Arvind Borde / PHY 11, Week 1: Introduction and Review

(1) Why are you here? _____

(2) _____

_____

_____

(3) Why different from chemistry or physiology?

_____

_____

1 _____

Physics has given us, we think, a good understanding of how much of the world works.

Some people believe we are close to the _____ _____.

Rather than slowly build to our present understanding, we'll start at the end of the story with...

2

...A crash course in the world

The whole world consists of two entities: _____ and _____.

Examples of matter are _____, _____ _____, and _____.

Examples of interactions are the _____ _____

3 .

These are the only known interactions (forces).

Unlike the four fundamental forces, it initially appears that matter may be more complicated. Take our bodies, for example.

(4) What are we mainly made of? _____ _____.

But there's other stuff: bones, flesh, hair, etc.

4

Similarly, if you look around the room, you'll see many different substances.

It's been known since the 1800s that the complexity of the material world is based on just a few basic things combining in different ways. These "basic things" are called _____.

5

(5) Name some elements.

_____

(6) Roughly how many elements are there?

_____

_____

(7) Elements come in basic "pieces." What are they called?

6 _____

ADDITIONAL NOTES

But that is not the end of the story. Each atom has structure and is itself made up of three more basic things.

(**8**) What are the constituents of an atom called?

_____

7

Protons and neutrons form the "nucleus" of the atom, and electrons swirl in a cloud around it.

Protons have positive electric charge, electrons an equal negative charge and neutrons are neutral. The electron cloud is "held in place" by the electric forces between them and the protons.

8

The simplest atom is that of hydrogen. It consists of a single proton and a single electron.

The nucleus is roughly 10^{-13}cm in radius and the electron cloud about 10^{-8}cm.

(**9**) That's a factor of about 100,000. Why?

_____

9

Can you subdivide further?

Not for electrons: they appear to have no internal structure.

But there's one step further for protons and neutrons: they have internal constituents called _____ .

10

At the micro level both matter and interactions are represented by particles, also called _____. (That's the plural. The singular is quantum.)

There are _____ and _____, distinguished by their _____. (Think of each as spinning like a top.) _____

_____

11 _____

All the known quanta

Fermions (matter)

6 "quarks":
up, down, charm, strange, top, bottom
(combinations give the proton, neutron, etc.)
6 "leptons":
electron, muon, tau and their neutrinos

12

ADDITIONAL NOTES

Bosons (interactions)

Electromagnetism: Photon
Strong: 8 Gluons (hold the nucleus together)
Weak: W^+, W^-, Z^0 (radioactive decay)
Gravitation: Graviton??????

These 24-odd particles make up the world and all its interactions, along with a final particle called the Higgs boson.

13

Different interactions important at different scales.

Weak and strong nuclear forces are short range & drop to zero outside the nucleus, so play no direct role at larger scales. Within the nucleus, they are much stronger than gravitation or electromagnetism, and are the dominant forces.

The strong force keeps the nucleus together. The weak force is causes "radioactive decay."

14

Electromagnetism is long range, and is why atoms, molecules and day-to-day objects behave the way they do,

Most larger objects are electrically and magnetically neutral, though, and electric and magnetic effects tend to cancel between large objects.

So this force is irrelevant between large objects that are far apart.

15

Gravity acts over large distances and there are no cancellations (no "anti-gravity").

It and it alone determines the large scale structure of the Universe. It explains why the moon goes around the earth as it does, why planets move around the sun, why the sun rotates around the center of the Milky Way.

16

OK, have you been listening?

Everything that's "held together" is held together by a basic force.
(10) How many are there? _____
(11) What are they?

_____

17 _____

(12) What holds the nucleus together (despite the like charges on the protons repelling each other)?

_____

(13) For certain nuclei – called radioactive – the nucleus can split. What causes that?

_____

_____

18

ADDITIONAL NOTES

(14) What holds an atom together?

_____

_____

_____

_____

_____

19

(15) What keeps a table together?

_____

(16) What keeps your nose on your face?

_____

(17) What holds the earth together?

_____

_____

20 _____

(18) What holds you to earth?

_____

(19) What keeps the solar system together?

_____

_____

_____

21

Physics studies both the laws that govern how/why interactions are the way they are, and their effects.

Studying the *effects* of interactions, irrespective of what causes them, belongs to a branch of physics called _____.

Study the laws that govern how/why these interactions are the way they are belongs to a branch of physics called _____.

22

(20) Does physics use math? _____

(21) Is physics different from math? _____

(22) How? _____

_____

_____

_____

23

Math Review

Whole Numbers

(23) $2 + 2 = ?$

(24) $1 + 2 + 3 = ?$

(25) $12 - 3 + 4 = ?$

24

ADDITIONAL NOTES

(26) $1 + 2 + 3 \ldots 100 = ?$

(27) How many such pairs are there? _____

(28) So, what is the sum? _____

25

(29) $1 + \frac{1}{2} + \frac{1}{3} + \frac{1}{4} \ldots = ?$

(30) $1 + \frac{1}{4} + \frac{1}{8} + \frac{1}{16} \ldots = ?$

26

OK. Back to "smaller" calculations:

(31) $2 - 2 = ?$ _____

(32) $2 + (-2) = ?$ _____

(33) $2 - (-2) = ?$ _____

27

Fractions

(34) $\frac{1}{2} + \frac{2}{3} = ?$

28

(35) $\frac{1}{2} - \frac{2}{3} = ?$

29

(36) $\frac{3}{2} + \frac{3}{4} = ?$

30

ADDITIONAL NOTES

(37) $\frac{3}{2} \times \frac{3}{4} = ?$

31

(38) $\frac{3}{2} \times \frac{4}{5} = ?$

OR

32

(39) $\frac{3}{2} \div \frac{4}{5} = ?$

33

Division by any number is the same as multiplication by its reciprocal.

Why?

Consider division by 2, as an example: Dividing something by 2 is the same as halving it. Therefore,

$$N \div 2 = N \times \frac{1}{2}$$

This is true for division by any number.

34

Order of Operations

You will be expected to know the addition, subtraction, multiplication and division of basic fractions, as well as simplifying the answer.

You will also be expected to know in which order you carry out these operations.

35

(40) $\frac{1}{2} + \frac{2}{3} \times \frac{2}{5} = ?$

36

ADDITIONAL NOTES

(41) $\left(\frac{1}{2}+\frac{2}{3}\right)\times\frac{2}{5}=?$

37

Equations

(42) Solve $3x-15=0$.

38

(43) Solve $4x-2=13-2x$.

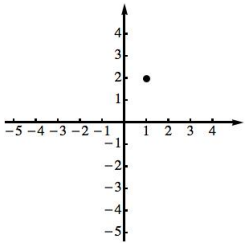
39

(44) Solve $-5x+1=0$

40

Coordinates

(45) What are the coordinates of



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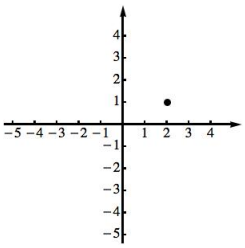
(46) What are the coordinates of



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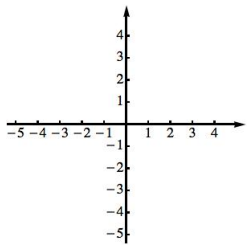
ADDITIONAL NOTES

(47) Plot the points $(-1, 3)$ and $(2, -3)$.



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Functions and Graphs

Definition

A _____ expresses a relationship between two (or more) variables.

Examples:

44

We distinguish between the variable that you can change freely, _____, and the variable(s) that depend(s) on it, _____ variable(s).

If two variables are separated, one on the left the other on the right, it's usually assumed that the right-hand variable is independent. For example, in $y = x^2 + 1$, _____

45

In more complicated situations, for example

$$2^u + v^3 = u - \sqrt{v},$$

you'll be told which variable you should think of as independent.

The set of _____ _____ is called the _____ of the function, and the set of _____ _____ the _____.

46

For example, the domain of $y = 1/x^2$ is the set of all values of x _____, and the range is all values of y _____.

(48) Why?

Domain: _____

Range: _____

We can write the domain as $(-\infty, \infty) - \{0\}$, and the range as $(0, \infty)$.

47

(49) What are the domain and range of

$$y = \frac{1}{x-1}?$$

_____

_____

48

ADDITIONAL NOTES

The dependent variable, say y, is called _____ _____.

We write this expression as _____, read as "_____." So,

$$y = x^2 + 1 \quad \text{and} \quad f(x) = x^2 + 1$$

have the same content. When we write $y = f(x)$ we're saying that y is a function of x.

49

Graphs of Linear Functions

To plot the linear function $2x - 1$:

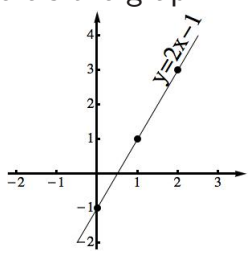
1) Write the equation $y = 2x - 1$.
2) Make a table:

	x	$2x-1$	y	
Chosen	0	$2(0)-1$	-1	Calculated
	1	$2(1)-1$	1	
	2	$2(2)-1$	3	

3) Plot the (x, y) values and connect them.

50

Here's the graph:



Note:
1) y-intercept is -1. (Why?)
2) x-intercept is the solution of $0 = 2x - 1$: $x = 1/2$.
3) Graph points upward.

51

(**50**) Plot $2x + 1$ and get the intercepts.

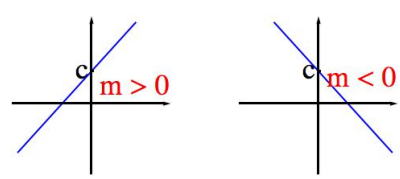
52

(**51**) Plot $-2x + 3$ and get the intercepts.

53

The General Linear Function: _____

1) Graph points upward (L to R) when _____, downward when _____. m is called the _____.
2) The y-intercept is _____.
3) The x-intercept is the _____ .



54

ADDITIONAL NOTES

Slope

55

Square Roots

(52) What is $\sqrt{4}$? _____.

(53) How do you know that ?

_____

(54) is there another number whose square is 4?

_____

_____

56 _____

(55) Assuming a and b are positive, is it correct to say that

$$\sqrt{a^2+b^2} = \sqrt{a^2} + \sqrt{b^2} = a + b?$$

57

Families of Functions

- _____, e.g., _____.
- _____, e.g., _____.
- _____, e.g., _____.
- _____, e.g., _____, _____.
- _____, e.g., _____.

58

Definition

The _____ of a polynomial is the highest power of the variable.

We classify polynomials by their degree. For example $2x^3 - 3x^2 + x - 6$ has degree _.

59

What are the degrees of

(56) $3x^4 - x + 1$? _____

(57) $-2x^5 - x^4 + x^3 - 2x^6 + x^2 + 4$? _____

60

ADDITIONAL NOTES

Degree 1: Linear Polynomials

Examples:

$-5x + 1$

$(4/2)x + \pi$

To get the "zeros" of the first of these:

$$-5x + 1 = 0$$
$$1 = 5x$$
$$x = 1/5$$

61

(58) What are the zeros of $3x - 15$?

62

(59) Solve $4x - 2 = 13 - 2x$

63

Examples:

$-5x^2 + x + 1$

$(4/2)x + x^2$

To get the zeros of the first of these you must solve the quadratic equation

$$-5x^2 + x + 1 = 0.$$

64

Solving Quadratic Equations

The general quadratic equation is

$$ax^2 + bx + c = 0$$

where a, b, and c are fixed numbers.

The solution can always be obtained from the quadratic formula:

65

(60) What are the zeros of $x^2 - 5x + 6$?

66

ADDITIONAL NOTES

To answer this you must solve $x^2 - 5x + 6 = 0$. Here $a = 1$, $b = -5$, and $c = 6$. Therefore,

$$\begin{aligned} x &= \frac{-(-5) \pm \sqrt{(-5)^2 - 4(1)(6)}}{2(1)} \\ &= \frac{5 \pm \sqrt{25 - 24}}{2} = \frac{5 \pm \sqrt{1}}{2} \\ &= \frac{5 \pm 1}{2} = \begin{cases} (5+1)/2 = 6/2 = 3 \\ \text{or} \\ (5-1)/2 = 4/2 = 2 \end{cases} \end{aligned}$$

67

(61) What are the zeros of $3x^2 - 2x - 1$?

68

(62) What are the zeros of $2x^2 + 3x - 1$?

69

(63) What are the zeros of $x^2 - 2x + 1$?

70

(64) What are the zeros of $x^2 + 1$?

71

(65) Can you give a verbal argument why no real values of x can make $x^2 + 1 = 0$?

72

ADDITIONAL NOTES

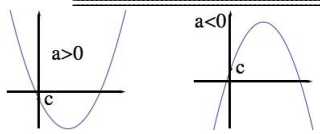
The General Quadratic Polynomial

_____

1) Graph points upward when _____, and downward when _____.

2) y-intercept is _____.

3) x-intercepts are _____.

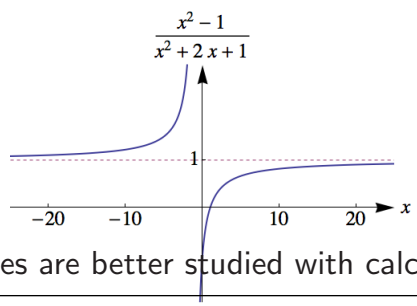


73

(66) We have seen that a quadratic expression can have two, one, or no zeros. This must match situations where the associated graph has two, one, or no x-intercepts. Sketch all three possibilities.

74

A _____ of a graph is a horizontal line that the graph approaches at its ends. To spot it visually, you have to play with the viewing window:



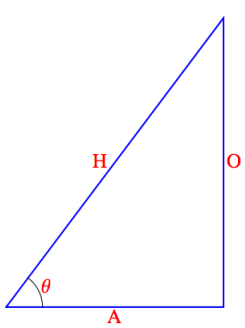
75 Asymptotes are better studied with calculus.

Function Family: Trigonometric Functions

You'll have seen two versions of trigonometry, _____ and _____.

76

Triangle Trigonometry



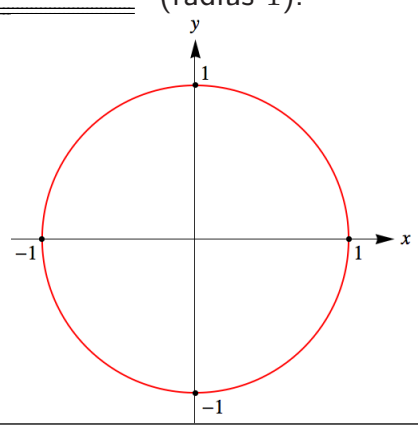
$cos(\theta)$=_____

$sin(\theta)$=_____

$tan(\theta)$=_____

77 Circle trigonometry is more fundamental.

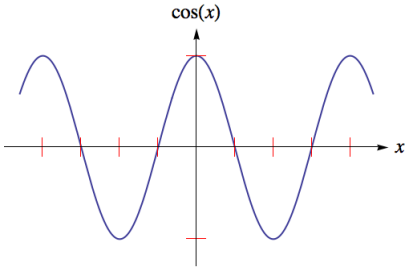
Draw a "_____" (radius 1):



78

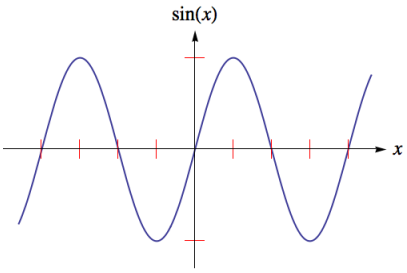
ADDITIONAL NOTES

(67) Label the ticks on this graph:



79

(68) Label the ticks on this graph:



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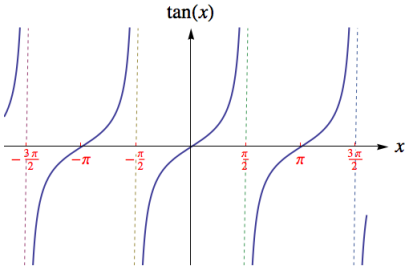
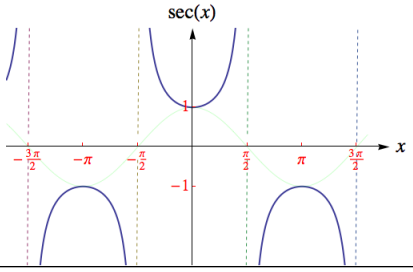
The graph of $tan(x) = sin(x)/cos(x)$ follows from the graphs of $sin(x)$ and $cos(x)$:



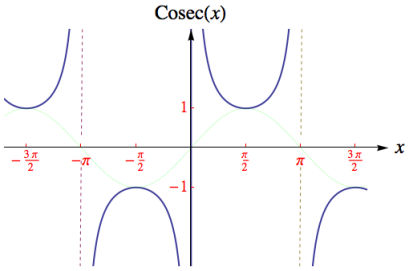
81

There are three associated trig functions, the reciprocals of the three basic ones. Here's the graph of _____:



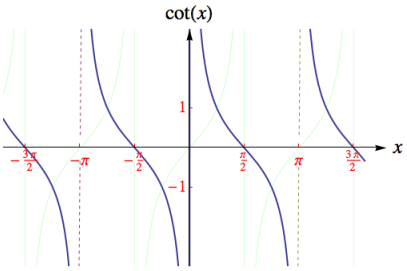
82

Here's the graph of _____:



83

Here's the graph of _____:



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ADDITIONAL NOTES

Function Family: Exponential and Log Functions

Definition

An _____ is one of the type a^x, where $a > 0$ is a fixed number.

Example:

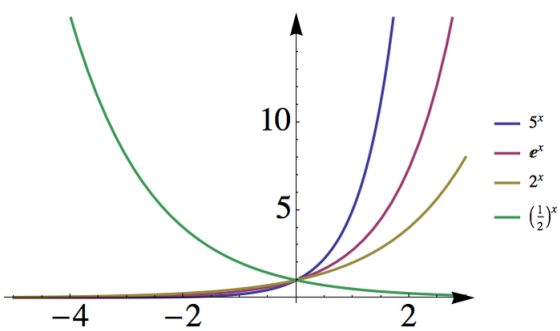
- $y = 2^x$
- $y = \left(\frac{1}{5}\right)^x$
- $y = e^x$

85

(69) What's e?

86

Exponentials are the most powerful functions known to woman (or to man).



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Logarithmic functions are the "opposites" (_____) of exponentials, rather as square-roots are the opposites of squares.

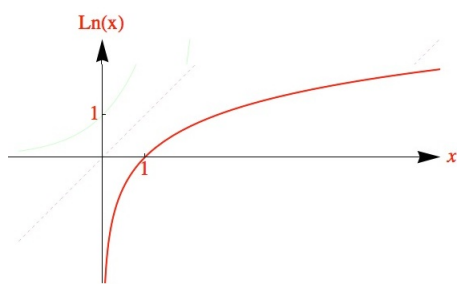
Example: $ln(x)$ is the inverse function of e^x.

(70) What's $ln(e^x)$? _____

(71) What's $e^{ln(x)}$? _____

88

Graphically:



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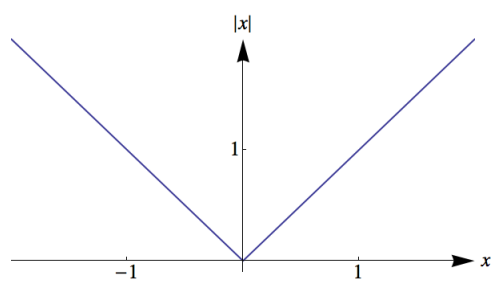
Function Family: Other Functions



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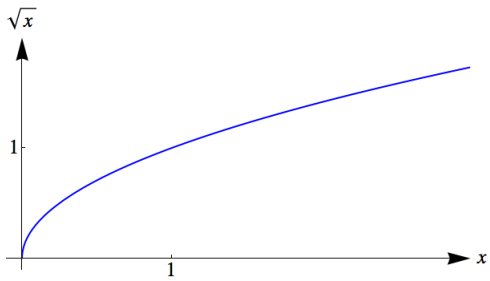
ADDITIONAL NOTES



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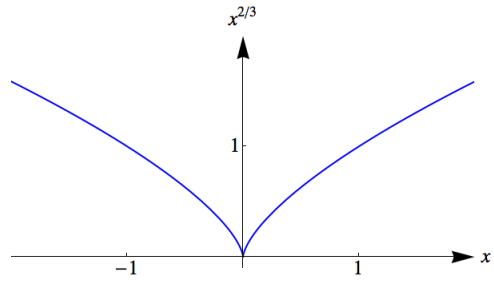

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Math Review: Powers of 10

(72) If you multiply two terms, such as $10^7 \times 10^5$ what answer do you get? _____

93

What are

(73) $10^{13} \times 10^{15}$? _____

(74) $10^{-3} \times 10^5$? _____

Note:

a) $10^{-2} = \dfrac{1}{10^2}$.

b) $10^0 = 1$.

94

(75) If you divide two powers of 10 (e.g., $10^7 \div 10^5$) what answer do you get? _____

What are

(76) $10^{13} \div 10^{15}$? _____

(77) $10^3/10^{-5}$? _____

95

We'll use the metric system and _____ over fractions for the most part and powers of 10 to express quantity.

96

ADDITIONAL NOTES

Express as decimals

(78) 3/10 _____

(79) 4/5 _____

(80) 1/3 _____

(81) 3/100 _____

97

Math Review: Proportionality

If we say $y = x$ then the quantity y equals the quantity x.

If we say $y = 5x$ then y is _____ x. We write this as

$$y \propto x$$

This is true whenever

$$y = kx$$

for any fixed $k > 0$ ("If _____").

98

(82) $y = kx$, as x goes up, y _____.

(83) $y = kx$, as x goes down, y _____.

(84) $y = \frac{k}{x}$, as x goes up, y _____

(85) $y = \frac{k}{x}$, as x goes down, y _____

100

We also need the idea of _____. If

$$y = k \times \frac{1}{x} = \frac{k}{x}$$

where k is fixed, then y is said to be inversely proportional to x.

99

Measurement and Uncertainty

Physics, by Giancoli, 7th ed, fig. 1-5, p6

101

_____

_____

_____

Example: from the picture, the width of the board would be measured as 8.8 ± 0.1 cm.

The "plus or minus 0.1 cm" is the estimated uncertainty in the measurement: you are saying the actual width most likely lies between 8.7 and 8.9 cm.

102

ADDITIONAL NOTES

The percent uncertainty is the ratio of the uncertainty to the measured value, multiplied by 100. In our example, the percent uncertainty is

$$\frac{0.1}{8.8} \times 100\% \approx 1.14\%$$

If the uncertainty is not given, the last digit is assumed to be uncertain to a few units.

103

(86) What is the difference between saying the measurement is 8.8 cm and 8.80 cm?

104

Is the diamond yours? A friend asks to borrow your diamond for a day to show her family. You're worried, so you carefully have your diamond weighed on a scale which reads 8.17 grams. The scale's accuracy is claimed to be ± 0.05 grams. The next day you weigh the returned diamond again, getting 8.09 grams. Could this be this your diamond or can you rule out that possibility?

105

The original measured mass is 8.17 ± 0.05 gm. The mass could be as low as _____.

The second measured mass is 8.09 ± 0.05 gm. The mass could be as *high* as _____.

There's an overlap, so _____ _____.

106

Significant Figures

Definition

The number of reliably known digits in a number is called its _____.

Examples:

- 32.29: 4 sf.
- $85{,}000$: 5 sf

(assuming uncertainty only in last digit).

- 0.00085: 2 sf.

107

How many significant figures are there in

(87) 70 _____

(88) 70.0 _____

108

ADDITIONAL NOTES

Multiplication can lead to misimpressions in significant figures.

Suppose a rectangle is measured to have a width of 5.6 m and a length of 13.8 m.

(**89**) What is its area?

109

(**90**) What is the implied uncertainty in 77.28?

(**91**) What are the implied uncertainties in 5.6 and 13.8?

110

(**92**) What are the smallest and biggest areas you can get from the uncertainties in width and length?

(**93**) Is this consistent with stating the area as $77.28\,\text{m}^2$?

111

Rough general rules:

Multiplying or dividing: answer should have no more *digits* than the numerical value with fewest *significant figures*.

Adding or subtracting: final result should have no more *decimal places* than the number with fewest *decimal places*.

112

For example:

$3.5 - 0.47 \approx 3.0$ (not 3.03);
$35 + 7.2 \approx 42$ (not 42.2).

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Scientific Notation

As said, this involves writing numbers as powers of ten. The distance of the earth from the sun can be written as $93{,}000{,}000$ miles, or in scientific notation as 9.3×10^7 miles.

The latter suggests that we know the distance to two significant figures. If we said the distance was 9.30×10^7 miles, we'd be implying that we know it to three.

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ADDITIONAL NOTES

Units

The numbers we use in physics refer to quantities of things, so you need to say what these things are: i.e., specify units.

For example, you cannot say this lecture has gone on for over 120. You need to say 120 something, such 120 hours , or 120 minutes.

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We will largely use the "SI" system of units (International Standard):

_____

_____

_____

Each unit has a standard that defines how big it is.

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The standards were originally defined in terms of large objects, but are now in terms of "fundamental constants of nature."

Example: The metre.
In 1889, there was one prototype meter, a bar made of a platinum iridium alloy with lines inscribed at each end; the distance between them defined the meter.

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Copies were sent to national labs across the world. Defects: Copies not identical, no way to detect a change due to aging or misuse.

Now: Defined as the length of the path traveled by light in vacuum during the time interval of $1/299{,}792{,}458$ of a second.

Based on our belief that the speed of light is a universal constant.

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Unit prefixes and their meanings

Name	Symbol	Value	In words
Giga	G		_____
Mega	M		_____
Kilo	K		_____
Centi	c		_____
Milli	m		_____
Micro	μ		_____
Nano	n		_____

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ADDITIONAL NOTES

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