

Don't Freeze the Engine – Answer Key

Antifreeze is used in a car's cooling system to protect the engine from freezing at various temperatures. In this activity, you will use an antifreeze chart to determine how much fluid in a vehicle's cooling system should be replaced with antifreeze to achieve a desired level of protection.

The antifreeze chart below shows how many quarts of antifreeze are needed, based on the cooling system capacity, to protect a car at various temperatures (in °F).

COOLING SYSTEM CAPACITY (QUARTS)	QUARTS OF ANTIFREEZE REQUIRED FOR PROTECTION TO THE GIVEN TEMPERATURE											
	1	2	3	4	5	6	7	8	9	10	12	13
8				-34								
9	24	14	0	-21	-50							
10	25	16	4	-12	-34	-62						
11	26	18	8	-6	-23	-47						
12		19	10	0	-15	-34	-57					
13		21	13	3	-9	-25	-45	-66				
14			15	6	-8	-18	-34	-54				
15			16	8	0	-12	-26	-43				
16			17	10	2	-8	-19	-34				
17			18	12	5	-4	-14	-27				
18			19	14	7	0	-10	-21	-34	-50	-65	
19			20	15	9	2	-7	-16	-28	-42	-65	
20				16	10	4	-3	-12	-22	-34	-48	-62

Part 1: Reading the Chart

- Determine how much antifreeze is needed to protect an engine with the following system capacity at the given temperatures.

SYSTEM CAPACITY	TEMPERATURE	QUARTS OF ANTIFREEZE NEEDED
18 quarts	-10°F	7
15 quarts	0°F	5
10 quarts	16°F	2
15 quarts	-43°F	8

The appropriate cells are highlighted in the table above.

Part 2: Getting the Right Mix

A 20-quart cooling system currently has a mix of water and antifreeze to protect the engine to temperatures as low as 10°F.

2. Complete the following chart using the above information and the antifreeze chart. (For the rest of this activity, this information will help you determine how to adjust the fluid in the current system to obtain protection as low as -48°F.)

NUMERICAL ANALYSIS OF THE SYSTEM		EXPLAIN HOW YOU KNOW
Cooling System Capacity (Quarts)	20	<i>Given</i>
Current Level of Protection (Temperature)	10°F	<i>Given</i>
Current Amount of Antifreeze (Quarts)	5	<i>From the antifreeze chart</i>
Current Amount of Water (Quarts)	15	<i>5 quarts of antifreeze; 20 quarts total $20 - 5 = 15$</i>
Percent Concentration of Antifreeze in the System (%)	25%	$\frac{5}{20} = 25\%$
Percent Concentration of Water in the System (%)	75%	$\frac{15}{20} = 75\%$ (or, $100 - 25 = 75\%$)
Antifreeze Needed for Target Protection Level (Quarts)	12	<i>From the antifreeze chart</i>
Water Needed for Target Protection Level (Quarts)	8	<i>12 quarts antifreeze, 20 quarts total $20 - 12 = 8$</i>
Percent Concentration of Antifreeze Needed for Target Protection Level (%)	60%	$\frac{12}{20} = 60\%$

3. When fluid is drained from a cooling system, some of the fluid is water and some of the fluid is antifreeze, depending on the percent concentration.

Refer to the current percent concentration of the system in Question 2. When the following amounts of fluid are drained from a 20-quart system at a 10°F level of protection, how many quarts of water are drained, and how many quarts of water remain in the system? Complete the following chart.

QUARTS OF FLUID DRAINED FROM 20-QUART SYSTEM	QUARTS OF WATER DRAINED FROM 20-QUART SYSTEM	QUARTS OF WATER REMAINING
0	0	15
2	$0.75(2) = 1.5$	$15 - 1.5 = 13.5$
4	$0.75(4) = 3.0$	$15 - 3.0 = 12.0$
6	$0.75(6) = 4.5$	$15 - 4.5 = 10.5$
8	$0.75(8) = 6.0$	$15 - 6.0 = 9.0$
10	$0.75(10) = 7.5$	$15 - 7.5 = 7.5$
12	$0.75(12) = 9.0$	$15 - 9.0 = 6.0$
14	$0.75(14) = 10.5$	$15 - 10.5 = 4.5$
16	$0.75(16) = 12.0$	$15 - 12.0 = 3.0$
18	$0.75(18) = 13.5$	$15 - 13.5 = 1.5$

4. The cooling system in Question 2 has a 20-quart capacity and protection to 10°F. Approximately how many quarts of fluid should be drained to leave the desired amount of water for protection to -48°F? Indicate the rows in the table above on which you based your decision. (Note that finding an exact value may be difficult, so give a range of possible values.)

Between 8 and 10 quarts. The appropriate rows are highlighted above.

5. About how much antifreeze should then be added to the system? Explain how you know.

Add 8 to 10 quarts, the same amount as the fluid drained.

6. Use any method you like to refine your estimate from Question 4. That is, narrow the range of values to find a better estimate for how much water should be drained. If possible, find an exact value.

Use the equation $15 - 0.75x = 8$, which gives $x \approx 9.33$ quarts of water should be drained.

7. Describe the relationship between the total amount of fluid, the percent concentration of antifreeze, and the amount of pure antifreeze in the cooling system.

Amount of Antifreeze in System = Total Fluid \times Percent Concentration of Antifreeze

Part 3: Word Problems

A mechanic has containers of pure antifreeze solution (which is 100% antifreeze) as well as containers with a 25% antifreeze solution. How many quarts of each should she mix together to get 20 quarts of a 60% antifreeze mixture?

8. Explain how this word problem is related to the activities from Parts 1 and 2. What is already done for you in the word problem that you had to do yourself in the activity?

In this problem, you do not have to determine how much fluid to drain.

9. There are two unknown quantities in the problem above. What are they?

Amount of 25% solution, and amount of 100% solution.

10. If the mechanic adds a quart of the 25% antifreeze solution to the mixture, how much pure antifreeze is added? What if she adds two quarts? ... x quarts?

*One quart gives 0.25 quarts of antifreeze; two quarts give 0.5 quarts of antifreeze.
With x quarts, there will be $0.25x$ quarts of antifreeze.*

11. If the mechanic adds a quart of the 100% antifreeze solution to the mixture, how much pure antifreeze is added? What if she adds two quarts? ... y quarts?

One quart of the solution gives one quart of antifreeze; two quarts give two quarts of antifreeze. With y quarts of the solution, there will be y quarts of antifreeze.

12. The mechanic wants to end up with 20 quarts of a 60% solution. In such a mixture, how many quarts will be pure antifreeze?

$$20 \times 0.60 = 12 \text{ quarts}$$

13. Use the information from Questions 10-12 to solve the original problem: How many quarts of each solution should she mix together to get 20 quarts of a 60% antifreeze mixture?

*Two equations can be generated: $0.25x + y = 12$ and $x + y = 20$.
These equations yield $x \approx 10.67$ and $y \approx 9.33$.*

This implies that 10.67 quarts of the 25% solution should be mixed with 9.3 quarts of the pure antifreeze to get 20 quarts of the 60% mixture.

14. Explain to a friend how to determine the percent concentration of antifreeze in a cooling system.

$$\text{Percent Concentration} = (\text{Amount of Antifreeze} \div \text{Total Fluid}) \times 100$$

15. Jonathan has a leak somewhere in his cooling system. As some of the fluid leaks out, he refills the system with water. Describe what impact this will have on the percent concentration of antifreeze in the system.

Some of the fluid in his system is antifreeze, so some antifreeze will be lost because of the leak. However, he is adding pure water which contains no antifreeze. Consequently, the mixture in his cooling system will be diluted, and it will contain less antifreeze than may be needed.

16. Brooke wants to make a 52% mixture, but she only has 30% acid solution and a 45% acid solution. Why will she not be able to get a mixture at the desired percent concentration? Explain how you know.

When mixing two solutions, the resulting mixture will have a percent concentration between the percent concentrations of the two solutions. In this case, a mixture would need to have a percent concentration between 30% and 45%, so 52% is not possible.

17. Willie read an antifreeze protection chart. For a 10°F level of protection in a 20-quart system, the chart suggested 4 quarts of antifreeze and 16 quarts of water. Because $4 \div 16 = 25\%$, Willie concluded that he needed a 25% percent mixture. Explain what is wrong with his reasoning.

The total number of quarts in the system is 20, not 16, so the correct percent concentration is $4 \div 20 = 20\%$.