SCUSD

8th Grade Unit of Study

Exponents

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| *DRAFT*  **8th Grade** **Unit of Study**  **Exponents** | | | |
| **Grade: 8** | **Topic: Exponent operations and rules** | **Length of Unit: 10 – 14 days** | |
| **Focus of Learning** | | | |
| **Common Core State Standards:**  **Expressions and Equations 8.EE**  **Work with radicals and integer exponents.**  **8.EE.1** Know and apply the properties of integer exponents to generate equivalent numerical expressions. *For example,*  **8.EE.3** Use numbers expressed in the form of a single digit times an integer power of 10 to estimate very large or very small quantities, and to express how many times as much one is than the other. *For example, estimate the population of the United States as and the population of the world of , and determine that the world population is more than 20 times larger.*  **8.EE.4** Perform operations with numbers expressed in scientific notation, including problems where both decimal and scientific notation are used. Use scientific notation and choose units of appropriate size for measurements of very large or very small quantities (e.g. use millimeters per year for seafloor spreading). Interpret scientific notation that has been generated by technology. | | | **Mathematical Practices:**   1. Make sense of problems and persevere in solving them. 2. Reason abstractly and quantitatively. 3. Construct viable arguments and critique the reasoning of others. 4. Model with mathematics. 5. Use appropriate tools strategically. 6. Attend to precision. 7. Look for and make use of structure. 8. Look for and express regularity in repeated reasoning. |
| **Enduring Understanding(s):** *Students will understand that…*   1. Number sense reasoning generates rules for multiplying and dividing powers with the same base. 2. The rules for multiplying and dividing powers with the same base generates the meaning of and rules for zero and negative exponents. 3. Place value and base-10 is integral to understanding scientific notation. 4. Scientific notation is used to represent large and small numbers. 5. Operations with scientific notation can be used to solve real world problems. | | | |
| **Essential Questions:** *These questions will guide student inquiry.*   1. Why is it helpful to use exponents? 2. How are exponents useful to model real world situations? 3. When is it appropriate to express numbers in scientific notation? 4. How can we estimate really large and really small quantities using exponents? 5. How does understanding the exponent rules help you solve real world problems involving scientific notation? | | | |

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| **Student Performance** | |
| **Knowledge:***Students will understand/know…*   * The definition of base, power, and coefficient * The exponent in an exponential term expresses how many times the base is to be multiplied (with positive integers only) * The rules for multiplying and dividing powers with the same base always work * The rule for raising an exponential term to another exponent always works * The proof of , when using the properties of exponents * Negative exponents can be rewritten using positive exponents * Scientific notation is used to represent large and small numbers * The rules for operations with exponents are used to perform operations with numbers expressed in scientific notation | **Application:***Students will be able to…*   * Expand, simplify, and evaluate expressions involving exponents, including products and quotients raised to powers * Prove the rules for operations of exponents with the same base (below) by using the definition of an exponent: * Generate and use the rules for multiplying and dividing powers with the same base * Generate and use the rules for zero exponents and negative exponents * Express large and small numbers in scientific notation * Perform operations with numbers expressed in scientific notation, and choose units of appropriate size to represent given measurements. * Solve real-world problems involving numbers expressed in scientific notation. |
| **Assessments** (attached with lessons) | |
| **Formative and Interim Assessments:**   * Illustrative Mathematics: 8.EE “Extending the Definitions of Exponents, Variation 1” (Lesson 4) * Illustrative Mathematics: 8.EE “Giantburgers” (Lesson 6) * Illustrative Mathematics: 8.EE “Ants versus Humans” (Lesson 6) * Smarter Balanced Sample Item: MAT.08.CR.000EE.B.494.C1.TB (Lesson 6)   **Post Assessment (Culminating Task):**   * “Blood in the Human Body” | |

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| **Learning Experiences** (Lesson Plans Attached) | | | |
| **Days** | **Lesson Sequence** | | **Materials** |
| 1 – 2 | **Lesson 1: Definition of an Exponent**  *Students will know:*   * The definition of base, power, and coefficient * The exponent in an exponential term expresses how many times the base is to be multiplied (with positive integers only)   *Students will be able to:*   * Expand, simplify, and evaluate expressions involving exponents, including products and quotients raised to powers. | |  |
| 2 | **Lesson 2: Properties for Operations of Exponents with the Same Base**  *Students will know:*   * The rules for multiplying and dividing exponents with the same base always work * The rule for raising an exponential term to another exponent always works   *Students will be able to:*   * Prove the rules for operations of exponents with the same base (below) by using the definition of an exponent:   1. b)  c) | |  |
| 1 – 2 | **Lesson 3: Properties for Zero and Negative Integer Exponents**  *Students will know:*   * The proof of , when using the properties of exponents (*see lesson 2*). * Negative exponents can be written as positive exponents using the rules for multiplying and dividing exponents with the same base.   *Students will be able to:*   * Use the rules that they generated in Lesson 2 (for multiplying and dividing exponents with the same base) to generate properties of zero and negative exponents.  1. b) | |  |
| 1 | **Lesson 4: Properties - Review and Assessment**  *Students will:*   * Propose, justify and communicate solutions | | **Interim Assessment:**   * Illustrative Mathematics: “Extending the Definitions of Exponents”   *(This Interim Assessment item is attached to the Lesson 4 lesson plan)* |
| 1 – 2 | **Lesson 5: Expressing Number in Scientific Notation**  *Students will know:*   * Scientific notation is used to represent large and small numbers   *Students will be able to:*   * Express large and small numbers in scientific notation | |  |
| 2 – 3 | **Lesson 6: Using Scientific Notation to Solve Real-World Problems**  *Students will know:*   * Scientific notation is used to represent large and small numbers * The rules for operations with exponents are used to perform operations with numbers expressed in scientific notation   *Students will be able to:*   * Express large and small numbers in scientific notation * Perform operations with numbers expressed in scientific notation, and choose units of appropriate size to represent given measurements. * Solve real-world problems involving numbers expressed in scientific notation. | | **Formative Assessments:**   * Illustrative Mathematics:   8.EE “Giantburgers”   * Illustrative Mathematics:   8.EE “Ants versus Humans”   * Smarter Balanced Sample Item: MAT.08.CR.000EE.B.494.C1.TB   (*these formative assessment items are attached to the Lesson 6 lesson plan*) |
| 1 | **Review**  *Students will:*   * Propose, justify and communicate solutions | |  |
| 1 | **Culminating Task**  *Students will:*   * Show their knowledge and understanding of exponents. | | **Post Assessment**   * Exponents “Blood in the Human Body” |
| **Resources** | | | |
| **Online** | | **Text** | |
| **Illustrative Mathematics**  <http://www.illustrativemathematics.org/>  **Inside Mathematics/MARS tasks**  <http://www.insidemathematics.org/> ; <http://map.mathshell.org/materials/index.php>  **National Library of Virtual Manipulatives**  <http://nlvm.usu.edu/en/nav/vlibrary.html>  **Progressions for the Common Core State Standards in Mathematics**  <http://ime.math.arizona.edu/progressions/>  **Smarter Balanced Assessment Consortium**  <http://www.smarterbalanced.org/smarter-balanced-assessments/#item> | | **Prentice Hall Mathematics. *California Algebra.***  **Boston: Pearson Education, Inc. 2009.**  **Shoseki, Tokyo. *Mathematics International:***  ***Grade 8*. 2012 (Japanese Text)**  **Van de Walle, John, and LouAnn Lovin. *Teaching***  ***Student-Centered Mathematics: Grades***  ***5-8.* Vol. 3. Boston: Pearson, 2006.** | |

Lessons

**Lesson 1: Definition of an Exponent**

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| **Unit: Exponents**  **Lesson 1: Definition of an Exponent** | Approx. time:  1 – 2 days | **CCSS-M Standards: 8.EE.1**  Know and apply the properties of integer exponents to generate equivalent numerical expressions. |
| A.Focus and Coherence  **Students will know…**   * The definition of base, power, and coefficient * The exponent in an exponential term expresses how many times the base is to be multiplied (with positive integer exponents only)   **Students will be able to…**   * Expand, simplify, and evaluate expressions involving exponents, including products and quotients raised to powers.   **Student prior knowledge:**   * Multiplication of factors   **Which math concepts will this lesson lead to?**   * Multiplying exponents with the same base * Dividing exponents with the same base * Products and quotients raised to exponents * Solving real-world problems involving exponents | | B. Evidence of Math Practices  *What will students produce when they are making sense, persevering, attending to precision and/or modeling, in relation to the focus of the lesson?*   * Students will precisely articulate the definition of an exponent through various examples; for example, they will say that 42 means 4 times 4; 43 means 4 times 4 times 4; and (42)3 means 42 times 42 times 42. They will say that negative and fractional bases work the same way, (e.g., (1/4)3 and (- 4)2),along with bases containing variables and coefficients (e.g., 4x2) * Students will precisely articulate the definitions of the words “base” and “exponent”. They will say that the base is the number we are multiplying and the exponent tells us how many times we multiply the base by itself (when the exponent is a positive integer). * Students will be able to predict how exponents may be useful to model real world situations. (i.e. Posting a picture on online social network sites and the number of people who could ultimately view that picture if it continues to get shared) |
| **Essential Question(s)**   1. Why is it helpful to use exponents? 2. How are exponents useful to model real world situations? 3. How is 3·4 (three times four) different from 34 (three to the fourth power)? | | |
| **Formative Assessments** (“Ticket-out-the-door Questions”)   1. Write 233 in expanded form. 2. Write a number in expanded form and show what it looks like in exponential form. Identify which term is the exponent and which term is the base. 3. Why can exponents be useful in real-life situations? | | |
| **Anticipated Student Preconceptions/Misconceptions**   * Students may confuse the base and the exponent, for example they may incorrectly multiply the exponent instead of the base, i.e. 23 = 3·3. * Students may think that exponents imply multiplication of the base and the exponent, i.e. 23 = 2·3. * Students may incorrectly put the expanded form of a number into exponent form, i.e. 2·2·2 = 83 | | |
| **Materials/Resources**   * Individual whiteboards to collect student feedback | | |
| C. **Rigor**: fluency, deep understanding, application and dual intensity  *What are the learning experiences that provide for rigor? What are the learning experiences that provide for evidence of the Math Practices? (Detailed Lesson Plan)* | | |
| **Warm Up**  *Using individual whiteboards*  How else could you write 3+3+3+3+3+3? ANSWER: 3·5 (or 5·3) | | |
| **Lesson**  Part I: Definition of Base and Exponent; Writing Expressions in Exponential and Expanded Form.   1. *Teacher:* Put the numbers 6 and 2 on the board. Have students predict some possible values for solutions given those two numbers, without any given operations.   Students should come up with:  6+2 = 8; 6x2 = 12; 6 – 2 = 4; 6/2 = 3.  Students may not know any more.  Teacher says, “I have another operation 62, what do you think its value might be?” Let students take guesses.    Have students take guesses until they discover 36, and tell them that 36 is correct. Show them that 62 = 6·6 = 36.  Do the same with 42, 33, 104, ect., allowing students to *take guesses* for the value of each expression, and letting students see the pattern of multiplying the base by itself.   1. Introduce the vocabulary “base” and “exponent” (these will probably be familiar to them from previous grade levels). Show them that the “big number” is the “base” and the “little number” is the “exponent.”   *Pose question to class:* “What does the base tell us and what does the exponent tell us in 42?” Direct students to think about their answers from #1 (i.e. 33 = 3·3·3). Write definition on board for students to copy down in their notes or math dictionary: “The exponent tells us how many times the base is to be multiplied by itself, when the exponent is a positive integer.”   1. Introduce the terms “exponential form” and “expanded form”   “Exponential form” is when the term has a base and an exponent, like expressions on the *left side* of the table.  “Expanded form” of is when the factors are written out with multiplication, like the expressions on the *right side* of the table.   |  |  | | --- | --- | | **Exponential Form** | **Expanded Form** | | 33 | 3·3·3 | | 45 | 4·4·4·4·4 | | 74 | 7·7·7·7 |   *Use white boards to collect student feedback.*  Have students write the expanded form of the following expressions:   1. 53 b)46 c)121   Have students write the exponential form of the following expressions:   1. 2x2 b) 100·100·100·100 c) 4 d) (-3) · (-3) · (-3)   \**Students may have questions about (d). Have students use the definitions of exponent and base to reason about rewriting this expression in the same way as the expressions with positive bases.*  Ask students for a number to use as a base (e.g. “7”) and a positive integer to use as an exponent (e.g “5”).  *Pose question:* “Suppose my base is 7 and my exponent is 5, write the expanded form of 75?”  \**Do more problems as necessary.*   1. Have students expand expressions with bases that are *not* positive integers: 2. (-3)2 3. (1/2)3 4. x4   *Use white boards to collect student feedback.*  Part II: Powers Raised to Exponents  As a whole group, expand and simplify:  *\*Refer back to the definitions of base and exponent.*   1. (42)3. The base is 42 and the exponent is 3. This means 42 times itself 3 times.   Expanded form: 42·42·42 = 4·4·4·4·4·4 = 46   1. (53)5   What is the base? What is the exponent?      What is the base? What is the exponent?  *Pose question to class:* “What do you notice?” (Don’t introduce rule of “multiplying powers together when you have an exponent raised to another exponent” - this will happen in the next lesson).  Have students write the following expressions in “exponential form”  *Use white boards to collect student feedback.*  (Include bases that are negative numbers, fractions, and variables, for example):        *\*Do more problems as necessary.* | | |
| **Closure**  Talk to your neighbor about what you learned today using our new vocabulary and explain what it means.  Have students share their explanations with the whole group.  Give the formative assessment on a half sheet to be turned in as a ticket out the door:  Ticket-out-the-door questions:   1. Write 233 in expanded form. 2. Write a number in expanded form and show what it looks like in exponential form. Identify which term is the exponent and which term is the base. 3. Why can exponents be useful in real-life situations? | | |
| **Suggested Homework/Independent Practice**  *Attached worksheet* | | |

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Date: \_\_\_\_\_\_\_\_\_\_\_

Lesson 1: Homework Worksheet

**Write in expanded form**

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| 1. 54 | 1. (-12)3 |
| 1. (½)5 | 1. (4*x*)6 |

**Write in exponential form**

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1. In the term, what is the base and what is the exponent? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

What does the baseintell us? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

What does the exponent in  tell us? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. What does an exponent of 1 mean? (For example, 51)
2. What is the difference between 5·3 and 53?

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1. Write a number in expanded form and show what it looks like as an exponential term. Identify which term is the exponent and which term is the base.

**Lesson 2: Properties for Operations of Exponents with the Same Base**

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| **Unit: Exponents**  **Lesson 2: Properties for Operations of Exponents with the Same Base** | Approx. time:  2 days | **CCSS-M Standards: 8.EE.1**  Know and apply the properties of integer exponents to generate equivalent numerical expressions. |
| A. **Focus and Coherence**  Students will know…   * The rules of multiplying and dividing exponents with the same base always work * The rule for raising an exponential term to another exponent always works   Students will be able to…   * Prove the rules for operations of exponents with the same base (below) by using the definition of an exponent: * b)  c)   Student prior knowledge:   * Definitions of exponent and base * Know how to expand, simplify, and evaluate expressions involving exponents, including products and quotients raised to powers * Simplifying fractions by canceling pairs of factors in the numerator and denominator   Which math concepts will this lesson lead to?   * Properties for zero and negative integer exponents * Fractional exponents * Scientific notation | | B. **Evidence** of Math Practices  *What will students produce when they are making sense, persevering, attending to precision and/or modeling, in relation to the focus of the lesson?*   * Students will generate the rules for operations of exponents with the same base by noticing repeated calculations. * Students will use the academic vocabulary appropriate for this lesson when responding to verbal questions during the lesson and in their “Ticket-Out-the-Door” written responses (power, base, exponent, factors, simplify, expanded form, etc.) * Students will use the definition of an exponent to explain and justify/prove why the rules of exponents with the same base always work. |
| **Guiding Question(s)**   1. How can we multiply or divide two powers with the same base without expanding the expression? 2. How can we raise a power to a power without expanding the expression? | | |
| **Formative Assessments**   * Choral Response to Examples 1,2, & 3 (see lesson) * Ticket-Out-the-Door Prompt:   Write a written explanation on how to multiply and divide powers with the same base, without  expanding the expression. | | |
| **Anticipated Student Preconceptions/Misconceptions**   * When multiplying powers with the same base, students multiply the exponents or multiple the bases. * When dividing powers with the same base, students divide the exponents or divide the bases. * When raising a power to a power, students perform the exponent operation on the base (e.g. (33)3 = 279) | | |
| **Materials/Resources**  Document camera, individual whiteboards and markers, math textbook (for homework only) | | |
| C. **Rigor**: fluency, deep understanding, application and dual intensity  *What are the learning experiences that provide for rigor? What are the learning experiences that provide for evidence of the Math Practices? (Detailed Lesson Plan)* | | | |
| **Warm Up**  Students answer warm-up problems individually, then teacher leads whole-class discussion:   1. Expand *x*5 2. Expand 57 3. Expand (54)3   (*for discussion:* Do you think it would be helpful to find a shortcut for #3?)   1. (What can we substitute for the blank to make this equation true?) 2. Simplify | | | |
| **Lesson**  Part 1: Multiplying Powers with the Same Base  Teacher guides discussion, asking the whole class questions and providing wait time for students to think.   1. What is the expanded form of this expression?          1. *Have students do more examples like the one in part (a) until they start to see a pattern.* 2. What do you notice about multiplying powers with the same base?    * + Is there a shortcut that we can use, without having to write the exponents in expanded form?      + Does the base change?      + Does the exponent change? How?      + What is the rule?   *After sufficient discussion from part (c), have students copy the rule for multiplying powers with the same base in their notebooks or math journals:*  When multiplying powers with the same base, add the exponents:     1. Practice for Part (1); Students try problems on their own, on individual whiteboards for immediate feedback.         * *\*Do more problems as necessary*    * Find two powers that will make the equation true: . Explain your reasoning to a partner. *Have a few students share their responses and explanations with the whole class.*   Part 2: Dividing Powers with the Same Base  Teacher guides discussion, asking the whole class questions and providing wait time for students to think.   1. Have students guess how to simplify.    * + A few students explain how they simplified (choose students who simplified in different ways)   *For example,*  *Or,*  *Or,*   1. *Have students do more examples of simplifying fractions like the one in part (a) until they see a pattern* 2. What do you notice about dividing powers with the same base?    * + Is there a shortcut that we can use, without having to write the exponents in expanded form?      + Does the base change?      + Does the exponent change? How?      + What is the rule?   *After sufficient discussion from part (c), have students copy the rule for dividing powers with the same base in their notebooks or math journals:*  When dividing powers with the same base, subtract the exponents:     1. Practice for Part (2); Students try problems on their own, on individual whiteboards for immediate feedback.        * *\*Do more problems as necessary*    * Find two powers that will make the equation true: . Explain your reasoning to a partner. *Have a few students share their responses and explanations with the whole class.*   Part 3: Raising a Power to a Power  Teacher guides discussion, asking the whole class questions and providing wait time for students to think.   1. Let’s look back to Warm-Up Question #3: Expand (54)3  * How did you get it? * If 54 is the base and 3 is the exponent, you can do 54 multiplied by itself 3 times, then continue to expand the exponents:  1. *Have students simplify more expressions, like the example in part (a), until they see a pattern*    * + (46)2      + (42)6 2. What do you notice about powers raised to other powers?    * + Is there a shortcut that we can use, without having to write the exponents in expanded form?      + Does the base change?      + Does the exponent change? How?      + What is the rule?   *After sufficient discussion from part (c), have students copy the rule for raising a power to a power in their notebooks or math journals:*  When raising a power to a power, multiply the exponents     1. Practice for Part (3); Students try problems on their own, on individual whiteboards for immediate feedback.  * Find two exponents that will make the equation true: . Explain your reasoning to a partner. *Have a few students share their responses and explanations with the whole class.* | | | |
| **Closure – “Ticket-Out-The-Door” Prompt:**  Write an explanation on how to multiply and divide powers with the same base.  Possible extension questions:   1. Simplify an expression and provide a written explanation for each step 2. Why do the powers have to have the same base to perform the operations you learned today? | | | |
| **Suggested Homework/Independent Practice**  Some homework problems from the textbook (for procedural fluency)  Using only three variables *x, y, z*, write the three rules of operations of exponents with the same base. | | | |

**Lesson 3:** **Properties for Zero and Negative Integer Exponents**

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| **Unit:** **Exponents**  **Lesson 3:** **Properties for Zero and Negative Integer Exponents** | **Approx. time:**  1 – 2 days | **CCSS-M Standards: 8.EE.1**  Know and apply the properties of integer exponents to generate equivalent numerical expressions. |
| A. **Focus and Coherence**  Students will know…   * The proof of , when , using the properties of exponents * Negative exponents can be expressed using positive exponents using the rules for multiplying and dividing exponents with the same base   Students will be able to…   * Use the rules that they generated in Lesson 2 (for multiplying and dividing exponents with the same base) to generate the property of zero exponents:      * Use the rules that they generated in Lesson 2 (for multiplying and dividing exponents with the same base) to generate the property of negative exponents:     Student prior knowledge:   * The rules for multiplying and dividing exponents with the same base always work  1. b)  * Identify multiple representations for names of 1.   Which math concepts will this lesson lead to?   * Understanding the relationship between square roots and cube roots and the fractional exponents of ½ and 1/3. * Propose, justify and communicate solutions involving properties of exponents. | | B. **Evidence** of Math Practices   * Student can explain with justification why any number to the zero power is one because they understand the rules of additive laws of exponents and multiplicative identity:  and , so * Students can use the additive law of exponents and the multiplicative identity to prove/justify that , for example:   because (additive law of exponents)    9 = 9  = 1 (multiplicative identity)   * Students can use the subtractive law of exponents and division to prove that for example:   ,and  So,   * Students can explain why a negative exponent is equivalent to its reciprocal because they understand the rules of additive laws of exponents and they’ve already proven that . Students will show that , and since , . This implies that and must be reciprocals.   For example:  is the unknown, but we know…      8 = 1  =, which is. |
| Essential Question(s):   1. Why is using exponents helpful? 2. How does understanding the exponent rules help you solve real-world problems? 3. Multiplication is to repeated addition, as Exponents are to…. ? 4. How does understanding the additive law of exponents help you develop rules for zero and negative exponents? | | |
| Formative Assessments:  Ask the following 3 questions as a Ticket-Out-The-Door closure item, for students to reflect on the day’s learning:   1. In , where did the exponent “2” in the answer come from? 2. Why is ? Is this always true? 3. Prove that | | |
| Anticipated Student Preconceptions/Misconceptions:  and other responses  and other responses | | |
| Materials/Resources:  Worksheet/workout paper, notebooks, individual whiteboards and markers | | |
| C. **Rigor**: fluency, deep understanding, application and dual intensity  *What are the learning experiences that provide for rigor? What are the learning experiences that provide for evidence of the Math Practices? (Detailed Lesson Plan)* | | |
| **Warm Up (Day 1)**  Use exponent rules to simplify:   1. = *ANS:* 2. = *ANS:* 3. *ANS:* 4. *ANS:* 5. What are your thoughts about the answer to #4?   **Warm Up (Day 2)**  Use exponent rules to simplify:   1. = *ANS:* 2. *ANS:* 3. *ANS: 1* 4. *ANS:* 5. What are your thoughts about the answer to #4? | | |
| **Lessons**  Day 1: Zero Exponents   1. Debrief warm up answers and have a whole-group class discussion about #4. 2. *Pose question to the class:* What are some guesses of the value of ? *Chart student guesses on the board.* 3. Use exponent rules to prove why 650 = 1   *For example:*  (additive law of exponents)  *There is one unknown that we’re trying to solve for (650 = ?)*    *x* = 1 (multiplicative identity)   1. *Show another way:* Use exponent rules to prove why 20 = 1:   , and  So,   1. Have students prove that each of the following equals 1 by using the strategies from #3 and/or #4 2. 70 b)  c) 1,0000 3. Have students reason about what must equal (when *a* is any non-zero number). 4. Put the rule for zero exponents on the board for class to copy down in notebooks  |  | | --- | | Zero as an Exponent  For every nonzero number, *a* |   Day 2: Negative Exponents:   1. Debrief warm up answers and have a whole-group class discussion about #4. 2. *Pose question to class:* What are some guesses of the value of ? *Chart student responses on the board* 3. Have students use the additive law of exponents to prove that   *Example:*  is the unknown but we know…  =    8 = 1, has to be … the multiplicative inverse!  So  Have students do various examples like the one above until they start to see a pattern.   |  |  |  | | --- | --- | --- | | Example 1:  What is?  We know that  (…see above to continue…)  So | Example 2:  What is?  So | Example 3:  What is  So |  1. Have students reason about what must equal 2. Put the rule for negative exponents on the board for the class to copy down in their notebooks.      |  | | --- | | Negative Exponents  For every nonzero number, *a* and integer *n,* | | | |
| **Closure**  Use the 3 formative assessment questions as a Ticket-Out-The-Door reflection from today’s work:   1. In , where did the exponent “2” in the answer come from? 2. Why is ? Is this always true? 3. Prove that | | |
| **Suggested Homework/Independent Practice**  Use the property for multiplying powers with the same base: to prove the following:   1. 50 = 1 2. (–25)0 = 1 | | |

**Lesson 4:** **Properties – Review and Assessment**

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| **Unit:** **Exponents**  **Lesson 4:** **Properties – Review and Assessment** | **Approx. time:**  1 day | **CCSS-M Standards: 8.EE.1**  Know and apply the properties of integer exponents to generate equivalent numerical expressions. |
| A. **Focus and Coherence**  Students will…   * Review the properties of exponents   a)  b)  c)  d)   * Propose, justify, and communicate solutions to an Interim Assessment task regarding properties of exponents | | B. **Evidence** of Math Practices   * Students will use words, symbols, and numbers to explain and justify why the properties of exponents work. * Students will articulate their thoughts accurately and precisely in writing. |
| Materials/Resources:  Interim Assessment worksheet and answer key (attached) | | |
| C. **Rigor**: fluency, deep understanding, application and dual intensity  *What are the learning experiences that provide for rigor? What are the learning experiences that provide for evidence of the Math Practices? (Detailed Lesson Plan)* | | |
| **Warm Up**  Review homework from Lesson 3:  Use the property for multiplying powers with the same base: to prove the following:   |  |  |  | | --- | --- | --- | | 1. 50 = 1 | 1. (–25)0 = 1 |  | |  |  |  | | | |
| **Lesson**  Administer Interim Assessment Task: “Extending the Definition of Exponents”(**attached**)  Students will complete this task independently. | | |
| **Closure**  Ticket-Out-The-Door written reflection:  What do you still need help with regarding exponent operations? | | |
| **Suggested Homework/Independent Practice**  None | | |

Lesson 4

Interim Assessment: “Extending the Definition of Exponents”

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Date: \_\_\_\_\_\_\_\_\_\_

Marco and Seth are lab partners studying bacterial growth. They were surprised to find that the population of the bacteria doubled every hour.

1. The table shows that there were 2,000 bacteria at the beginning of the experiment. What was the size of the population of bacteria after 1 hour? After 2, 3, and 4 hours? Enter this information into the table:

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Hours into study |  |  |  | 0 | 1 | 2 | 3 | 4 |
| Population in thousands |  |  |  | 2 |  |  |  |  |

1. If you know the size of the population at a certain time, how do you find the population one hour later?
2. Marco said he thought that they could use the equation to find the population at time *t.* Seth said he thought that they could use the equation. Decide whether either of these equations produces the correct populations for t = 1, 2, 3, and 4.
3. What number would you use to represent the time 1 hour before the study started? 2 hours before? 3 hours before? Complete the first row of the table showing the 3 hours prior to the beginning of the study.
4. Assuming the population doubled every hour before the study began, what was the population of the bacteria 1 hour *before* the students started their study? What about 3 hours before? Complete the second row of your table to show the population of the bacteria during the 3 hours prior to the beginning of the study.
5. Use Seth’s equation to find the population of the bacteria 1 hour before the study started. Use the equation to find the population of the bacteria 3 hours before the study started. Are these the same values you found in part (e) and entered into your table?

Lesson 4

**Answer Key** – “Extending the Definition of Exponents”

1. After 1 hour the population is 4 thousand, after 2 hours it’s 8 thousand, after 3 hours it’s 16 thousand, and after 4 hours it’s 32 thousand.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Hours into study |  |  |  | 0 | 1 | 2 | 3 | 4 |
| Population in thousands |  |  |  | 2 | 4 | 8 | 16 | 32 |

1. If you know the population at a certain time, you can multiply by 2 to get the size of the population an hour later.
2. Seth’s equation is correct because it gives the correct population sizes for hours 1, 2, 3 and 4. The equation doubles the number every hour into the study.
3. I used –1 to represent the time 1 hour before the study, –2 to represent 2 hours before the study, and –3 to represent 3 hours before the study.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Hours into study | –3 | –2 | –1 | 0 | 1 | 2 | 3 | 4 |
| Population in thousands |  |  |  | 2 | 4 | 8 | 16 | 32 |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Hours into study | –3 | –2 | –1 | 0 | 1 | 2 | 3 | 4 |
| Population in thousands |  |  | 1 | 2 | 4 | 8 | 16 | 32 |

double

double

double

1. Seth’s equation gives the same values that I found in part (e) and put in the table.

I usedand I plugged in *t =* –1, –2, and –3.

|  |  |  |
| --- | --- | --- |
| At *t* = –1 | At *t* = –2 | At *t* = –3 |
| = 1 |  |  |

**Lesson 5: Expressing Numbers in Scientific Notation**

|  |  |  |
| --- | --- | --- |
| **Unit: Exponents**  **Lesson 5: Expressing Number in Scientific Notation** | Approx. time:  1 – 2 days | **CCSS-M Standards: 8.EE.3**  Use numbers expressed in the form of a single digit times an integer power of 10 to estimate very large or very small quantities, and to express how many times as much one is than the other. *For example, estimate the population of the United States as* *and the population of the world of , and determine that the world population is more than 20 times larger.* |
| A. **Focus and Coherence**  Students will know…   * Scientific notation is used to represent large and small number   Students will be able to…   * Express large and small numbers in scientific notation   Student prior knowledge:   * Definition of an exponent * Rules for multiplying and dividing powers with the same base * The proof of x0 = 1 * Rewriting negative exponents as positive exponents * Place value chart   Which math concepts will this lesson lead to?   * Applying scientific notation to real world situations | | B. **Evidence** of Math Practices  *What will students produce when they are making sense, persevering, attending to precision and/or modeling, in relation to the focus of the lesson?*   * Students will explain when it is appropriate to express a number in scientific notation. * Students will justify why their expression written in scientific notation is equivalent to the expanded form of the number (e.g. “I know that 7,000,000 is 7 x 106 because 106 represents 1,000,000 and 7 times 1,000,000 is 7,000,000”). * Students will precisely articulate how to properly read numbers written in scientific notation (e.g. “7 x 106 is seven times ten to the sixth”) |
| Essential Question(s):   1. When is it appropriate to express numbers in scientific notation? 2. How can we estimate numbers written in scientific notation? (Know certain place values)  * The distance from planet X to planet Y is 6.953 x 106 miles. Approximately how many miles is that? Students knowing that the exponent of “6” is for million, so that’s about 7 million miles. | | |
| Formative Assessments:  Ticket-Out-The-Door writing prompt:  Why do scientists and mathematicians sometimes use scientific notation as opposed to standard form? | | |
| Anticipated Student Preconceptions/Misconceptions:   * Format for writing in Scientific Notation * Concept of base 10 * Possible unresolved issues with positive, negative and zero powers * “Adding zeros” as opposed to moving the decimal point * Why we use “X” vs. multiplication point or parentheses * Forgetting that the first number must be greater than or equal to 1 and less than 10 | | |
| Materials/Resources   * Individual whiteboards, markers, and erasers | | |
| C. **Rigor**: fluency, deep understanding, application and dual intensity  *What are the learning experiences that provide for rigor? What are the learning experiences that provide for evidence of the Math Practices? (Detailed Lesson Plan)* | | |
| **Warm Up**  Which expression represents the greatest amount? How do you know?   * 8.2 x 102 * 9 x 103 * 7.356 x 104   (*Answer:* 7.356 x 104) | | |
| **Lesson**  Part 1  *Understanding Scientific Notation*  Whole-Class Discussion around the following talking points:   * Mathematicians and scientists used what’s called “Scientific Notation” to express really large or really small numbers.   + For example, the earth is 4,600,000,000 years old. That’s a really big number with a lot of zeros! There is a way to write that number without all of the zeros, which is what we will be learning about today.   + For example, the mass of an ant is 0.000073 kg. That’s a really small number with a lot of zeros! There is a way to write that number without all of the zeros, which is what we will be learning about today. * When do you think it is appropriate to express numbers in scientific notation?   + Give an example of when you might use a really big number or a really small number to represent something in the real world.   Part 2  *Writing Numbers in Scientific Notation*  Have students write down:   1. 945 followed by 7 zeros, 2. 945 followed by 15 zeros, 3. 945 followed by 25 zeros.   Whole-Class Discussion around the following questions:   1. Is there a way to write these numbers without all the zeros? 2. What does it mean when we have a base of 10? (E.g. 102, 103, 106, etc.) Can we use that information to help us write these numbers without all of the zeros?    1. Any guesses?   *Write down student guesses and listen to student explanations.*  *Work out problems as a group until correct answers have been discovered.*   1. How to read numbers in scientific notation:    1. 9.45 x 105 is “9 and 45 hundredths times 10 to the 5th power”    2. 6 x 103 is “six times 10 to the 3rd power”    3. *More examples as needed* 2. What’s bigger: 9 x 101, 5 x 102, 4 x 103, or 1 x 104?    1. How do you know?    2. Do you have to expand each of the numbers in order to know which one is bigger?    3. Can you just look at the power of 10?   *For students who may still be struggling with this concept and need a visual representation, you can draw a visual of 1 block, 10 x 10 square, 10 x 10 x 10 cube, etc.*  *This might help with comparisons when deciding which value is greater.*  Have students repeat this process with other examples as needed.  Pay close to attention to the *first* number in Scientific Notation – it must be greater than or equal to 1 and less than 10.  Part 3  *Writing Numbers in Standard Form*  Present problems in scientific notation and have students work backwards to put them into standard form.  Put the following numbers in standard form:   1. 5.23 x 105 2. 3 x 10-3 3. 4.2 x 107 4. 9.999 x 103 5. *More examples as needed* | | |
| **Closure**  Ticket-Out-The-Door writing prompt:  Why do scientists and mathematicians sometimes use scientific notation as opposed to standard form? | | |
| **Suggested Homework/Independent Practice**  *Prentice Hall Mathematics: California Algebra 1 Textbook*  Chapter 7-2, pages 337 #12, 13, 18, 22, 24, 27, 34 – 39.  (These problems get at the computational skills involved with writing numbers in scientific notation and in standard form; the following lesson will focus on the real-world application of scientific notation). | | |

**Lesson 6: Using Scientific Notation to Solve Real World Problems**

|  |  |  |
| --- | --- | --- |
| **Unit:** **Exponents**  **Lesson 6:** **Using Scientific Notation to Solve Real World Problems** | Approx. time:  2 – 3 days | **CCSS-M Standards: 8.EE.4**  Perform operations with numbers expressed in scientific notation, including problems where both decimal and scientific notation are used. Use scientific notation and choose units of appropriate size for measurements of very large or very small quantities (e.g., use millimeters per year for seafloor spreading). Interpret scientific notation that has been generated by technology. |
| A. **Focus and Coherence**  Students will know…   * Scientific notation is used to represent large and small numbers * The rules for operations with exponents are used to perform operations with numbers expressed in scientific notation   Students will be able to…   * Perform operations with numbers expressed in scientific notation and choose units of appropriate size to represent given measurements. * Solve real-world problems involving numbers expressed in scientific notation. * Convert between units of measurement using numbers expressed in scientific notation   Student prior knowledge:   * Express large and small numbers in scientific notation * Write measurements in standard form and/or scientific notation. * Perform operations of exponents (multiply, divide, zero and negative exponents) * Convert between different units of measurement (i.e. dimensional analysis)   Which math concepts will this lesson lead to?   * Propose, justify and communicate solutions to real-world problems that involve scientific notation and exponents | | B. **Evidence** of Math Practices  *What will students produce when they are making sense, persevering, attending to precision and/or modeling, in relation to the focus of the lesson?*   * Students will make sense of word problems by appropriately converting unit measurements, and determining the reasonableness of their results. * Students will apply exponent operations and scientific notation rules in solving real world problems and justify their solutions. * Students will make predictions and inferences using data with scientific notation (in graphs, tables, or diagrams). * Students will use appropriate vocabulary and units of measurements to represent predictions and inferences. |
| Guiding Question(s)   1. Why is using exponents helpful? 2. When is it appropriate to express numbers in scientific notation? 3. How can we estimate quantities of variable lengths using exponents? 4. How does understanding the exponent rules help you solve real-world problems involving scientific notation? | | |
| Formative Assessments **(see attached)**   * “Ants vs. Humans” (*sample problem from www.IllustrativeMathematics.org)* * “Giantburgers” (*sample problem from www.IllustrativeMathematics.org)* * “Distance to the Sun” (*sample problem from Smarter Balanced*) | | |
| Anticipated Student Preconceptions/Misconceptions   * Calculators can handle all types of numbers * Performing operation does not involve grouping terms * Products or quotients do not need to be changed to a scientific notation * When converting between standard form and scientific notation, there will be a misconception in moving the decimal based on the sign of the exponent. | | |
| Materials/Resources   * Formative assessments (see attached) | | |
| C. **Rigor**: fluency, deep understanding, application and dual intensity  *What are the learning experiences that provide for rigor? What are the learning experiences that provide for evidence of the Math Practices? (Detailed Lesson Plan)* | | |
| **Warm Ups**  **Day 1**  Simplify. Express all exponents as positive numbers:   * (23)(25) = * = * = * =   **Day 2**  Express the following numbers in scientific notation:   * The age of the earth: 4,600,000,000 years * The mass of an ant: 0.004 grams   **Day 2 or 3**  The current United States population is about 314,000,000 people. If an iPad costs $500.00, what would be the total cost of purchasing an iPad for each person?   1. Express the U.S. population in scientific notation. 2. Write an expression to represent the total cost of purchasing iPads for everyone in the U.S. 3. What is the total cost of purchasing IPads for everyone in the U.S.? 4. Explain how you know your answer is correct (model, draw a picture, etc.). | | |
| **Lesson** (to be taught over 2 – 3 days)    **Direct Instruction:**  Today you will use all exponent rules to perform operations of numbers written in scientific notation such as the rules for multiplying and dividing powers with the same base. Teacher goes over the rules, then, invites the attention of the students on the board to follow through the review on how the rules will apply to the given examples on the board.  **Model Instruction:**  Give at least two examples on the white board/projector of multiplying numbers expressed in Scientific Notation and also dividing numbers expressed in Scientific Notation:  Example #1) (5 x 103)(5 x 10 2) = (5)(5)x(103)(102)  =25 x 105 = 2.5 x 106  Example #2) = 0.25 x 104 = 2.5 x 103  Example #3) Convert the following units:   * 500 inches = \_\_\_ feet * 10,000 miles = \_\_\_\_ inches * 65 kilograms = \_\_\_\_ grams * 2 liters = \_\_\_\_ milliliters   Provide practice problems for students to work on in pairs or groups, similar to examples 1, 2, and 3.  **Guided Practice:**  Solve word problems that allow students to perform operations with numbers expressed in scientific notation. Do 2 problems as a whole group.  *Example 1:*  The average mass of an adult human is about 65 kilograms while the average mass of an ant is approximately 4 x 10-3 grams. The total human population in the world is approximately 6.84 billion, and it is estimated there are currently about 10,000 trillion ants alive.  Make a decision about the following:  □ The total mass of ants is greater than the total mass of humans; **or**  □ The total mass of humans is greater than the total mass of ants  How do you know? Explain your reasoning.  *Example 2:*  The population of the United States is about 3 x 108 and the population of the world is about 7 x 109. How much larger is the world population than the United States population? How do you know? How did you figure it out?  *Students may have been able to do this problem in their head to estimate that the world population is more than 20 times larger. Or other students may have divided to give an exact answer of 23.33 times larger. Take time to explore how different students solved this problem.*  Other ideas for real-world application problems:   * Calculating masses of protons, electrons and neutrons in atoms. * Calculating air pollutants and making predictions of the air quality. * Calculating distance between planets and stars. * Calculating the number of atoms and molecules in a given mass of an element or a compound and relate to stoichiometric problems to determine yields in the industry. * Calculating carbon footprints.   **Group/Partner work:**   * Have students do formative assessment questions in partners or small groups (**see attached**)   + Possible “Stations Activity” where each station contains a different real-world application problem involving operations with scientific notation. Have students work in groups at their station then rotate to a different station (depending on time allotted).   + **Calculators may be used for these problems** * Whole group share out and debrief | | |
| **Closure**  Presentations from group work | | |
| **Suggested Homework/Independent Practice**  *Prentice Hall Mathematics: California Algebra 1 Textbook*  Chapter 7-2, pages 337 #26, 28, 32, 42, 43, 45 | | |

Lesson 6

Formative Assessment Questions for group work:

*Calculators may be used for these problems*

1. “Ants vs. Humans”

The average mass of an adult human is about 65 kilograms while the average mass of an ant is approximately 4 x 10-3 grams. The total human population in the world is approximately 6.84 billion, and it is estimated that there are currently about 10,000 trillion alive.

Based on these values, how does the total mass of all living ants compare to the total mass if all living humans?

1. “Giantburgers”

This headline appeared in a newspaper:

Every day 7% of Americans eat at Giantburger restaurants.

Decide whether this headline is true or false using the following information.

* There are about 8 x 103 Giantburger restaurants in America.
* Each restaurant serves on average 2.5 x 103 people every day.
* There are about 3 x 108 Americans.

Explain your reasoning and show clearly how you figured it out.

1. “Distance to the Sun”

The average distance from Jupiter to the Sun is about 5 x 108 miles. The average distance from Venus to the Sun is about 7 x 107 miles.

The average distance from Jupiter to the Sun is about how many times as great than the average distance from Venus to the Sun?

Culminating Task:

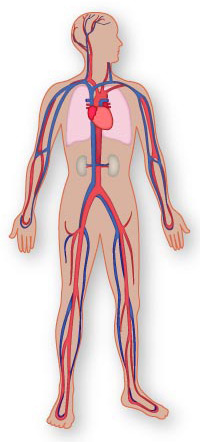
“Blood in the Human Body”

|  |  |
| --- | --- |
| **8th Grade Exponents – Culminating Task** | Name\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ |
| Post Assessment  “Blood in the Human Body” | Date\_\_\_\_\_\_\_\_\_\_\_\_\_ |

Today you will be asked to solve several questions that require the use of the properties of exponents. Before you begin, please provide a convincing argument to show why the following rules are true.

1) Prove that 

2) Prove that 

Use the properties of exponents, as they apply, to solve the following problems.

3) There are 2.7 x 108 hemoglobin molecules in a single human red blood cell, and there are about 5.0 x 106 human red blood cells in one cubic mm of blood. How many hemoglobin molecules are in one cubic mm of blood? Show your work.

1. Irving claims he used a property of exponents to solve question 3. What property of exponents did Irving use? How do you know?
2. A red blood cell has a diameter of approximately 7.5 x 10-4 cm and a certain artery has a diameter of approximately 3 x 10–2 cm. How many times larger is the diameter of the artery than the diameter of a red blood cell?
3. When you donate a pint of blood, the American Red Cross has a policy that says you must wait 56 days before donating blood again. They are currently re-assessing their policy.

One pint of blood contains about 2.4x1012 red blood cells. Your body normally produces about 2x1011 red blood cells per day. Do you agree or disagree with the 56 day waiting period of the American Red Cross? If you disagree, do you think that the waiting period should be longer or shorter than 56 days?



56 day waiting period

8th Grade Exponents – Culminating Task

“Blood in the Human Body” **Sample Responses and Scoring Rubric**

|  |  |
| --- | --- |
| **Sample Top-Score Responses** | **Scoring Rubric** |
| 1.  Using the definition of an exponent, you can expand the numerator and the denominator and simplify the fraction by making ones, for example: .  Or you can subtract the exponents, 5 – 2 = 3, to represent that the 2 b’s in the denominator cancel (i.e. “make one”) with 2 of the b’s in the numerator. | Responses to this item will receive 0 – 2 points based on the following:  **2 points:** Student provides a clear and accurate proof of, showing why the property is true.  **1 point:** Student shows some understanding of this property of exponents, but cannot provide a convincing argument or example for why this property works.  **0 points:** Student shows no understanding of this property of exponents and provides no argument or example for why this property works. |
| 2.  Knowing the property for multiplying powers with the same base: , I could write an equation to solve for :    must equal 1 because anything multiplied by 1 equals itself.  Therefore, .  **Or...**  Knowing the property for dividing powers with the same base: , I could write an equation to solve for :  . Anything divided by itself equals 1, so , so | Responses to this item will receive 0 – 2 points based on the following:  **2 points:** Student provides a clear and accurate proof of using properties of exponents for *either* multiplying powers with the same base or dividing powers with the same base.  **1 point:** Student shows some understanding of , but cannot provide a convincing argument or example for why this property works.  **0 points:** Student shows no understanding of this property of exponents and provides no argument or example for why this property works. |
| 3.  (2.7 x 108)(5.0 x 106) = 1.35 x 1015 hemoglobin molecules | Responses to this item will receive 0 – 2 points based on the following:  **2 points:** Student correctly multiplies and provides the correct answer of 1.35 x 1015  **1 point:** Student attempts to multiply the values together, but makes a minor computational error and does not provide the correct answer.  **0 points:** Student does not multiply the values together and does not provide a correct result. |
| 4.  Irving used the additive property of exponents (**or**)because when multiplying bases with the same base, so you can add the exponents. | Responses to this item will receive 0 – 2 points based on the following:  **2 points:** Student correctly identifies that the property that Irving used was: (i.e. the property that says that when multiplying powers with the same base, you can add the exponents). Student recognizes that problem 3 required multiplication of two values with the same base (10), and therefore the exponents could be added together.  **1 point:** Student recognizes that problem 3 involved multiplication of numbers written in scientific notation, but does not make the proper connection to the additive property of exponents.  **0 points:** Student shows no understanding or recognition of how problem 3 was solved or how it relates to properties of exponents. |
| 5.  The diameter of the artery is 40 times larger than the diameter of the red blood cell.  *Optional work shown:*  (3 x 10–2) ÷ (7.5 x 10-4) = .4 x 102 = 4 x 101 | Responses to this item will receive 0 – 2 points based on the following:  **2 points:** Student correctly identifies that the artery is 40 (or 4 x 101) times larger than the red blood cell.  **1 point:** Student attempts to divide 3 x 10–2 by 7.5 x 10-4, but makes a minor computational error and does not produce the correct result.  **0 points:** Student does not divide nor identify the artery as 40 times larger. |
| 6.  If you can produce 2 x 1011 red blood cells per day, in 56 days you can produce (56)( 2 x 1011) = 1.12 x 1013 red blood cells. This number is about 5 times larger than 2.4 x 1012, which is the amount you need to donate a pint of blood. I disagree with the 56 day waiting period and think that the waiting period should be shorter than 56 days, since you will have enough red blood cells before then.  **Or**  It would take (2.4 x 1012)/(2 x 1011) = 12 days to replenish the red blood cells lost for donating one pint of blood, which is less than 56 days. I disagree with the 56 days waiting period and think that the waiting period should be shorter than 56 days. | Responses to this item will receive 0 – 2 points based on the following:  **2 points:** Student makes accurate calculations to identify that your body will produce enough red blood cells to donate a pint of blood in a shorter amount of time than the 56 day waiting period. Student disagrees with the 56 day waiting period and thinks that the waiting period should be shorter than 56 days.  **1 point:** Student makes accurate calculations appropriate for the problem, but does not make sense of the calculations to determine whether or not the 56 day waiting period is reasonable.  **0 points:** Student does not make accurate calculations appropriate for the problem and does not determine whether or not the 56 day waiting period is reasonable. |
| TOTAL | **12 points** |