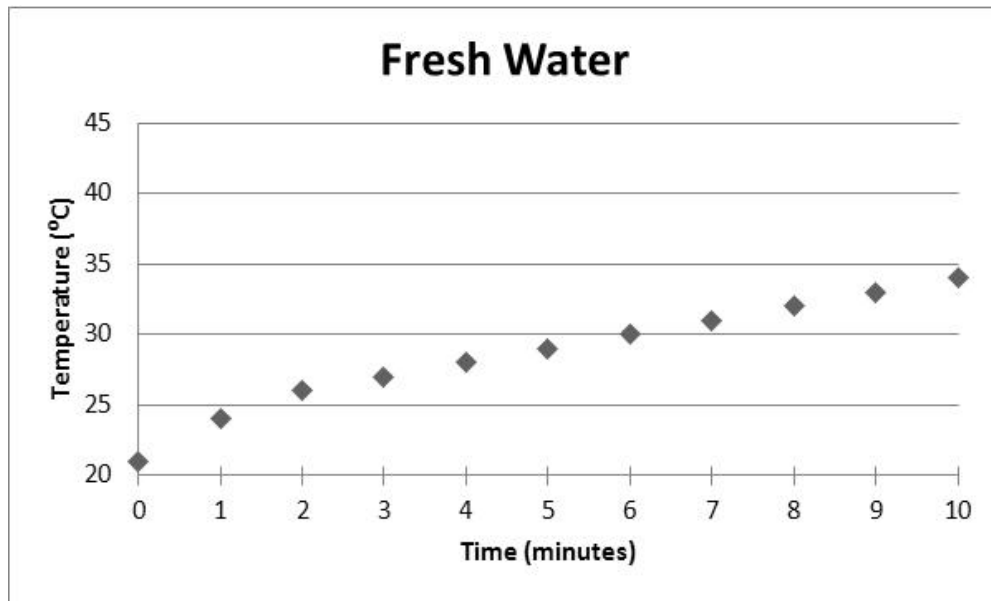
- When instructed to do so, put your beaker of liquid on the hot pad and take the initial temperature reading. Record all temperature readings in the table below.
- **After a minute**, stir the liquid gently with the thermometer and take a temperature reading.
 - Rotate who takes the temperature measurement.
- Take temperature readings once every minute for 10 minutes. After your final temperature measurement, turn off the hot plate.

Time (minutes)	Temperature (°C)	Temperature (K)
0	21	294
1	24	297
2	26	299
3	27	300
4	28	301
5	29	302
6	30	303
7	31	304
8	32	305
9	33	306
10	34	307

- **Leave the beaker on the hot plate** and go back to your seat and complete the worksheet:
 - Graph temperature vs. time
 - Calculate the heat transferred during the 10-minute time interval
 - Answer the questions
- Have one person from your group write your results from $\Delta T=10$ minutes in the table on the classroom board so the class can see all results. Record class results on the page 2 table.

Graph Your Results

For fluid: **B**



Calculate the heat transferred during the entire 10-minute time period using the equation:

$$Q = m \cdot C \cdot \Delta T$$

where Q is heat (kJ), m is the mass of material (kg), C is specific heat capacity (kJ/kg-K), and ΔT is the change in temperature (K).

$$Q = m \cdot C \cdot \Delta T$$

$$Q = 0.5(\text{kg}) \cdot 4.19(\text{kJ/kg-K}) \cdot 13(\text{K})$$

$$Q = 27.24 \text{ kJ}$$

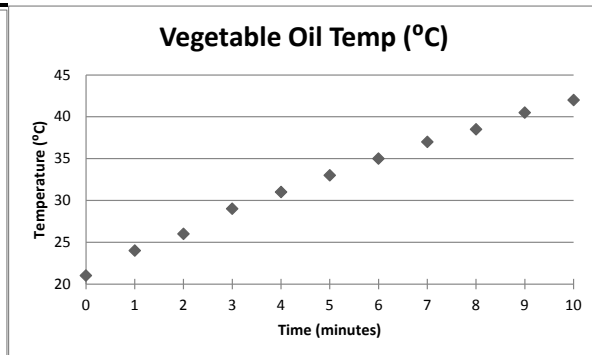
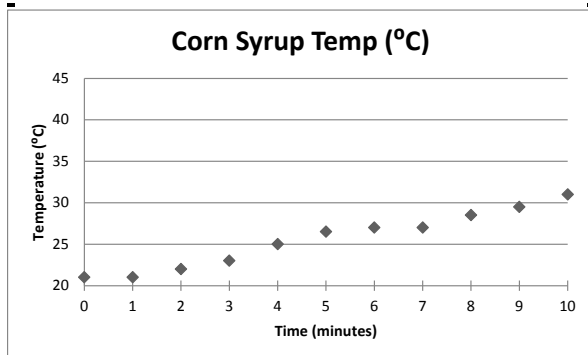
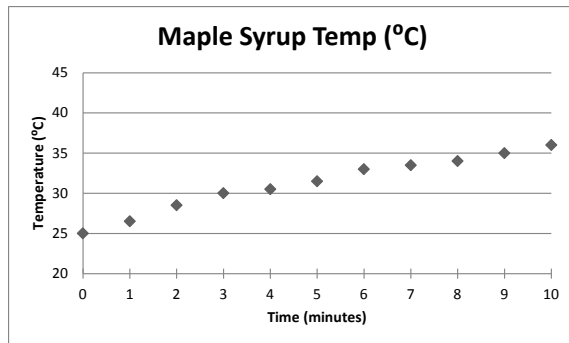
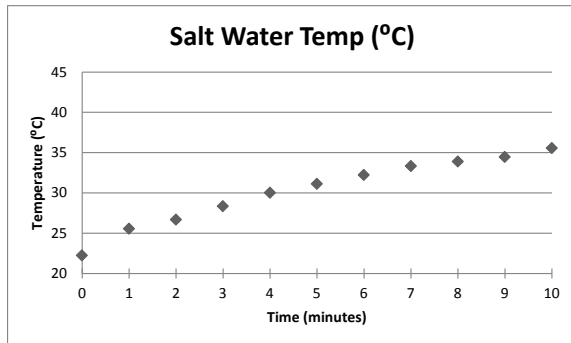
Class Results Students fill out this table to compile the results from all groups, as written on the board.

Liquid	Heat Transferred During 10min (kJ)
A = salt water	26.78
B = fresh water	27.24
C = maple syrup	15.25
D = vegetable oil	16.22
E = corn syrup	19.18

Teacher note: Below are results achieved when performing the experiment in preparation for the activity, with the hot plate set to $t \approx 200\text{ }^{\circ}\text{C}$, which worked well in producing decent temperature changes in the span of 10 minutes while not heating the liquids too much and causing safety risks. Your values may be different, depending on the hot plate temperature. Expect graphs to be linear (or close to it) as long as the liquids are kept well below the boiling point.

Time (mins)	Fresh Water Temp ($^{\circ}\text{C}$)	Salt Water Temp ($^{\circ}\text{C}$)	Corn Syrup Temp ($^{\circ}\text{C}$)	Maple Syrup Temp ($^{\circ}\text{C}$)	Vegetable Oil Temp ($^{\circ}\text{C}$)
0	21	22.2	21	25	21
1	24	25.6	21	26.5	24
2	26	26.7	22	28.5	26
3	27	28.3	23	30	29
4	28	30.0	25	30.5	31
5	29	31.1	26.5	31.5	33
6	30	32.2	27	33	35
7	31	33.3	27	33.5	37
8	32	33.9	28.5	34	38.5
9	33	34.4	29.5	35	40.5
10	34	35.6	31	36	42

Sp. Heat Cap. (kJ/kg-K)	4.19	3.93	2.72	2.10	1.67
Mass (kg)	0.50	0.51	0.71	0.66	0.46
Delta T (K)	13	13.3	10	11	21
Heat (kJ)	27.24	26.78	19.18	15.25	16.22



Questions

1. Define heat and describe three different ways that it can be transferred.

Heat is the transfer of thermal energy between two systems or throughout a single system. Heat can be transferred by:

- conduction, which is when a system of high thermal energy transmits heat to a system of lower thermal energy
- convection, which is when heat is transferred through bulk motion and density changes
- radiation, where electromagnetic waves transmit heat to the matter they come into contact with

2. Explain what it means for a liquid to have a high specific heat capacity? A low specific heat capacity?

A liquid with a high specific heat capacity can absorb high amounts of thermal energy per unit mass without undergoing a high temperature change. Liquids with low specific heat capacities will undergo greater temperature changes for the same amount of thermal energy comparatively.

3. Looking at your results, how does the specific heat capacity affect the heat transferred to the different liquids?

The general trend is that the higher the specific heat capacity, the larger the amount of heat that was transferred.

4. Which liquid do you think would work as the best radiator fluid? Why?

Liquid B would work the best because it had the highest amount of heat transferred and would therefore adsorb the largest amount of heat from the engine.

5. What other factors should engineers consider besides a liquid's specific heat capacity when choosing a radiator liquid?

It is also important to consider how well the liquid would flow in the engine, and if it would leave any residues. Also, it is important to consider if it would help prevent rust, or if freezing in cold weather would be an issue.

Teacher note: At this point, reveal to the students the identities of the five different “unknown” liquids and discuss why fresh water works the best of these options, but that other requirements and/or factors (as mentioned in the previous paragraph, such as adding antifreeze for cold weather; water alone would freeze when the engine was not running) must be taken into consideration.

6. A businesswoman travelling cross-country in her car notices the temperature gauge on her dashboard is in the red and reads 150°C. She pulls over and inspects her radiator fluid. She sees that there is no coolant in the radiator. Her car's engine is made of cast iron (specific heat = 0.460 kJ/kg-K) and she estimates that it is 200 kilograms. She wants to get the engine down to a safe temperature of 100°C. She has a jug of water at 20°C in her trunk. What volume of water does she need to put into the radiator? Assume that the water and engine exchange heat only with each other, not with the surrounding air or other mechanical parts.

Heat lost by the engine:

$$Q = m \cdot C_p \cdot \Delta T = (200 \text{ kg})(0.460 \text{ kJ/kg-K})(150^\circ\text{C} - 100^\circ\text{C}) = 4600 \text{ kJ}$$

Because the engine and water interact only with each other (no heat is lost from this system) the law of conservation of energy states that the heat lost by the engine must be gained by the water.

Heat gained by the water:

$$Q = 4600 \text{ kJ}$$

Rearranging the energy equation to solve for the mass of water needed:

$$m = Q / (C_p \cdot \Delta T) = 4600 \text{ kJ} / [(4.19 \text{ kJ/kg-K}) \cdot (100^\circ\text{C} - 20^\circ\text{C})] = 13.72 \text{ kg}$$

To find the volume of water:

$$V = m / \text{density of water} = 13.72 \text{ kg} / 1.0 \text{ kg/L} = \mathbf{13.72 \text{ L}}$$