

③a) Logarithmic Functions - What are they?

A logarithm is the inverse of an exponential. When we try to solve/find the inverse of an exponential we get stuck. So, to get around this, we use log.

In exponential functions, the input is the exponent of a base and the output is an answer. Because a log function is the inverse, its variables are switched.

So: In log functions, the input is the answer (of a base raised to a power) and the output is the exponent of the base to give you the answer (the input).

Evaluating logs

• $\log_3 9 = ?$

$(\log_b(x) = y)$

$\log_3 9 = 3$

because: $3^3 = 9$

① Think of what each number represents. The question reads, "log of 9 base 3". This means, with a base of 3, the INPUT/ANSWER is 9. So think, what does the OUTPUT/EXPONENT have to be for a base of 3 to equal 9?

$$\log(x) = \log_{10}(x)$$

This is a common log.
So if there is no written base, it is 10.

because: $5^2 = 32$

Logarithms:
input (x-values) = answer of b^x
output (y-values) = exponent

• $\log_2 32 = ?$

$$(\log_b(x) = y)$$

$$\log_2 32 = 5$$

① Think of what the numbers represent.
What OUTPUT/EXPONENT is needed on the base to give the INPUT/ANSWER of 32?

• $\log_4 \frac{1}{16} = ?$

$$(\log_b(x) = y)$$

$$\log_4 \frac{1}{16} = -2$$

because: $4^{-2} = \frac{1}{16}$

① Label what each of the numbers represents in the log function.
What OUTPUT/EXPONENT will give you the INPUT/ANSWER of $\frac{1}{16}$?

★ since $\frac{1}{16}$ is a fraction, it is possible it is the reciprocal of a base raised to a negative power.

• $\log_5 \frac{1}{125} = ?$

$$(\log_b(x) = y)$$

$$\log_5 \frac{1}{125} = -3$$

because: $5^{-3} = \frac{1}{125}$

① Recognize what each part of the function is.
Think, what OUTPUT/EXPONENT on the base of 5 will give an INPUT/ANSWER of $\frac{1}{125}$?

★ Again, since $\frac{1}{125}$ is a fraction, it could be the reciprocal of a number raised to the negative power.

• $\log_3 81 = ?$

$$\log_3 81 = 4$$

Steps now will be recorded shorter and to the point. For in-depth "thinking steps" look at examples 1-4

① What exponent on the base of 3 will give 81?

• $\log 1000 = ?$

$$\log 1000 = 3$$

① NOTE, log has no written base. So, it is a common log. A common log has a base of 10.

What exponent does the base 10 need to be raised to to get 1000?

(3b) Switching from exponential form to logarithmic form (and vice versa)

$$y = b^x \leftrightarrow x = \log_b(y)$$

↑ base ↑ input/exponent ↑ output/exponent ↑ subscript for base input/answer (of base being raised to power of x)

EXP. FORM → LOG FORM: input becomes output, base becomes base of log, output becomes input.

LOG. FORM → EXP. FORM: base to the power of the output will equal the input

Switch forms for the following:

$3^4 = 81$
 $(b^x = y)$
 $(x = \log_b(y))$
 $4 = \log_3(81)$

① Recognize what each number means (in terms of variables)

② Plug it into the log function "formula" (Plug values: b, x, y into log "formula")

③ Think about what you just did.

In exponential form, you said the output 81 is obtained by raising base 3 to the exponent 4.

In log form, you are saying the opposite.

You are saying: The output exponent of 4 has to be the exponent on base 3 to give an input of 81.

In exponential form: Solution = answer

In logarithmic form: Solution = exponent

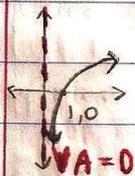
$\log_a b = c$
 $(\log_b(y) = x)$
 $(y = b^x)$
 $b = a^c$

① Identify / match the variables to the "log formula"

② Plug the values of b, x, y into the "formula" for an exponential function

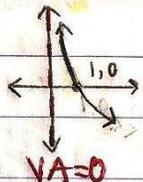
③ Here, what you did was start by saying the log of b base a raised to the exponent c is equivalent to the output b is obtained by taking a and raising it to the power of c .

③c Log growth parent graph if $b > 1$, it is a growth.



x int: $1, 0$
 point: $b, 1$
 Domain: $\{x \in \mathbb{R}, x > 0\}$
 Range: $\{y \in \mathbb{R}\}$

Log decay parent graph if $0 < b < 1$, it is a decay.



x int: $1, 0$
 point: $b, 1$
 Domain: $\{x \in \mathbb{R}, x > 0\}$
 Range: $\{y \in \mathbb{R}\}$

③d How to sketch a transformed logarithm

$f(x) = -4 \log(-2x + 6) + 1$
 $y = -4 \log(-2(x - 3)) + 1$

$a = -4$ (reflected in x -axis vertical stretch)

$b = -2$ (reflected in y -axis horizontal compression)

$c = 3$ (shift 3 units right) $d = 1$ (shift 1 unit up)

① Isolate x within the brackets to see horizontal stretch/compression and shift.

② State transformations that are done to $y = \log_b x$

When graphing an exponential/log, you need the asymptote and 2 points!

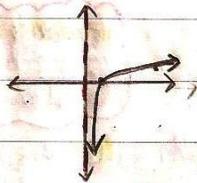
③ Graph base parent function

$$y = \log_{10} x$$

$$x \text{ int: } 1, 0$$

$$\text{point: } 10, 1$$

$$VA = 0$$



$$VA = 0$$

What you are doing here?

apply a-value by multiplying y coord of base parent.

THEN, with new points, apply b-value. Do this by dividing x-coord of base parent.

④ Apply vertical stretch and horizontal compression.

$$a = -4$$

$$(1, 0) \cdot -4$$

$$(10, 1) \cdot -4$$

$$(10, -4)$$

$$b = -2$$

$$(1, 0)$$

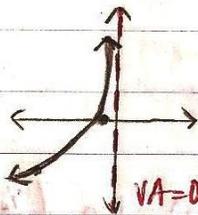
$$\div -2$$

$$\left(-\frac{1}{2}, 0\right)$$

$$(10, -4)$$

$$\cdot -2$$

$$(-5, -4)$$



$$VA = 0$$

⑤ Apply horizontal/vertical shift.

$$\text{(new) } x \text{ int } \left(-\frac{1}{a}, 0\right)$$

$$\text{(new) point } (-5, -4)$$

$$c = 3$$

$$d = 1$$

$$-\frac{1}{a}, 0$$

$$2.5, 0$$

+1

$$\uparrow +3$$

$$(2.5, 0)$$

$$(2.5, 1)$$

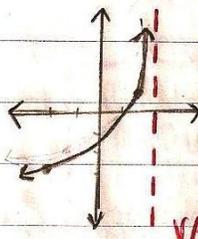
$$-2, -4$$

+1

$$\uparrow +3$$

$$(-2, -4)$$

$$(-2, -3)$$



$$VA = 3$$

APPLY horizontal shift to vertical asymptote!!!!

$$VA = 0 + 3$$

$$VA = 3$$

THIS is the fully transformed log.

③e) What does e^x and $\ln x$ represent?

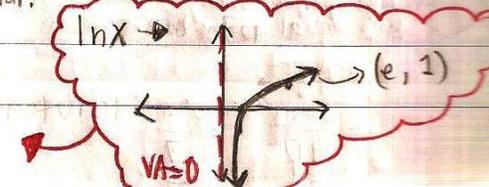
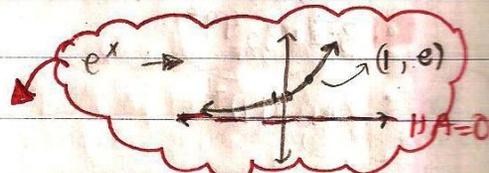
$e^x \rightarrow$ natural exponential

e is a constant similar to what π is. e is equal to 2.718... When e is raised to an exponent, it is an exponential.

$\ln x \rightarrow$ natural log

$\ln x$ can be rewritten as: $\log_e x$

$\ln x$ or $\log_e x$ is the inverse of the natural exponential function.



4a) Properties and Laws of Logs

Product Law

$$\log_b(x) + \log_b(y) = \log_b(xy)$$

$$\begin{aligned} & \bullet \log_3 9 + \log_3 81 \\ & = \log_3(9 \times 81) \\ & = \log_3 729 \\ & \updownarrow \\ & = 729 = 3^6 \\ & = 6 \end{aligned}$$

Product Law: Taking 2 logs of the same base that are being added and multiplying their inputs.

① Take the input of the first log and the input of the second log and multiply them. The product is the input for a \log_3 function. (\log_3 because that is the similar base in this case)

② Simplify the $\log_3 729$.

Quotient Law

$$\log_b(x) - \log_b(y) = \log_b\left(\frac{x}{y}\right)$$

$$\begin{aligned} & \bullet \log_2 48 - \log_2 3 \\ & = \log_2\left(\frac{48}{3}\right) \\ & = \log_2(16) \\ & \updownarrow \\ & = 16 = 2^4 \\ & = 4 \end{aligned}$$

Quotient Law: Taking 2 logs of the same base that are being subtracted and dividing their inputs.

① Take the input of the first log and the input of the second log and divide them. The product is the input for a \log_2 function. (\log_2 because that is the base both logs have in this case)

② Simplify the $\log_2 16$.

Power Law

$$n \log_b(x) = \log_b(x)^n$$

$$\begin{aligned} & \bullet 3 \left(\frac{1}{2} \log_3 49\right) \\ & \cancel{3} \log_3 (49)^{\frac{1}{2}} \end{aligned}$$

This cancels because of a

log exponent with base equal to the base.

$$\begin{aligned} & = 49^{-\frac{1}{2}} \\ & = \left(\frac{1}{49}\right)^{\frac{1}{2}} = \left(\frac{1}{7}\right) \end{aligned}$$

Power Law: Taking the coefficient of a log and turning it into the exponent on the input.

① Take the $-\frac{1}{2}$ and bring it to the 49.

Make sure the $-\frac{1}{2}$ is only being applied to the input.

② Cancel $3 \log_3$

③ Evaluate what you have left

$$\log_b(1) = 0$$

$$\log_b(b) = 1$$

These apply to all values of b and are basic properties of logs.

$$10^{\ln 1} = 10^0 = 1$$

$$\ln 1 = \log_e 1 = 0$$

$$e^0 = 1$$

Change of Base

$$\log_b(x) = \frac{\log_{\#}(x)}{\log_{\#}(b)}$$

represents the base of the log that you want.

Change of Base: This allows you to take the input and base of a log, and use them as inputs in this formula to create a log/log's with a desired base.

• $\log_5 6 \rightarrow$ change this log to base 3

$$\frac{\log_3 6}{\log_3 5}$$

- Replace the # signs in the formula with the number 5. Replace (x) with the input 6. Replace (b) with the base 3.

• $\log_{\sqrt{3}} 9 \rightarrow$ change this log to base 3

$$= \frac{\log_3(9)}{\log_3(\sqrt{3})} = \frac{2}{\frac{1}{2}} = 2(2) = 4$$

- Replace # with 3. Replace (x) with 9. Replace (b) with $\sqrt{3}$.

- Evaluate anything if possible

$$\log_3(9) = \log_3(3^2) = 2$$

$$\log_3(\sqrt{3}) = \log_3(3^{\frac{1}{2}}) = \frac{1}{2}$$

Cancelling properties

$$\log_b(b)^x = x$$

• $\ln e^5 = \log_e(e^5) = 5$

- Recognize that $\ln = \log_e$. So, $\log_e(e)$ cancel.

$\log_b(b)^x = x$: This tells us that if a log of base b has an input of b to the power of x , the \log_b and b cancel. Therefore, this leaves x as the answer.

• $\log 1000$

$$= \log(10)^3 = \log_{10}(10)^3 = 3$$

- Manipulate base 1000 to have a base of 10
- Recognize the common log has a base of 10. $\log_{10}(10)$ cancel.

$$b^{\log_b(x)} = x$$

• $10^{\log 7} = \log_{10} 7 = 7$

- Recognize the common log has a base of 10.
- 10 and \log_{10} cancel to leave the answer (7)

$b^{\log_b(x)} = x$: This tells us that if base b is raised to the power of \log base b to the power of x , the base b and \log base b cancel. Therefore, this leaves x as the answer.

Expand → inputs without exponents if possible

(4b) Expanding expressions using log laws

• $\log(xy^3)$
 $\log(x) + \log(y^3)$
 $= \log(x) + 3\log(y)$

- Reverse the product law since the input is written as a product.
- To get y as a single input, use the reverse of the power law.

• $\log_3\left(\frac{1}{x^2}\right)$
 $\log_3(1) - \log_3(x^2)$
 $\log_3(1) - 2\log_3(x)$
 $0 - 2\log_3(x)$
 $= -2\log_3(x)$

- Reverse the quotient law since the input is written as a quotient.
- To get x as a single input, reverse the power law.
- Evaluate

• $\ln(3+x)$
 $\neq \ln 3 + \ln x$

WRONG!

The input is an expression so you cannot apply the log laws here. Just like $(3+x)^2 \neq 3^2 + x^2$,

$\ln(3+x) \neq \ln 3 + \ln x$

THIS IS NOT POSSIBLE TO SIMPLIFY/expand USING LOG LAWS.

(4c) Condensing expressions using log laws

• $5\ln x - 2\ln x - 2\ln y$
 $3\ln x - 2\ln y$
 $\ln(x^3) - \ln(y^2)$
 $= \ln\left(\frac{x^3}{y^2}\right)$

- Recognize that $5\ln x$ and $2\ln x$ are like terms.
- Use the power law to make the bases equal
- Use the quotient law to simplify because both logs have the same base and are being subtracted.

• $3\ln(x^4y) + 2\ln(yz^5)$
 $\ln(x^4y)^3 + \ln(yz^5)^2$
 $\ln(x^{12}y^3) + \ln(y^2z^{10})$
 $\ln(x^{12}y^3y^2z^{10})$
 $= \ln(x^{12}y^5z^{10})$

- Use the power law to get log (ln) by itself
- Distribute exponents into the input only
- Use the product law to simplify since the bases are the same and there is addition.

• $3\log(x+3) - 2\log(x-1)$
 $\log(x+3)^3 - \log(x-1)^2$
 $= \log\left(\frac{(x+3)^3}{(x-1)^2}\right)$

- Use the power law to get log by itself
- CANNOT distribute exponents like in prev. example. So, leave as is and simplify using quotient law because you have 2 equal bases and there is subtraction.

In an example like this, brackets are SO important. Make sure you keep all parts/terms associated with one another as they should be!!

(4b) COMPLEX example of expanding using log laws

• If $\log x = 2$, $\log y = 3$, $\log z = 5$, evaluate.

$$\begin{aligned} & \log(x\sqrt{yz}) (\log(xy))^2 \\ & (\log(x) + \log\sqrt{yz}) (\log(x) + \log(y))^2 \\ & (\log(x) + \frac{1}{2}\log(yz)) (\log(x) + \log(y))^2 \\ & (\log(x) + \frac{1}{2}(\log(y) + \log(z))) (\log(x) + \log(y))^2 \\ & (2 + \frac{1}{2}(3+5)) (2+3)^2 \\ & (2 + \frac{1}{2}(8)) (5)^2 \\ & (6)(25) \\ & = 150 \end{aligned}$$

① The values given are when the inputs and the log base are isolated. So, begin to isolate by using product law.

② Rewrite \sqrt{yz} as $(yz)^{\frac{1}{2}}$. Then, use the power law

③ Use the product law to isolate the inputs y and z .

④ Now, all inputs are isolated. So, sub in given information.

(4d) Changing the base of a logarithm

• Change $y = \log_3 x$ into a log base of 9

$$\begin{aligned} y &= \log_3 x & \frac{\log_{\#}(x)}{\log_{\#}(b)} \\ & \quad \uparrow \quad \nwarrow \\ & \quad b \quad x \\ \frac{\log_9(x)}{\log_9(3)} &= \frac{\log_9(x)}{\frac{1}{2}} \\ &= 2(\log_9(x)) \\ &= 2\log_9(x) \end{aligned}$$

① Recognize the numbers in this log function and think about what they represent in the change of base formula. Plug in the information you know.

② Evaluate if possible

③ Instead of dividing by a fraction, multiply by the reciprocal.

Changing the base of an exponential

• Change $y = 8^x$ into exponential of base 11

$$\begin{aligned} y &= 8^x \\ y &= 11^{\log_{11}(8)^x} \\ y &= 8^x & b^{\log_b(x)} = x \end{aligned}$$

To do this, you have to create base and an exponent with a log base that will cancel to give you your input (which should be the original base with exponent x .)

∴ The exponential $y = 8^x$ with base 11

looks like this: $y = 11^{\log_{11}(8)^x}$

① Manipulate exponential to be able to use the law $b^{\log_b(x)} = x$

YOU CAN'T TAKE THE LOG OF A NEGATIVE NUMBER

TIP: WHEN SOLVING, DON'T ROUND UNTIL END TO ENSURE ANSWER IS EXACT.

(4e) Common mistakes with logs

• $\ln(x+3)$

WRONG: $\ln(x) + \ln(3)$

Because there is an expression in the input, you can't distribute the ln.

RIGHT: $\ln(x+3)$

It can't be simplified further so it should be left like this.

• $\frac{\log 5x}{\log x}$

WRONG: $\frac{\log 5x}{\log x} = 5$

You cannot cancel log on its own and you can't cancel the x's because they are inputs.

What if: $\frac{\log 5x}{\log x} = \frac{\log 5 + \log x}{\log x} = \log 5$

Here, you can't cancel because of addition in the numerator!!

WRONG!

RIGHT: $\frac{\log_b(x)}{\log_b(b)} = \log_b(x)$

re-write using change in base formula.

$\log_x(5x)$

• $\ln e^{5x} + \ln x$

WRONG: $5x + \ln x$

(you can't cancel ln and e because the exponent one has addition.)

This is NOT the correct way to get answer.

RIGHT: $\ln e^{5x} + \ln x$

$= \ln[e^{5x} e^{\ln x}]$
 $= \ln[e^{5x} x]$

LOG (use product law)

$= \ln(e^{5x} + \ln x)$
 $= 5x + \ln(x)$

• $\log_a(5x^7)$

WRONG: $7 \log_a(5x)$

The exponent of 7 is only on the variable x. To use the power law, the exponent needs to be on the ENTIRE INPUT.

RIGHT: $\log_a(5x^7)$

$\log_a(5) + \log_a(x^7)$

① use product law

$\log_a(5) + 7 \log_a(x)$

② use power law NOW.

• $\log_3 7 - \log_3 8$

WRONG: $\log_3 7$

$\log_3 8$

RIGHT: when you have 2 logs with the same base and subtraction between them, you only want to write the INPUTS as a quotient when using the quotient law. There is only ONE \log_b .

$\log_3 7 - \log_3 8$

$= \log_3\left(\frac{7}{8}\right)$

• $\ln x^a = \ln(x)^a$ **Doesn't apply to coefficient if present!**

$\ln^2(x) = (\ln x)^2$ $\ln^2(x) \neq (\ln)(\ln)(x)$

If a function is squared, the entire function is squared, not just ln.

5b) Solving Logarithmic Equations

• $\log_x 8 = \frac{1}{4}$

SWITCH AND SOLVE

$8 = x^{\frac{1}{4}}$

~~$(8)^4 = (x^{\frac{1}{4}})^4$~~

$8^4 = x$

$4096 = x$

① Switch from log form to exponential form to easily see what the base needs to be for the exponent $\frac{1}{4}$ to equal 8.

② Take the power of 4 to both sides to cancel the $\frac{1}{4}$.

Then, your x-value is your base of $\log_x 8 = \frac{1}{4}$

• $\log_3(x)^5 = -\log_3(x) = 12$

$\log_3\left(\frac{x^5}{x}\right) = 12$

$\log_3(x^4) = 12$

$x^4 = 3^{12}$

$\sqrt[4]{x^4} = \sqrt[4]{531441}$

$x = \pm 27$ then discard -27

① Use the quotient law for simplifying logs because you have 2 logs with the same base

② Simplify, input and then switch forms to get x as the output.

③ Evaluate and then take the $\sqrt[4]{\quad}$ of both sides to isolate x

Your x-value is the input for the original: $\log_3(x)^5 = -\log_3(x) = 12$

• $\log_9\left(\frac{9}{5}x\right) = \log_9\left(\frac{63}{10}\right) + \log_2(4)^{-2}$

$\log_9\left(\frac{9}{5}x\right) = \log_9(63) - \log_9(10) + \log_2(4)^{-2}$

$\log_9\left(\frac{9}{5}x\right) = \log_9(63) - \log_9(10) + \log_2(2^2)^{-2}$

$\log_9\left(\frac{9}{5}x\right) = \log_9(63) - \log_9(10) + (-4)$

$\log_9\left(\frac{9}{5}x\right) = \log_9\left(\frac{63}{10}\right) - 4$

$\log_9\left(\frac{9}{5}x\right) \approx 0.838 - 4$

$\log_9\left(\frac{9}{5}x\right) \approx -3.16$

\downarrow

$\frac{9}{5}(x) = 9^{-3.16}$

$x = \frac{5}{9}(9^{-3.16})$

$x = 0.000536$

$x \approx 0.00054$

① Expand using log laws

② Evaluate if possible

③ Condense $\log_9(63)$ and $\log_9(10)$ and then evaluate.

④ Isolate for x

NOTE:

TRY NOT TO

ROUND

UNTIL

VERY

END!

Otherwise,

answer will

not be

exact.

Real-life applications with Logarithms

(e) pH word problem

$$\text{pH} = -\log(\text{H}^+)$$

↑
mol/L

- Lemon juice has a pH of 2.0. Rainwater has 1000 times less concentration of hydrogen ions. What is the pH of rainwater?

Lemon juice

Rainwater

$$\text{pH} = 2$$

$$\text{pH} = ?$$

$$\text{H}^+ = ?$$

$$\text{H}^+ = \frac{\text{H}^+ \text{ of lemon juice}}{1000}$$

$$\text{pH} = -\log(\text{H}^+)$$

$$2 = -\log(\text{H}^+)$$

$$-2 = \log(\text{H}^+)$$

$$(\text{H}^+) = 10^{-2}$$

$$\text{H}^+ = 0.01$$

$$\text{H}^+ = \frac{0.01}{1000}$$

$$\text{H}^+ = 0.00001$$

$$\text{H}^+ = 10^{-5}$$

① Write down the variable values that you know and identify what you need.

② Solve for H^+ of lemon juice because you need it to solve for pH of rainwater.

Isolate the log on one side then switch forms.

③ Find H^+ of rainwater by dividing 0.01 by 1000.

$$\text{pH} = -\log(\text{H}^+)$$

$$\text{pH} = -\log(0.00001)$$

$$\text{pH} = 5$$

∴ the pH of rainwater is 5.

④ Now, you can solve for the pH of rainwater (Evaluate.)

⑥f) Decibels word problem

Standing 10m from a motorcycle, the sound is about 88 dB. A chainsaw is approximately 158 times more intense. What is the sound level for the chainsaw in dB?

Motorcycle	Chainsaw
$L = 88$	$L = ?$
$I_1 = ?$	$I_2 = 158 \times I_1$

$$L = 10 \log \left(\frac{I}{I_0} \right)$$

$$\frac{88}{10} = \log \left(\frac{I}{10^{-12}} \right)$$

$$8.8 = \log \left(\frac{I}{10^{-12}} \right)$$

$$\frac{I}{10^{-12}} = 10^{8.8}$$

$$I = 10^{8.8} (10^{-12})$$

$$I = 10^{-3.2}$$

$$I_2 = 158 \times 10^{-3.2}$$

$$L = 10 \log \left(\frac{I_2}{10^{-12}} \right)$$

$$L = 10 \log \left(\frac{158 (10^{-3.2})}{10^{-12}} \right)$$

$$L = 10 \log (158 (10^{(-3.2) - (-12)}))$$

$$L = 10 \log (158 (10^{8.8}))$$

$$L = 109.98$$

$$L \approx 110 \text{ dB}$$

$$L = 10 \log \left(\frac{I}{I_0} \right) \left. \begin{array}{l} \text{comparison} \\ \text{of} \\ \text{intensities} \end{array} \right\}$$

↑
dB

↑
 $10^{-12} \text{ Watts/m}^2$

① Write down the variable values that you know and what you need to find.

② Solve for I_1 in order to get I_2 .
Isolate the log then switch forms.

③ Find I_2
(keep it like this to simplify in next step)

④ Solve L for the chainsaw

∴ The sound level for the chainsaw in dB is 110 (approx.)

⑥g) Earthquake word problem

What is the magnitude of an earthquake 10,000 times more intense than a 1.5 magnitude earthquake?

Earthquake #1	Earthquake #2
$M = 1.5$	$M = ?$
$I_1 = ?$	$I_2 = 10,000 \times I_1$

$$M = \log \left(\frac{I}{I_0} \right)$$

$$1.5 = \log \left(\frac{I}{10^{-4}} \right)$$

$$\frac{I}{10^{-4}} = 10^{1.5}$$

$$I = 10^{1.5} (10^{-4}) \quad I = 10^{-2.5}$$

$$I_2 = 10,000 \times I_1$$

$$I_2 = 10,000 (10^{-2.5})$$

$$M = \log \left(\frac{I}{I_0} \right) \left. \begin{array}{l} \text{comparison} \\ \text{of} \\ \text{intensities} \end{array} \right\}$$

← 10^{-4} microns

① Write down the variable values that you know and that you need to find.

② Solve for I_1 in order to solve for I_2 .

③ Find I_2
(and keep in exact form)

$$M = \log\left(\frac{I_2}{I_1}\right)$$

$$M = \log\left(\frac{(10^{-2.5})(10,000)}{10^{-4}}\right)$$

$$M = \log(10^{2.5-4}) (10,000)$$

$$M = \log(10^{1.5} (10,000))$$

$$M = 5.5$$

④ Now, solve for the magnitude of Earthquake #2.

∴ the magnitude of the earthquake 10,000 times more intense than a 1.5 magnitude earthquake is 5.5.