Getting started with 

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Basics of R - basic math operators

Let's type on the console window:

```
1 + 0.001
```

```
## [1] 1.001
```

```
2*pi - 3
```

```
## [1] 3.283185
```

```
exp(1)-exp(-1)
```

```
## [1] 2.350402
```

```
log(3.2) # natural logarithm
```

```
## [1] 1.163151
```

```
log(32,2) # the binary logarithm of 32
```

Basics of R - basic math operators

Calculate the following formulas:

- (a) $\frac{1}{4^{-6}}$
- (b) $\sqrt[4]{22}$
- (c) 4^{3+2}
- (d) $\frac{4+7}{12-2}$
- (e) $(12-5)^{4/3}$
- (f) $\frac{2^3}{3^2}$
- (g) $ln\left(\frac{2+3}{4-1}\right)$.

Basics of R - variable assignment

We can use "<-" or "=" for assigning value to a variable

```
x<-3.25 # variable name is x
x
```

```
## [1] 3.25
```

```
x^2+exp(x)-3
```

```
## [1] 33.35284
```

```
y=2
x^y
```

```
## [1] 10.5625
```

Variable names can contain any combination of alphanumeric characters along with periods (.) and underscores (_). However, they cannot start with a number or an underscore.

Basics of R - removing variables

```
123x<-3.25
# check if there is an error
```

```
_x<-3.25
# check if there is an error
```

To remove a variable, we use function *rm()*

```
x<-3.25
x
```

```
## [1] 3.25
```

```
rm(x)
x
```

```
## Error in eval(expr, envir, enclos): object 'x' not found
```

Basics of R - numerical variables

- There are 4 main types of variables: **numeric**, **character (string)**, **Date/Time** and **logical**.
- **Numeric** is similar to float or double in other languages.

```
x<-5
is.numeric(x)
```

```
## [1] TRUE
```

- An **integer** variable is also a numerical variable.

```
x<-5
is.integer(x)
```

```
## [1] FALSE
```

- To assign an integer value to variable x:

```
x<-5L
```

Basics of R - numerical variables

Operator	Description
+	Addition
−	Subtraction
*	Multiplication
/	Division
^	Exponent
exp()	Natural Exponent
%%	Modulus (Remainder from division)
%/%	Integer Division

Basics of R - numerical variables

```
6.5 %/% 2
```

```
## [1] 3
```

```
6.5 %% 2
```

```
## [1] 0.5
```

```
((-1)/0)*(1/0)
```

```
## [1] -Inf
```

```
log(-2)
```

```
## [1] NaN
```

```
log(-2)*(1/0)
```

```
## [1] NaN
```

Basics of R - logical variables

- Logical variables can be either **TRUE** or **FALSE**.
- Numerically, **TRUE** is the same as 1 and **FALSE** is the same as 0.
- Logical variables are results from relational operations

```
x<-TRUE
x
```

```
## [1] TRUE
```

```
x*2
```

```
## [1] 2
```

```
y<-FALSE
x + y
```

```
## [1] 1
```

Basics of R - logical variables

Operator	Description
$<$	Less than
$>$	Greater than
$<=$	Less than or equal to
$>=$	Greater than or equal to
$==$	Equal to
$!=$	Not equal to
!	Not
&	And
|	Or

Basics of R - logical variables

```
x<-(1>=2)
x
```

```
## [1] FALSE
```

```
y<-(x==0)
y
```

```
## [1] TRUE
```

```
x+y
```

```
## [1] 1
```

```
x&y
```

```
## [1] FALSE
```

```
x|y
```

Basics of R - character variables

- In any language, **character variables** should be use with care.

```
x<-"Ice cream"
is.character(x)
```

```
## [1] TRUE
```

- Capital letter "I" and normal letter "i" are different.

```
x == "ice cream" # capital letter
```

```
## [1] FALSE
```

- Funtion *nchar(x)* count the characters in string *x*

```
nchar(x) # number of characters
```

```
## [1] 9
```

Basics of R - character variables

- Function *paste()* concatenate number of strings into a single string

```
x<-paste("We", "are", "the champion", sep = " ")
x
```

```
## [1] "We are the champion"
```

- Function *substr()* extract a substrings in a character vector.

```
substr("abcdefgh",3,4)
```

```
## [1] "cd"
```

- Function *sub()* and *gsub()* perform replacement of the first and all matches, respectively

```
sub("a","1234","abcdefga")
```

```
## [1] "1234bcdefga"
```

Basics of R - Date/time variables.

- Dealing with dates and times can be difficult in any language.
- Date variables store a date as number of days since January 1, 1970 while POSIXct stores a time as number of seconds since 07:00:00 Jan 1, 1970.

```
date1<-as.Date("2019-12-05")
as.numeric(date1) # number of days since Jan 01, 1970
```

```
## [1] 18235
```

```
time1<-as.POSIXct("1970-01-01 07:00:01")
as.numeric(time1) # number of seconds since 7AM Jan 01, 1970
```

```
## [1] 1
```

```
as.numeric(substr(time1,12,13)) # extract hour from date2
```

```
## [1] 7
```

Basics of R - Date/time variables.

Base R does not well support to date/time variables, we use packages **lubridate** instead

```
library(lubridate)
today()
```

```
## [1] "2021-06-20"
```

```
now()# Universal Time Coordinated (UTC)
```

```
## [1] "2021-06-20 22:27:47 +07"
```

```
mdy("December 31st, 2021")
```

```
## [1] "2021-12-31"
```

```
dmy("31-Dec-2021")
```

```
## [1] "2021-12-31"
```

Basics of R - vertors (1)

- A vector is a collection of elements, all of the **same type**.
- Vectors play a crucial and helpful role **R**. **R** is also call a **vectorized** language.
- There are many ways to create a vector in R

```
x<-c(2,3,5,7,11,13) # 1st way to create a vector, "c" means co
x
```

```
## [1]  2  3  5  7 11 13
```

```
length(x)
```

```
## [1] 6
```

```
s<-c("R", "VBA", "Python","C++")
s
```

```
## [1] "R"      "VBA"    "Python" "C++"
```

Basics of R - vertors (2)

To access elements of a vector, we uses **[]**

```
x<-5:10 # 2nd way to create a vector
x[5]
```

```
## [1] 9
```

```
x[2:4]
```

```
## [1] 6 7 8
```

Third way to create a vector

```
x<-seq(1,2,0.2) # from 1 to 2 with jump = 0.3
length(x)
```

```
## [1] 6
```

```
x<-seq(1,2,length=11) # from 1 to 2 with length 11
x
```

Basics of R - vertors (3)

```
x<-1:5
x*2
```

```
## [1]  2  4  6  8 10
```

```
x^2
```

```
## [1]  1  4  9 16 25
```

Example 1: Calculate $\sum_{n=1}^{100} \frac{1}{n^2}$. *We DO NOT need a loop for, indeed,*

```
n<-100
x<-1:n
sum(1/x^2)
```

```
## [1] 1.634984
```

Basics of R - vertors (4)

Example 2: Calculate $\sum_{n=0}^{100} \frac{1}{n!}$.

```
n<-100
x<-0:n
sum(1/factorial(x))
```

```
## [1] 2.718282
```

Example 3: Calculate $\int_0^2 e^x \, dx$ *and compare the result to* $e^2 - 1$. Note that $\int_a^b f(x) \, dx$ is approximated by

$$\int_a^b f(x) \, dx \sim \sum_{i=1}^{n} \frac{b-a}{n} \times f\left(a + \frac{i(b-a)}{n}\right) \quad \textit{with } n \textit{ is large}$$

Basics of R - vertors (5)

```
n<-10000
x<-seq(0+(2-0)/n,2,(2-0)/n)
(2-0)/n*sum(exp(x))
```

```
## [1] 6.389695
```

```
exp(2)-1 # Analytical solution
```

```
## [1] 6.389056
```

Basics of R - vertors (5)

```
n<-10000
x<-seq(0+(2-0)/n,2,(2-0)/n)
(2-0)/n*sum(exp(x))
```

```
## [1] 6.389695
```

```
exp(2)-1 # Analytical solution
```

```
## [1] 6.389056
```

Example 4: The standard normal random variable has distribution function $\mathbb{P}(X \leq x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{x} e^{-\frac{t^2}{2}}\, dt$. *Calculate* $\mathbb{P}(-0.5 < X \leq 1)$.

Basics of R - vertors (5)

```
n<-10000
x<-seq(0+(2-0)/n,2,(2-0)/n)
(2-0)/n*sum(exp(x))
```

```
## [1] 6.389695
```

```
exp(2)-1 # Analytical solution
```

```
## [1] 6.389056
```

Example 4: The standard normal random variable has distribution function $\mathbb{P}(X \leq x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{x} e^{-\frac{t^2}{2}}\, dt$. *Calculate* $\mathbb{P}(-0.5 < X \leq 1)$. *Answer*

```
n<-1000
x<-seq(-0.5+(1--0.5)/n,1,length=n)
1/sqrt(2*pi)*(1.5/n*sum(exp(-x^2/2)))
```

```
## [1] 0.5327246
```

Basics of R - vertors (6)

- Logical operations on vectors result in a logical vector:

```
x<-1:7
x
```

```
## [1] 1 2 3 4 5 6 7
```

```
x<=3
```

```
## [1]  TRUE  TRUE  TRUE FALSE FALSE FALSE FALSE
```

```
sum(x<=3)
```

```
## [1] 3
```

```
any(x==1)
```

```
## [1] TRUE
```

```
all(x==1)
```

Basics of R - vertors (7)

Example 5: **AirPassengers** is a dataset (in vector) in **R**

- Is there any month that the average number of passengers is more than 650 ?
- What is the proportion of months that the average number of passengers are less than 300 ?

Basics of R - vertors (7)

Example 5: **AirPassengers** is a dataset (in vector) in **R**

- Is there any month that the average number of passengers is more than 650 ?
- What is the proportion of months that the average number of passengers are less than 300 ?

Answer

```
any(AirPassengers>650)
```

```
## [1] FALSE
```

```
sum(AirPassengers<300)/length(AirPassengers)
```

```
## [1] 0.5694444
```

Basics of R - operations between vectors

- Combine vectors

```
x<-1:3
y<-4:8
z<-9:10
c(x,y,z)
```

```
##  [1]  1  2  3  4  5  6  7  8  9 10
```

```
x<-seq(1,2,0.5)
y<-c(3,4)
z<-seq(5,6,length=3)
c(x,y,z)
```

```
## [1] 1.0 1.5 2.0 3.0 4.0 5.0 5.5 6.0
```

Basics of R - operations between vectors

```
x<-"I am an actuary, "
y<-"what is your talent ?"
c(x,y)
```

```
## [1] "I am an actuary, "      "what is your talent ?"
```

```
z<-paste(x,y)
z
```

```
## [1] "I am an actuary,  what is your talent ?"
```

Basics of R - operations between vectors

- Subtract vector

```
x<-c(2,3,5,7,11,13,17,19,23,29)
x %% 2 == 1
```

```
##  [1] FALSE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
```

```
y<-(x %% 2 == 1)
x[y]
```

```
## [1]  3  5  7 11 13 17 19 23 29
```

```
y<-c(10,1,4)
x[y]
```

```
## [1] 29  2  7
```

Basics of R - operations between vectors

- *Example 6 Taking the numbers of passengers in months of June out of AirPassengers dataset*

Basics of R - operations between vectors

- *Example 6 Taking the numbers of passengers in months of June out of AirPassengers dataset*

```
y<-0:11*12+6
AirPassengers[y]
```

```
##  [1] 135 149 178 218 243 264 315 374 422 435 472 535
```

Which month has the lowest average number of passengers ?

Basics of R - operations between vectors

- *Example 6 Taking the numbers of passengers in months of June out of AirPassengers dataset*

```
y<-0:11*12+6
AirPassengers[y]
```

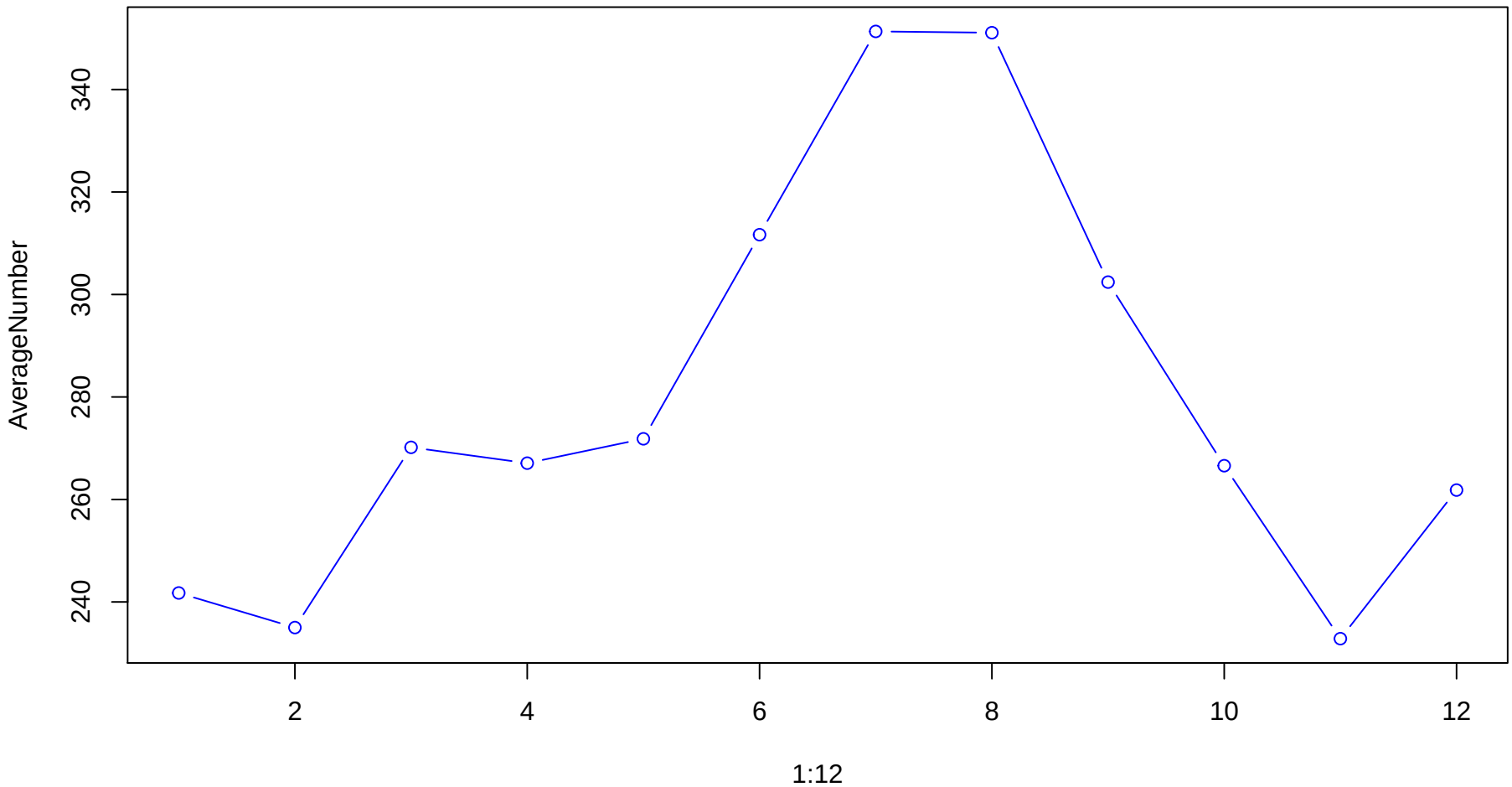
```
##  [1] 135 149 178 218 243 264 315 374 422 435 472 535
```

Which month has the lowest average number of passengers ?

```
AverageNumber<-rep(0,12)
for (i in 1:12){y<-0:11*12+i
AverageNumber[i]<-mean(AirPassengers[y])}
```

Basics of R - operations between vectors

```
plot(x=1:12,y=AverageNumber,col="blue",type="b")
```



Basics of R - operations between vectors

- Operation between vectors with **the same length**: Let $\mathbf{x} = (x_1, x_2, \cdots, x_n)$ and $\mathbf{y} = (y_1, y_2, \cdots, y_n)$, then $\mathbf{x}\Delta\mathbf{y}$ will result in $\mathbf{z}$ where $z[i] = x[i]\Delta y[i]$ for all operation Δ.

```
x<-1:7
y<-7:1
x*y
```

```
## [1]  7 12 15 16 15 12  7
```

```
x<y
```

```
## [1]  TRUE  TRUE  TRUE FALSE FALSE FALSE FALSE
```

```
round(x/y,2)
```

```
## [1] 0.14 0.33 0.60 1.00 1.67 3.00 7.00
```

Basics of R - missing data

- Missing data plays a critical role in both statistics and computing.
- R uses**NA** to denote missing data.

```
x<-c(1,2,3,NA,5,NA)
is.na(x)
```

```
## [1] FALSE FALSE FALSE  TRUE FALSE  TRUE
```

```
x*2
```

```
## [1]  2  4  6 NA 10 NA
```

```
x>3
```

```
## [1] FALSE FALSE FALSE    NA  TRUE    NA
```

```
y<-c(NA,2,NA,4,5,6)
x*y
```

```
## [1] NA  4 NA NA 25 NA
```

Basics of R - often used functions with vectors

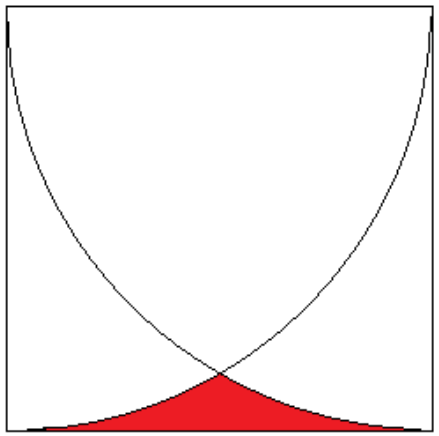
length(x)	:	number of elements in vector **x**
sum(x)	:	sum of all elements in vector **x**
mean(x)	:	average of all elements in vector **x**
sd(x)	:	standard deviation of all elements in vecto
prod(x)	:	product of all elements in vector **x**
min(x)	:	minimum value of all elements in vector **x**
max(x)	:	maximum value of all elements in vector **x**
sort(x,decreasing = TRUE)	:	sorts vector **x** in decreasing order
sort(x,decreasing = FALSE)	:	sorts vector **x** in increasing order

Basics of R - exercises

- Ex1: Calculate from *AirPassengers* dataset, **the proportion** of months with average number of passengers is
  - Less than 100?
  - More than 300 but less than 400 ?
  - More than 400 but less than 450 or more than 500 but less than 550 ?
- Ex 2: Given $\mathbf{x} = (31, 2, 11, 37, 5, 13, 17, 29, 23, 19, 3, 7)$. Assigning to vector **y** values in vector **x** but in reserve order.
- Ex 3: Let **x** = Nile (measurements of the annual flow of the river Nile, in 10^2 km^2, from 1871 to 1970).
  - What is the smallest and the largest values of annual flow?
  - In which year the annual flow is the smallest, is the largest?
  - In which year the annual flow is the 20^{th} largest?

Basics of R - exercises

- Ex 4: Calculate $\int_0^3 x^{1.5}\, e^{-0.3x}\, dx$
- Ex 5: Calculale A:



- Ex 6: Let **x** = presidents
  - How many **NA** values are in **x**?
  - Which years there are no observation?