Student Name

Mathematics Stage 5 Paths

LOGARITHMS

Book 2 Establish and apply the laws of logarithms to solve problems

Version: 260207

Report mistakes & suggest improvements:
https://MrDingMaths.com

CONTENTS

OVERVIEW

SYLLABUS CONTENT

MA5-LOG-P-01 establishes and applies the laws of logarithms to solve problems

Establish and apply the laws of logarithms to solve problems

- Deduce laws of logarithms from laws of indices
- Establish and use a variety of logarithmic results
- Apply the laws of logarithms to evaluate and simplify expressions
- Solve simple equations that involve exponents or logarithms
- Examine logarithmic scales and explain their use in various contexts

REVIEW OF PRIOR KNOWLEDGE

LOGARITHM LAWS

THE INVERSE RELATIONSHIP

- Logarithms and exponentiating are inverse operations.
- Taking the logarithm will "undo" exponentiation.

$\text{Log}_a\, a^x = x$ for all real x

$a^{\log_a x} = x$ for all real $x > 0$

Example Simplify expressions using logarithm laws.

$\log_7 7^{12}$	$5^{\log_5 11}$
$= 12$	$= 11$

Simplify these logarithms.

a $\log_{10} 10^3$ 3

b $\log_{12} 12^{1.3}$ 1.3

c $10^{\log_{10} 100}$ 100

d $4^{\log_4 3.6}$ 3.6

LOG LAWS

- Logarithm laws work like index laws.

$$x = a^y \quad \Leftrightarrow \quad y = \log_a x$$

Inverse Relationship	$\log_a a^x = a^{\log_a x} = x$
Log Law of Multiplication	$\log_a(xy) = \log_a x + \log_a y$
Log Law of Division	$\log_a\left(\frac{x}{y}\right) = \log_a x - \log_a y$
Log Law of Indices	$\log_a(x^n) = n \log_a x$

Example Simplify expressions using logarithm laws.

$\log_6 2 + \log_6 4$	$\log_3 15 - \log_3 3$	$2 \log_4 5$
$= \log_6 8$	$= \log_3 5$	$= \log_4 5^2$
		$= \log_4 25$

Simplify these logarithms.

a $\log_7 2 + \log_7 3$ $\log_7 6$

b $\log_9 18 - \log_9 3$ $\log_9 6$

c $\log_a 22 - \log_a 11$ $\log_a 2$

d $3 \log_a 2$ $\log_a 8$

1 Complete these logarithm laws.

a $\log_b(xy) = \log_b x + \ldots\ldots\ldots\ldots$

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

c $\log_a b^m = m \times \ldots\ldots\ldots\ldots$

d $\log_a a = \ldots\ldots\ldots\ldots$

e $\log_c 1 = \ldots\ldots\ldots\ldots$

f $\log_a\left(\frac{1}{b}\right) = \ldots\ldots\ldots\ldots$

2 Simplify using the log laws.

a	$\log_a 3 + \log_a 2$	**b**	$\log_a 5 + \log_a 3$	**c**	$\log_a 6 + \log_a 3$
d	$\log_a 3 + \log_a 6$	**e**	$\log_a 15 + \log_a 1$	**f**	$\log_a 1 + \log_a 17$
g	$\log_a 10 - \log_a 5$	**h**	$\log_a 36 - \log_a 12$	**i**	$\log_a 100 - \log_a 10$
j	$\log_a 28 - \log_a 14$	**k**	$\log_a 3 - \log_a 2$	**l**	$\log_a 7 - \log_a 5$

3 Rewrite these expressions without a factor in front using $n \log_a x = \log_a(x^n)$

a	$2 \log_a 3$	**b**	$2 \log_a 5$	**c**	$3 \log_a 3$
d	$4 \log_a 2$	**e**	$5 \log_a 2$	**f**	$3 \log_a 10$

4 Rewrite these expressions in terms of $\log_a 2$

a	$\log_a 8$	**b**	$\log_a 16$	**c**	$\log_a 64$
d	$\log_a \frac{1}{2}$	**e**	$\log_a \frac{1}{8}$	**f**	$\log_a \sqrt{2}$

EVALUATING LOGARITHMS USING THE LAWS

$\log_a(1) = 0$	because $1 = a^0$
$\log_a(a) = 1$	because $a = a^1$
$\log_a(\sqrt{a}) = \frac{1}{2}$	because $\sqrt{a} = a^{\frac{1}{2}}$
$\log_a \frac{1}{a} = -1$	because $\frac{1}{a} = a^{-1}$
$\log_a \left(\frac{1}{x}\right) = -\log_a x$	because $\log_a \frac{1}{x} = \log_a x^{-1} = -\log_a x$

Example Evaluate expressions using logarithm laws.

$\log_2 6 - \log_2 3$ $= \log_2 2$ $= 1$	Which log law did we use to simplify $\log_2 6 - \log_2 3$ to $\log_2 2$? *Log law of ..... says subtracting two logs of the same ..... is the same as ..... the insides of the log.*
$\log_6 \frac{1}{36}$ $= \log_6 36^{-1}$ $= \log_6 6^{-2}$ $= -2 \log_6 6$ $= -2$	Why did we want to write $\frac{1}{36}$ as a power of 6? *We want the base of the number inside the logarithm to match the ..... of the .....*

Simplify and evaluate these expressions.

a $\log_6 2 + \log_6 3$ 1

b $\log_3 15 - \log_3 5$ 1

c $\log_2 16$ 4

Key ideas

1. To evaluate logarithms, we want the base of the number ..... the logarithm to match the base of the .....

1 Write the missing numbers.

a $\log_2 \square = 1$	**b** $\log_3 \square = 0$	**c** $\log_\square 32 = 5$
d $\log_a 2 + \log_a \square = \log_a 8$	**e** $\log_a 36 - \log_a \square = \log_a 3$	**f** $\square \log_a 5 = \log_a 5^3$
g $\log_a 3^4 = \square \log_a 3$	**h** $\log_a \frac{1}{7} = \log_a 7^\square$	**i** $\square \log_a 3 = \log_a \frac{1}{3}$

2 Evaluate these logarithms.

a	$\log_3 1$	**b**	$\log_7 1$	**c**	$\log_4 4$	**d**	$\log_{18} 18$
e	$5 \log_2 1$	**f**	$3 \log_4 4$	**g**	$\frac{1}{3} \log_7 7$	**h**	$\frac{2}{3} \log_{10} 10$
i	$-6 \log_5 1$	**j**	$\log_{10} 10^3$	**k**	$\log_7 7^5$	**l**	$\log_{10} 100$
m	$\log_2 32$	**n**	$\log_3 27$	**o**	$-2 \log_5 25$	**p**	$4\log_{10} 1000$
q	$\frac{\log_{15} 225}{2}$	**r**	$\frac{\log_3 243}{10}$	**s**	$\log_2 \frac{1}{4}$	**t**	$\log_3 \frac{1}{27}$
u	$\log_5 \frac{1}{5}$	**v**	$\log_2 \sqrt{8}$	**w**	$\log_2 \sqrt{32}$	**x**	$\log_2 \sqrt[3]{16}$
y	$\log_{10} \sqrt{1000}$	**z**	$\log_7 \sqrt[3]{7}$	**aa**	$\log_{10} \frac{1}{\sqrt{10}}$		

3 Simplify these expressions.

a	$\log_6 2 + \log_6 3$ $= \log_6 6$ $= \ldots\ldots\ldots\ldots$	**b**	$\log_{15} 3 + \log_{15} 5$	**c**	$\log_{10} 4 + \log_{10} 25$
d	$\log_3 15 - \log_3 15$	**e**	$\log_4 20 - \log_4 5$	**f**	$\log_2 24 - \log_2 3$
g	$\log_{12} 72 + \log_{12} 2$	**h**	$\log_{10} 50 + \log_{10} 20$	**i**	$\log_6 18 + \log_6 2$
j	$\log_5 50 - \log_5 2$	**k**	$\log_3 810 - \log_3 10$	**l**	$\log_2 96 - \log_2 3$
m	$\log_{30} 2 + \log_{30} 3 + \log_{30} 5$	**n**	$\log_{12} 9 + \log_{12} 2 + \log_{12} 8$		
o	$\log_2 12 + \log_2 6 - \log_2 9$	**p**	$\log_3 6 + \log_3 12 - \log_3 8$		
q	$\log_5 2 - \log_5 50$	**r**	$\log_2 6 - \log_2 48$		
s	$\log_2 12 + \log_2 \frac{1}{3}$	**t**	$\log_7 \frac{1}{9} + \log_7 9$		

4 Use a combination of log laws to simplify these.

a $2\log_3 2 + \log_3 5$

b $4\log_{10} 2 + \log_{10} 3$

c $3\log_{10} 2 - \log_{10} 4$

d $5\log_7 2 - \log_7 16$

e $2\log_3 2 + \log_3 5$

f $4\log_{10} 2 + \log_{10} 3$

g $\frac{1}{2}\log_3 4 + 2\log_3 2$

h $\log_5 3 - \frac{1}{2}\log_5 9$

i $\frac{1}{3}\log_2 27 - \frac{1}{3}\log_2 64$

j $\frac{1}{4}\log_5 16 + \frac{1}{5}\log_5 243$

5 Evaluate these logs given $\log_a 2 = 0.3$, $\log_a 3 = 0.5$ and $\log_a 5 = 0.7$

a $\log_a 6$

$= \log_2 2 + \log_a 3$

$= \ldots\ldots\ldots$

b $\log_a 30$

c $\log_a 1.5$

d $\log_a 2.5$

e $\log_a 9$

f $\log_a 16$

g $\log_a 0.6$

h $\log_a 1.2$

i $\log_a 3\sqrt{2}$

6 Find the value of each of these logarithms.

a $\log_a a^4 =$	**b** $\log_x x^9 =$	**c** $\log_x x^m =$	**d** $\log 10^{3k} =$
e $\log_a \sqrt{a} =$	**f** $\log_x \sqrt[3]{x} =$	**g** $\log_y \frac{1}{y} =$	**h** $\log_a \frac{1}{a^5} =$
i $\log_y \frac{1}{\sqrt{y}} =$	**j** $\log_x x\sqrt[3]{x} =$	**k** $\log_x \sqrt{x^7} =$	**l** $\log_a \left(\frac{1}{\sqrt[4]{a}}\right)^3 =$

7 Read the proof of the log of a product law and complete the other proofs.

a

Prove $\log_a xy = \log_a x + \log_a y$

Proof:

Using the index law:

$a^m \times a^n = a^{m+n}$

Take $\log_a$ of both sides:

$\log_a (a^m \times a^n) = \log_a (a^{m+n})$

$\therefore \log_a (a^m \times a^n) = m + n$ (i)

Let $a^m = x$ hence $m = \log_a x$

and $a^n = y$ hence $n = \log_a y$

Substitute these into equation (i):

$\therefore \log_a xy = \log_a x + \log_a y$

b

Prove $\log_a \frac{x}{y} = \log_a x - \log_a y$

c

Prove $\log_a x^n = n \log_a x$

SOLVING EXPONENTIAL EQUATIONS USING LOGARITHMS

- Logarithms are used to find an unknown index number by taking the logarithm of both sides.
- Most calculators can find log base 10 [log] of any number.
- Some calculators can find the log of any base [log▪□]
- If your calculator does not have the [log▪□] button, you must use the change of base law.

Change of Base Law
$\log_a b = \frac{\log_n b}{\log_n a}$
Where n is any number.

Example Solve equations using logarithms.

Solve $2^x = 7$ to three decimal places.

Method 1: Calculator with only [log] button.

$$2^x = 7$$
$$\log_{10} \quad \log_{10}$$
$$\log_{10} 2^x = \log_{10} 7$$
$$x \log_{10} 2 = \log_{10} 7$$
$$\div \log_{10} 2 \quad \div \log_{10} 2$$
$$x = \frac{\log_{10} 7}{\log_{10} 2}$$
$$= 2.807$$

Method 2: Calculator with [log▪□] button.

$$2^x = 7$$
$$\log_2 \quad \log_2$$
$$x = \log_2 7$$
$$= 2.807$$

Describe what happened in method 1. This is called the change of base law: $\log_a x = \frac{\log_b x}{\log_b a}$

We applied the ..... of base 10 to both sides, then rearranged for x.

We can apply the logarithm of any base to both sides, but we used base 10 because there is a button on the ..... that can evaluate logarithms of base 10.

Solve these equations using logarithms. Round your answer to 3 decimal places.

a $3^x = 15$

$x = \log_3 15$ or

$x = \frac{\log_{10} 15}{\log_{10} 3}$

$= .....$

2.465

b $1.5^x = 2.5$

2.260

c $50 \times 1.1^x = 100$

7.273

d $27^x = 3$

$\frac{1}{3}$

e $4^x = -2$

no solution

f $4^{t+1} = \frac{1}{8\sqrt{2}}$

$-\frac{11}{4}$

1 Using your calculator, find the value of these logarithms. Round to 4 significant figures.

Depending on your calculator, you may need the change of base formula: $\log_a x = \frac{\log_{10} x}{\log_{10} a}$

a	$\log_2 7$	**b**	$\log_5 2$	**c**	$\log_2 0.07$
d	$\log_7 31$	**e**	$\log_3 0.004$	**f**	$\log_{0.8} 0.2$

2 Solve each equation. Round your answer to 4 significant figures.

a	$2^x = 15$ $x = \log_2 15$ $= \ldots\ldots\ldots\ldots\ldots$	**b**	$2^x = 1.45$	**c**	$2^x = 0.1$
d	$3^x = 10$	**e**	$5^x = 10$	**f**	$12^x = 150$
g	$8^x = \frac{7}{9}$	**h**	$6^x = 1.4$	**i**	$30^x = 2$
j	$0.7^x = 0.1$	**k**	$0.98^x = 0.03$	**l**	$0.99^x = 0.01$

3 Solve each equation. Round your answer to 4 significant figures.

a	$10 \times 2^x = 30$ $2^x = 3$ $x = \ldots\ldots\ldots\ldots\ldots$ $x = \ldots\ldots\ldots\ldots\ldots$	**b**	$25 \times 3^x = 75$	**c**	$4 \times 1.5^x = 20$
d	$3.8 \times 1.7^x = 9.5$	**e**	$300 \times 0.9^x = 150$	**f**	$7.3 \times 0.4^x = 1.8$

4 Solve these equations.

a	$5^x = 125$	**h**	$4^x = 512$	**o**	$3^x = 13$
b	$5^x = 625$	**i**	$2^x = 512$	**p**	$3^x = 169$
c	$5^x = 243$	**j**	$512 = 2^x$	**q**	$3^x = 13^2$
d	$3^x = 243$	**k**	$512 = x^9$	**r**	$3^x = 13^3$
e	$3^x = 2187$	**l**	$2^x = \frac{1}{512}$	**s**	$13^x = 169$
f	$3^x = 512$	**m**	$4^x = \frac{1}{512}$	**t**	$13^x = \frac{1}{169}$
g	$8^x = 512$	**n**	$8^x = \frac{1}{512}$	**u**	$3^{2x+1} = 169$

8 By using the change of base law

$$\log_a b = \frac{\log_n b}{\log_n a}$$

Simplify the following **without** a calculator by changing the base to the specified value.

a $\log_8 32$ (base 2)

b $\log_{0.25} 32$ (base 2)

c $\log_{\frac{1}{9}} 27$ (base 3)

d $\log_{25} 125$ (base 5)

9

a Using the change of base law, show that $\log_a b = \frac{1}{\log_b a}$

b Hence find the value of $\log_{\sqrt{27}}(3)$

10 Consider $\log_5 y = 3 - 2\log_5 x$.

By changing the subject to y, show that $y = \frac{5^3}{x^2}$

11 Consider $p = \frac{\log_{10} a}{\log_{10} x}$. Show that $x^p = a$

12 Show that $\log_{xy}(a) = \frac{\log_x(a)}{1+\log_x(y)}$

13 Show that $\log_{xy}(a) = \frac{\log_x(a)}{1+\log_x(y)}$

14 Show that $\log_{a^x}(b) = \frac{\log_a b}{x}$

15 Solve $\log_8 x + \log_4 x = 5$

16 By writing in index form, show the following is true.

a $\log_8 64 = 2$

b $\log_{64} 8 = \frac{1}{2}$

c $\log_8 \frac{1}{64} = -2$

d $\log_{64} \frac{1}{8} = -\frac{1}{2}$

Hence evaluate the following:

e $\log_2 8$

f $\log_8 2$

g $\log_2 \frac{1}{8}$

h $\log_8 \frac{1}{2}$

17 Simplify the following expressions:

a $\log_a a^n$

b $\log_{(a^n)} a$

c $\log_a \frac{1}{a^n}$

d $\log_{a^n} \frac{1}{a}$

18 Use the given fact to evaluate the given expression.

a $\log_5 125 = 3$
$\log_{125} 5 = ?$

b $\log_{100} 10 = \frac{1}{2}$
$\log_{10} 100 = ?$

c $\log_4 \frac{1}{64} = -3$
$\log_{64} \frac{1}{4} = ?$

d $\log_{36} 6 = \frac{1}{2}$
$\log_{36} \frac{1}{6} = ?$

19 Fill in the blanks.

a $\log_4 16 = \log_2 \square = \log_\square 9 = \log_\square \square$

b $\log_2 16 = \log_{10} \square = \log_\square 81 = \log_\square \square$

c $\log_{16} 4 = \log_{100} \square = \log_\square 2 = \log_\square \square$

d $\log_2 \frac{1}{2} = \log_3 \square = \log_\square \frac{1}{5} = \log_\square \square$

e $\log_4 8 = \log_{16} \square = \log_\square 27 = \log_\square \square$

EXPONENTIAL MODELLING

- When solving exponential equations, use logarithms to find the missing index.

1. Write the formula.
2. Substitute given values.
3. Isolate exponential term.
4. Solve using logarithms.

Example Apply logarithms to exponential models.

An investment of \$10 000 grows by 5% p.a according to the compound interest formula:

$$FV = 10000(1.05)^n$$

Where n is the number of years. Find the time required for the investment to grow to \$32000.

1. $FV = 10000(1.05)^n$
2. $32000 = 10000(1.05)^n$
3. $3.2 = 1.05^n$
4. $n = \log_{1.05} 3.2$
   ≈ 23.84 years

a An investment of \$20 000 grows by 6% p.a according to the compound interest formula:

$$FV = 20000(1.06)^n$$

Where n is the number of years. Find the time required for the investment to grow to \$50000. Round to 2 decimal places.

15.73 years

b A population of mosquitoes is given by $P = 8^t$ where t is measured in days.
Find the number of days, correct to 2 decimal places, required for the population to reach 200.

2.55 days

1 The number of plankton in a tank is doubling every 5 days, given by the formula:

$$P = 15000 \times 2^{\frac{t}{5}}$$

Where P is population (number of plankton) after t days from commencement of study.

a What was the initial population when the study commenced? ……

b What was the population after 15 days? ……

c At what time will the population reach 1 920 000? Answer to the nearest day and hour.

2 The temperature in a tank of water is decreasing according to the formula

$$T = 100 \times (0.87)^h$$

Where T is temperature in degrees Celsius after h minutes.

a What was the initial temperature? ……

b How long would it take for the temperature to drop to $70°\text{C}$?

3 The mass, in grams, of a decaying substance is given by

$$M = 18 \times (1.75)^{-\frac{3t}{5}}$$

Where t is measured in days.

a What was the initial mass? ……

b What is the half-life? (How long will it take to decay to half its current mass?)

4 A few years ago, Rahul and Fiona were interested in building a new garage, whose price is rising with inflation at 5% per annum. Its price then was $12000.

a Explain why the cost after 1 year is 12000×1.05

……

b Explain why the cost after 2 years is $12000 \times 1.05 \times 1.05$

……

c Explain why the cost C in dollars is $C = 12000 \times 1.05^n$, where n is the years since.

……

d Find, correct to the nearest 0.1 years, how many years later the cost will be $18000

5 50 kg of a radioactive isotope is decaying at a rate of 1% per year.

a Explain why the mass after 1 year is 50×0.99

……

b Explain why the mass after 2 years is $50 \times 0.99 \times 0.99$

……

c Explain why the mass of the isotope (m kg) is therefore given by $m = 50 \times 0.99^n$, where n is the number of years.

……

d Find the time (to 2 decimal places) when the mass of the isotope reduces to 40 kg.

……

6 A bacterial population starts with 1000 bacteria and doubles every half hour.

a How many bacteria are there after 1 hour? ……

b How many bacteria are there after 2 hours? ……

c How many bacteria are there after 3 hours? ……

d Write down an equation for the population of the bacteria after t hours.

……

e How long will it take for the population to exceed 1 million? Round to the nearest minute.

7 The value of a bank balance increases by 10% per year. The initial amount is \$2000.

a Write the equation in the form $FV = PV(1 + r)^n$ .....

b Find the time, correct to two decimals, when the balance is double the original amount.

8 The value of a car is expected to reduce by 8% per year. The original cost is \$300 000.

a Write the equation in the form $S = V_0(1 - r)^n$ .....

b Find the time it takes for the car's value to be half the original value.

Round your answer to 1 decimal place.

9 A container of hot water is placed in a refrigerator running at $0°\text{C}$. The water is known to cool according to Newton's Law of Cooling; with a given starting temperature of $96°\text{C}$ its temperature halves every 20 minutes. The formula is given by

$$T = 96 \times \left(\frac{1}{2}\right)^{3n}, \text{where } n \text{ is in hours}$$

a What is the temperature after 2 hours? .....

b How long does it take, correct to the nearest minute, for the temperature to fall to 1°C?

10 The population of a country is doubling every 30 years and was 3 000 000 at the last census.

a Show, by establishing a pattern, why the population P after n years is $P = 3\,000\,000 \times 2^{\frac{n}{30}}$

b Find when the population will be 1 billion.

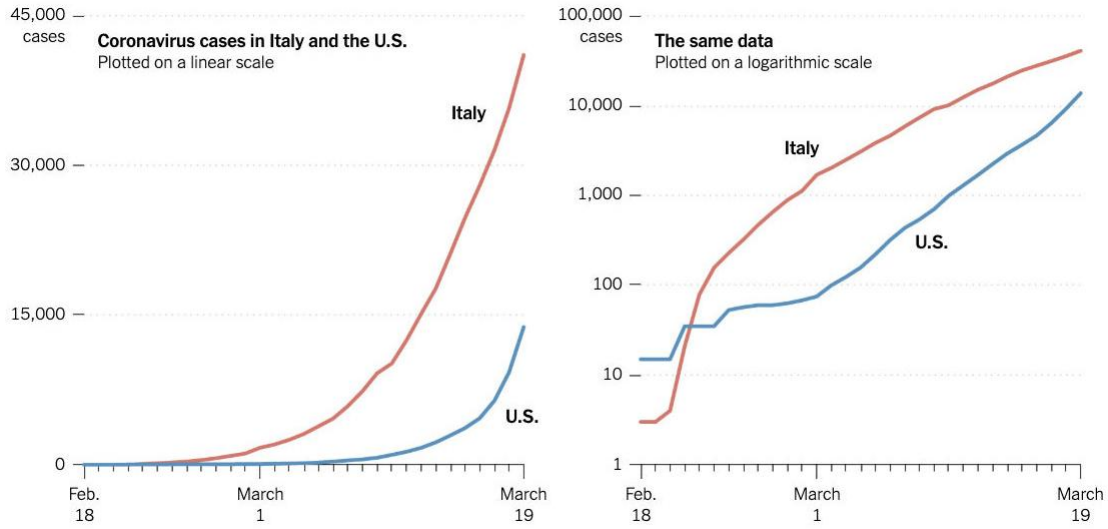
11 The half-life of a substance is the time it takes for the substance to reduce to half its original mass. Find the half-life of 10 kg of radioactive material if its mass reduces by 1% per year.

LOGARITHMIC SCALES

- A logarithmic scale multiplies instead of adds.
- it makes small changes look bigger and large changes look smaller.

FOUNDATION

1 Total COVID-19 cases in Italy and the US in early 2020:



a What scale is the second graph using? How can you tell?

……

b Using the logarithmic scale, what can you say about Italy's case numbers? Is it slowing down or accelerating?

……

c Using the logarithmic scale, what can you say about USA's case numbers? Is it slowing down or accelerating?

……

d Why might scientists prefer to use logarithmic scales to track exponential growth scenarios, such as infectious diseases?

……

2 Earthquake intensity is measured using the Richter scale

$$M = \log_{10} A$$

M is the magnitude of an earthquake.

A is the amplitude of ground movements.

a Rewrite the formula with A as the subject. ……

How many times more powerful are these earthquakes compared to each other?
i.e. find the ratio of the amplitudes.

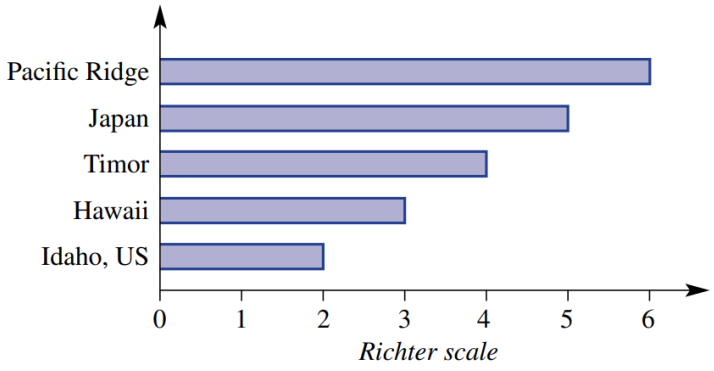
b Magnitude 2 (smallest humans can feel)
Magnitude 6 (major damage)

c 3.5 and 6?

d 3.2 and 8.6?

e 2.8 and 3.6?

3 This chart shows the Richter scale measurements rounded to the nearest integer for five different earthquakes recorded in 2022.



a What is the difference between the magnitude of the earthquakes for Pacific Ridge compared to Timor?

……

b Therefore, explain why the earthquake in Pacific ridge was 100 times more powerful compared to Timor.

……

c What is the difference between the magnitude of the earthquakes for Japan compared to Idaho?

……

d Therefore, how many times more powerful was the earthquake in Japan compared Idaho?

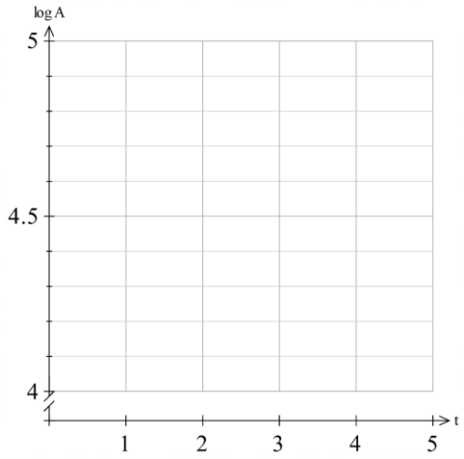
……

4 The following table includes data about the value of an investment \$A over t years.

a Calculate the value of $\log_{10} A$ for each of the values of A on the table.

t	0	1	2	3	4	5
A	10 000	12 000	14 400	17 280	20 736	24 883.2
$\log_{10} A$						

b Plot $(t, \log_{10} A)$ on this graph.



c What does this say about the type of relationship between t and and A?

……

5 The pH of a solution describes whether it is basic or acidic.
It is measured according to the concentration of hydrogen ions.

$$\text{pH} = -\log_{10} M$$

Where M is the concentration of hydrogen ions in moles per litre (mol/L).

Calculate the pH of the solutions that contain the following concentrations of hydrogen ions:

a 10^{-3} mol/L

b 3.6×10^{-5} mol/L

c 4.9×10^{-9} mol/L

d Rewrite the formula with M as the subject. ……

Determine the concentration of hydrogen ions, given these pH values.

e $\text{pH} = 7$ (water)

f $\text{pH} = 2.1$ (lemon juice)

g $\text{pH} = 11.9$ (ammonia)

6 The human ear is very sensitive. Sound intensity is measured using decibels (dB).

$$S = 10 \log_{10} \frac{I}{I_0}$$

Where S is the sound intensity in decibels,

$\frac{I}{I_0}$ is how many times louder a sound is compared to the threshold of human hearing.

How many times louder than the threshold for human hearing is the sound of the following?
(i.e., Find $\frac{I}{I_0}$)

a	Normal conversation 60 dB	**b**	Whispering 20 dB	**c**	How many times louder is 60 dB vs 20 dB?
d	Motorcycle 80 dB	**e**	Quiet street 50 dB	**f**	How many times louder is 80 dB vs 50 dB?
g	Jet engine 140 dB	**h**	Threshold of hearing 0 dB	**i**	How many times louder is 140 dB vs 0 dB?

7 Using a log base 10 scale, the magnitude of the volume of water in Lake Victoria is 8 and the magnitude of the volume of water in Lake Anne is 5.
There is 500 000 ML of water in Lake Anne.

That means Lake Victoria has 800 000 ML of water.

Explain why Victor is incorrect and state the correct volume of Lake Victoria.

……

……

……