Lecture 1

2025/2026

Microwave Devices and Circuits for Radiocommunications

2025/2026

- 2C/1L, **MDCR**
- **Attendance at minimum 7 sessions (course or laboratory)**
- Lectures- **associate professor Radu Damian**
  - Tuesday 16-18, ~~Online~~, P8
  - E – 50% final grade
  - **problems** + (2p atten. lect.) + (3 tests) + (bonus activity)
    - first test L1: 24.02.2026 (t2 and t3 not announced, lecture)
    - 3att.=+0.5p
  - **all materials/equipments authorized**

2025/2026

- Laboratory – **associate professor Radu Damian**
  - Monday 14-16, II.13 / (even weeks)
  - L – 25% final grade
    - ADS, 4 sessions
    - Attendance + **personal results**
  - P – 25% final grade
    - ADS, 3 sessions (-1? 24.02.2026)
    - personal homework

Materials

- https://rf-opto.etti.tuiasi.ro

Materials

- RF-OPTO
  - **https://rf-opto.etti.tuiasi.ro**
- **David Pozar, "Microwave Engineering"**, Wiley; 4th edition , 2011
  - 1 exam problem ← Pozar
- Photos
  - sent by ~~email~~/**online exam**
  - used at lectures/laboratory

Photos

Date:

Grupa	5304 (2015/2016)
Specializarea	Tehnologii si sisteme de telecomunicatii
Marca	5184

Trimite email acestui student | Adauga acest student la lista (0)

Detalii curente

Finantare	Buget
Bursa	Fara Bursa

Observatii

Date:

Grupa	5304 (2015/2016)
Specializarea	Tehnologii si sisteme de telecomunicatii
Marca	5244

Trimite email acestui student | Adauga acest student la lista (0)

Detalii curente

Finantare	Buget
Bursa	Bursa de Studii

Observatii

Date:

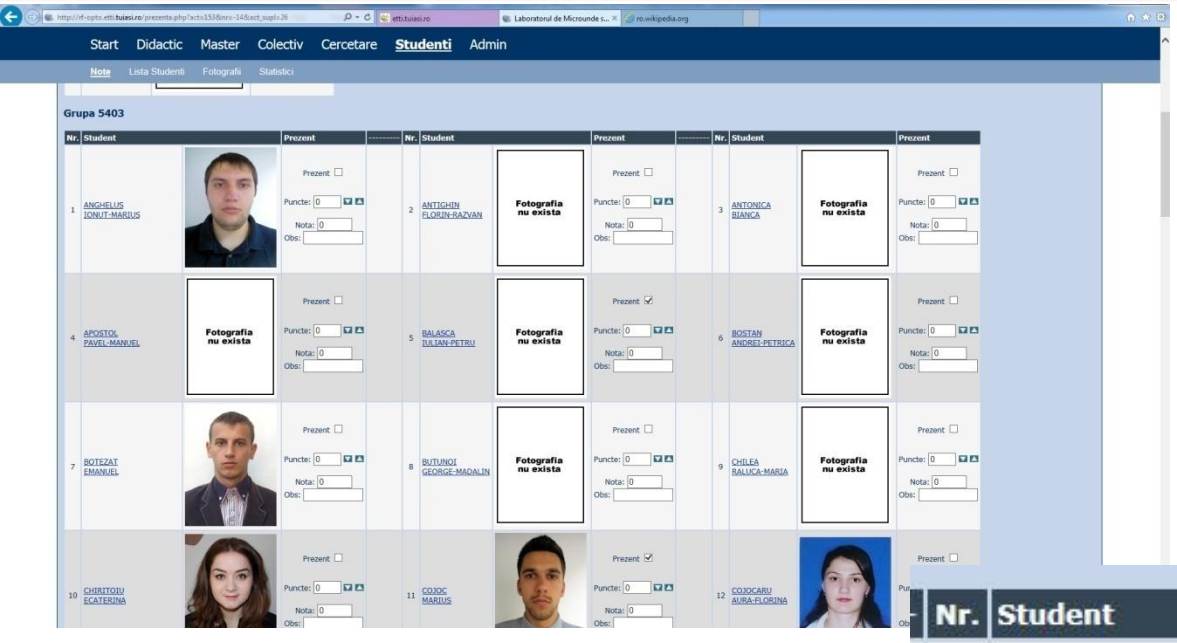
Grupa	5304 (2015/2016)
Specializarea	Tehnologii si sisteme de telecomunicatii
Marca	5184

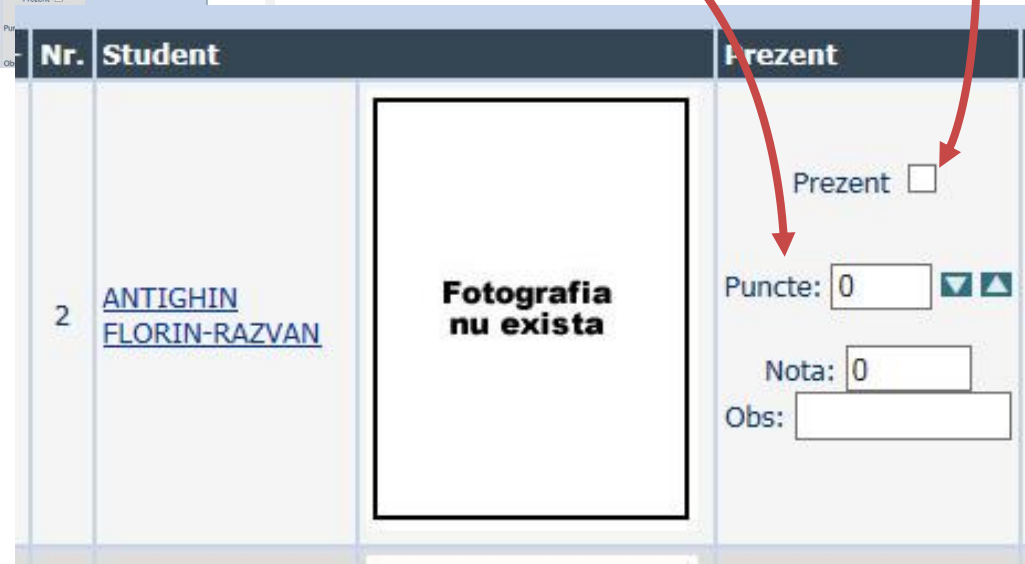
Acceseaza ca acest student

Note obtinute

Disc.	Tip	Data	Descriere	Nota	Obs.
TW	Tehnologii Web				
	N	17/01/2014	Nota finala	10	-
	A	17/01/2014	Calificativ Tehnologii Web 2013/2014	10	7.55
	B	17/01/2014	Laborator Tehnologii Web 2013/2014	9	-
	D	17/01/2014	Tema Tehnologii Web 2013/2014	9	-

Photos


Start
Didactic
Master
Colectiv
Cercetare
Studenti
Admin
Note
Lista Studenti
Fotografii
Statistici
Grupa 5403
Nr.
Student
Prezent
ANGHELUS IONUT-MARIUS
ANTIGHIN FLORIN-RAZVAN
ANTONICA BIANCA
APOSTOL PAVEL-MANUEL
BALASCA IULIAN-PETRU
BOSTAN ANDREI-PETRICA
BOTEZAT EMANUEL
BUTUNOI GEORGE-MADALIN
CHILEA RALUCA-MARIA
CHIRITOIU ECATERINA
COJOC MARIUS
COJOCARU AURA-FLORINA
Fotografia nu exista
Puncte:
Nota:
Obs:

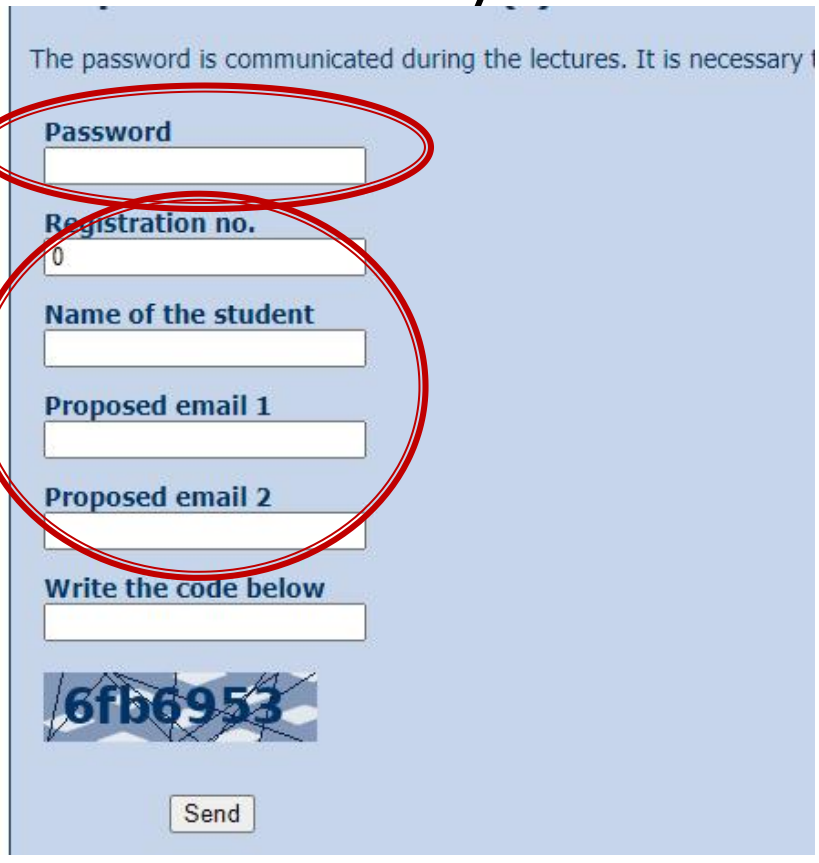

Nr.
Student
Prezent
2
ANTIGHIN FLORIN-RAZVAN
Fotografia nu exista
Prezent
Puncte: 0
Nota: 0
Obs:

Adrese email

- Șefii de grupa
  - lista cu adrese de email **utilizate** de toti studentii
    - poate fi @student.etti.tuiasi.ro (@gmail ~~@yahoo~~ etc.)
  - **rdamian@etti.tuiasi.ro**

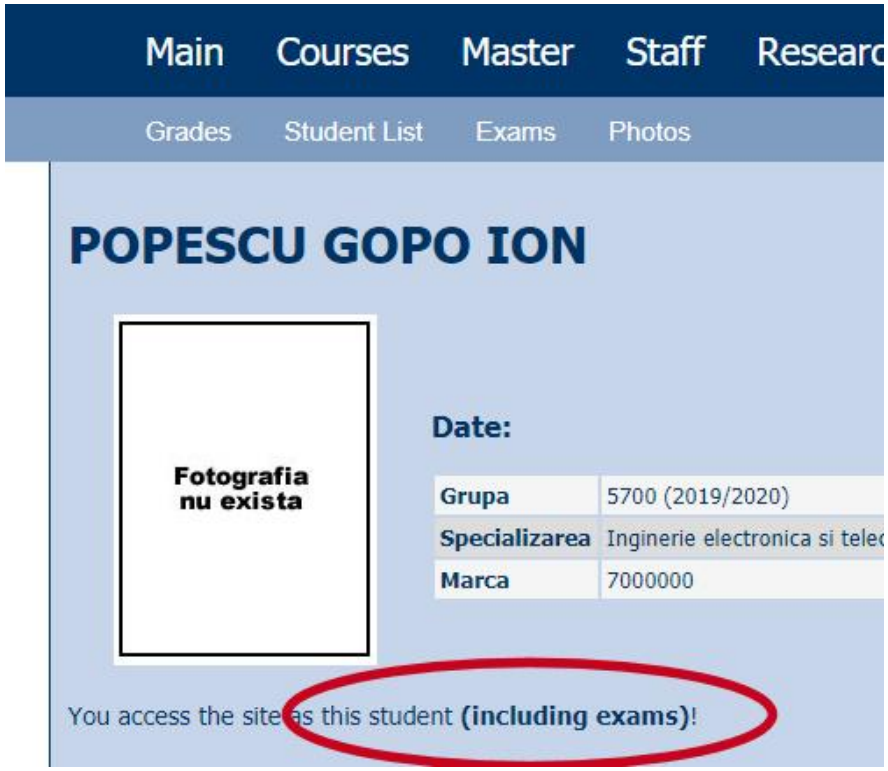
Online – Registration no.

- access to **online exams** requires the **password** received by email



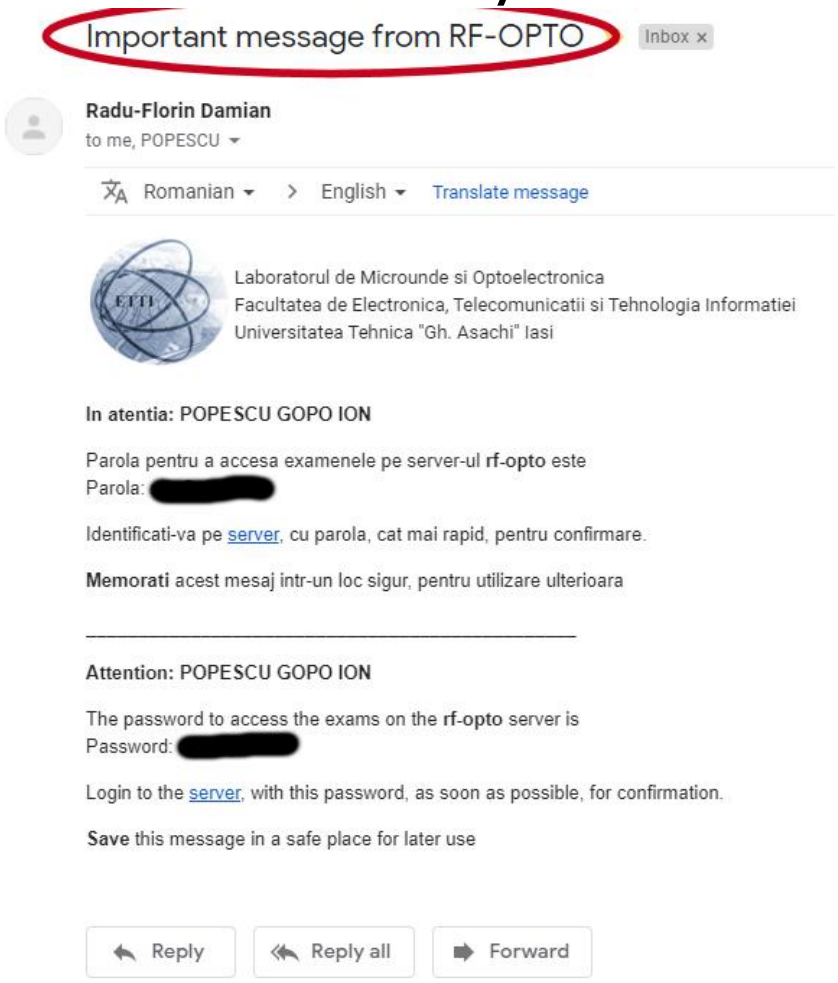
Online

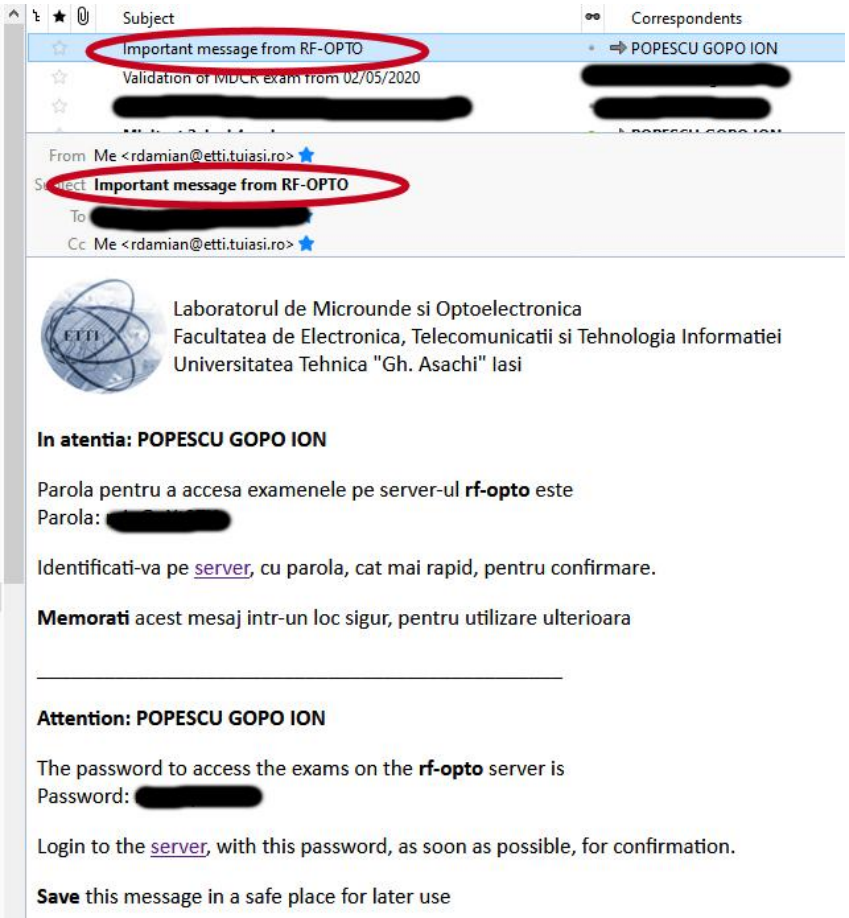
- access email/password



Password

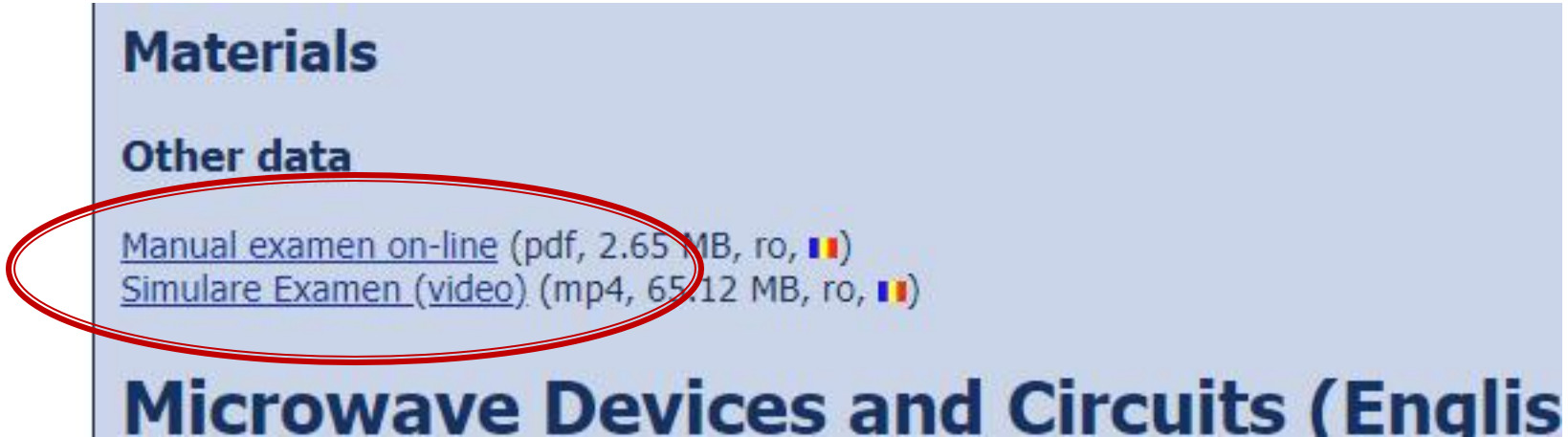
- received by email





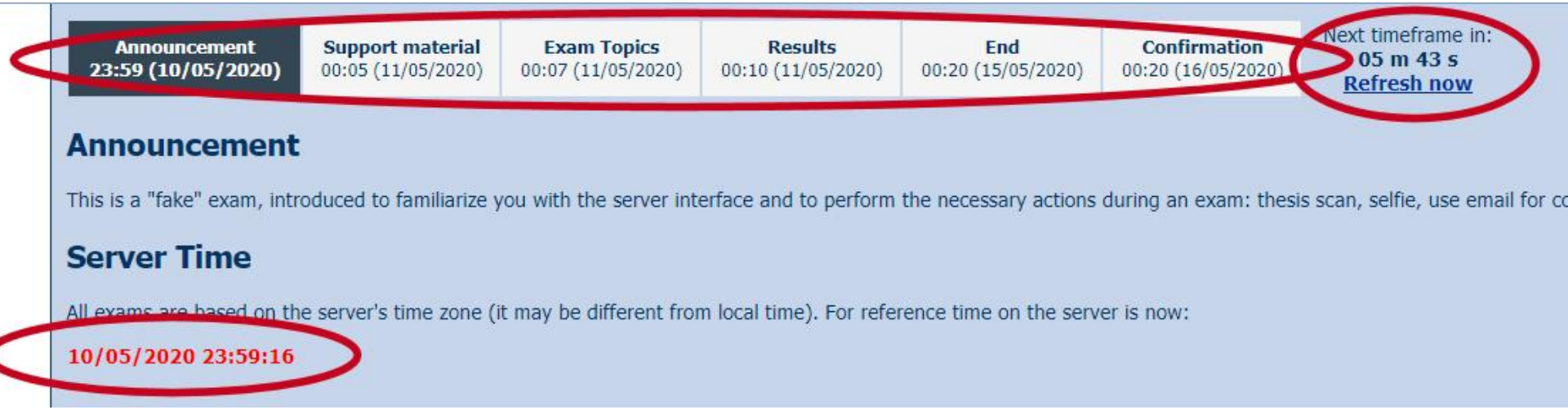
Online exam manual

- The online exam app used for:
  - ~~lectures (attendance)~~
  - laboratory
  - project
  - ~~examinations~~



Online exam

- always against a **timetable**
  - long period (project submission/laboratory results)
  - ~~short period (tests: 15min, exam: 2h)~~



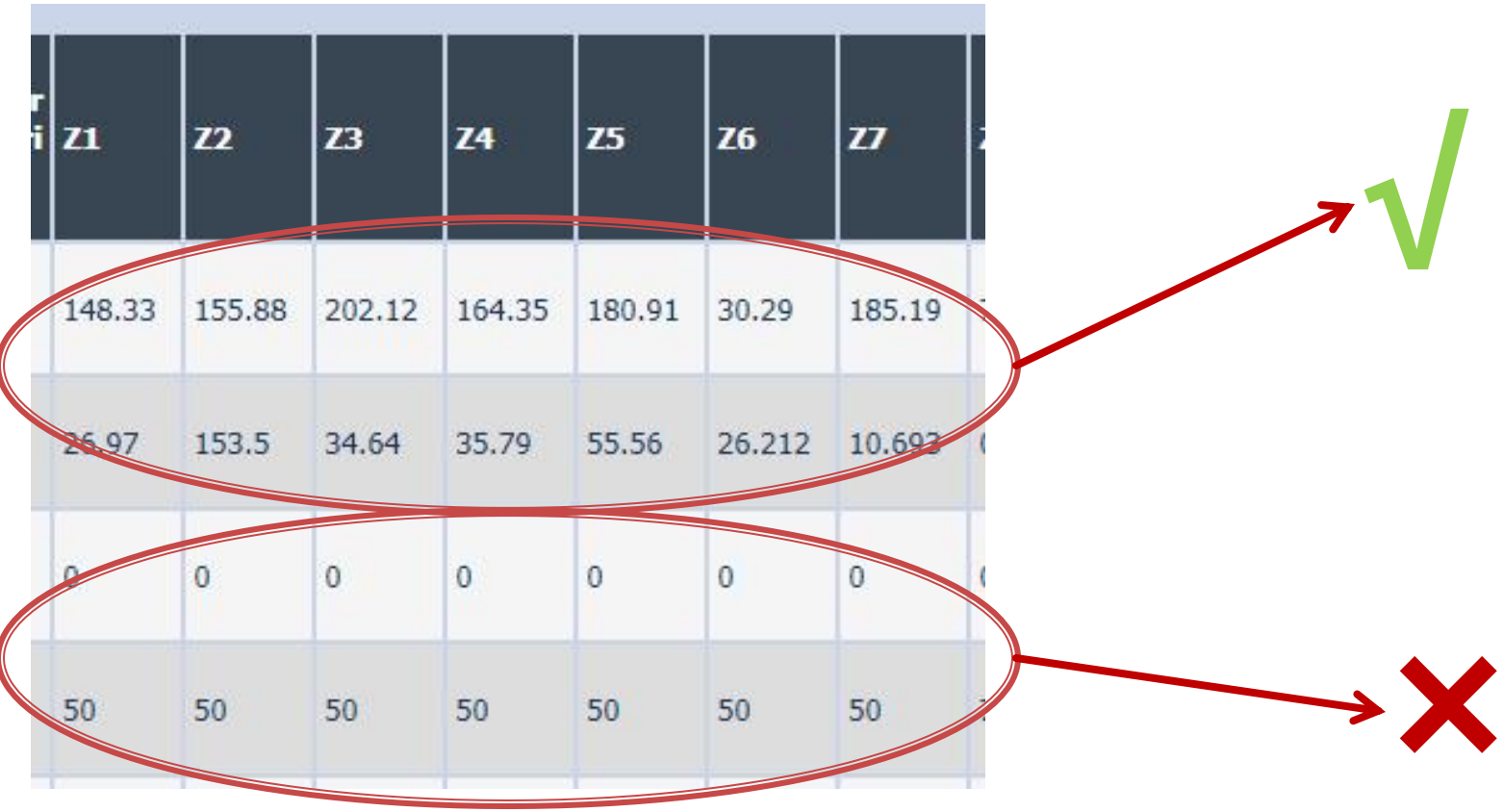
Online results submission

- many numerical values/files

Schema finala	Rezultate - castig	Rezultate - zgomot	Fisier justificare calcul (factor andrei)	Fisier zap (optional)	T1, fisier parametri S	T2, fisier parametri S	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Ze1	Zo1	Ze2	Zo2	Ze3	Zo3	Ze4	Zo4	Ze5	Zo5	Ze6
86 - 5428 - 259 ...	86 - 5428 - 260 ...	86 - 5428 - 261 ...	86 - 5428 - 316 ...	-	86 - 5428 - 314 ...	86 - 5428 - 315 ...	148.33	155.88	202.12	164.35	180.91	30.29	185.19	79.9	37	68.89	45.14	61.83	45.05	57.97	46.02	61.85	45.05	68.8
86 - 5622 - 259 ...	86 - 5622 - 260 ...	86 - 5622 - 261 ...	86 - 5622 - 316 ...	86 - 5622 - 262 ...	86 - 5622 - 314 ...	86 - 5622 - 315 ...	26.97	153.5	34.64	35.79	55.56	26.212	10.693	0	0	0	0	0	0	0	0	0	0	0
86 - 5488 - 259 ...	86 - 5488 - 260 ...	86 - 5488 - 261 ...	86 - 5488 - 316 ...	86 - 5488 - 262 ...	86 - 5488 - 314 ...	86 - 5488 - 315 ...	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
86 - 5391 - 259 ...	86 - 5391 - 260 ...	86 - 5391 - 261 ...	86 - 5391 - 316 ...	-	-	-	50	50	50	50	50	50	50	70.14	40.39	61.85	44.59	55.7	45.2	54.89	45.38	58.65	45.8	70.0
86 - 5664 - 259 ...	86 - 5664 - 260 ...	86 - 5664 - 261 ...	86 - 5664 - 316 ...	-	86 - 5664 - 314 ...	86 - 5664 - 315 ...	168.02	150.5	178.28	133.75	92.12	121.67	144.48	94.36	36.19	70.77	42.56	65.69	42.05	55.17	42.29	65.59	42.05	70.7
86 - 5665 - 259 ...	86 - 5665 - 260 ...	86 - 5665 - 261 ...	86 - 5665 - 316 ...	-	86 - 5665 - 314 ...	86 - 5665 - 315 ...	162.2	80.8	209.2	140.85	135.1	183.7	167.6	94.58	36.15	78.16	39.77	65.57	45.05	65.57	45.05	78.16	39.77	94.5
86 - 5433 - 259 ...	86 - 5433 - 260 ...	86 - 5433 - 261 ...	86 - 5433 - 316 ...	-	86 - 5433 - 314 ...	86 - 5433 - 315 ...	165.138	106.228	226.157	130.134	72.71	180.177	164.616	101.36	36.11	77.22	42.49	68.02	45.62	60	45.42	68.02	45.62	77.2
86 - 5608 - 259 ...	86 - 5608 - 260 ...	86 - 5608 - 261 ...	86 - 5608 - 316 ...	-	86 - 5608 - 314 ...	86 - 5608 - 315 ...	150.84	152.5	30.94	32.37	54.36	19.837	29.85	64.14	40.145	54.32	46.32	53.8	46.7	53.8	46.7	54.32	46.32	54.9
86 - 5555 - 259 ...	86 - 5555 - 260 ...	86 - 5555 - 261 ...	86 - 5555 - 316 ...	-	86 - 5555 - 314 ...	86 - 5555 - 315 ...	168.001	150.288	178.399	133.115	92.491	121.257	144.126	97.05	36.16	71.13	43.09	65.45	42.12	55.66	42.18	65.45	42.12	71.1

Online results submission

- many numerical values



Online results submission

Grade = Quality of the work +

+ Quality of the submission

MOTTO (RO)

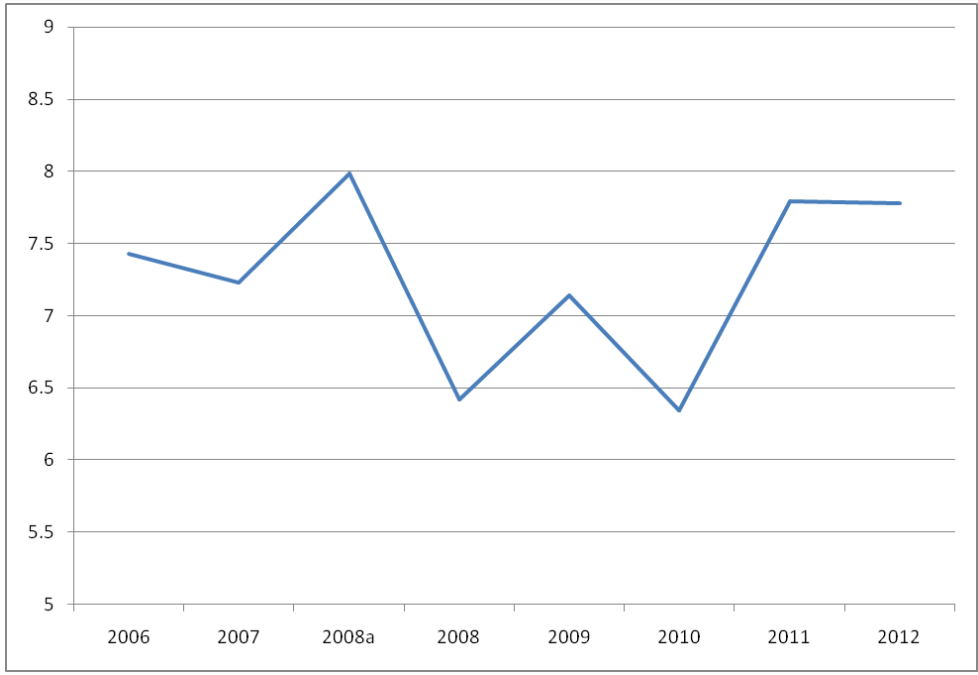
- “Universitatea nu e pentru mase locul de unde emana cunoasterea, ci un obstacol intre individ si diploma pe care i-a harazit-o destinul”

- “Universitatea fiind ceva care se interpune in mod imoral intre individ si dreptul lui natural de a fi diplomat, individul are obligatia morala sa triumfe asupra universitatii prin orice mijloace”

  - Sursa citat: Internet, user: ”un student batran si plesuv”

Exam

- individual topics
- Grades
  - 2006: 7.43
  - 2007: 7.23
  - 2008: 7.98
  - 2008: 6.42
  - 2009: 7.14
  - 2010: 6.34
  - 2011: 7.79
  - 2012: 7.77



- First time (unannounced)
  - 50% of the students left the exam in the first 10 minutes
  - 50% of those who stayed did not pass
  - overall passing percentage 25%, litigation rate: 0%
- Next examinations (announced)
  - litigation rate : 0%

Exam

Grades

Microwave Devices and Circuits (English)

Course: MDC (2020-2021)

Course Coordinator: Assoc.P. Dr. Radu-Florin Damian
Code: EDID407
Discipline Type: DID; Required, Domain
Credits: 3
Enrollment Year: 4, **Sem.** 8

Activities

Course: Instructor: Assoc.P. Dr. Radu-Florin Damian, 2 Hours/Week, Specialization Section, Timetable:
Laboratory: Instructor: Assoc.P. Dr. Radu-Florin Damian, 1 Hours/Week, Group, Timetable:

Evaluation

Type: **Colloquium**

A: 50%, (Test/Colloquium)
B: 25%, (Seminary/Laboratory/Project Activity)
D: 25%, (Homework/Specialty papers)

Grades

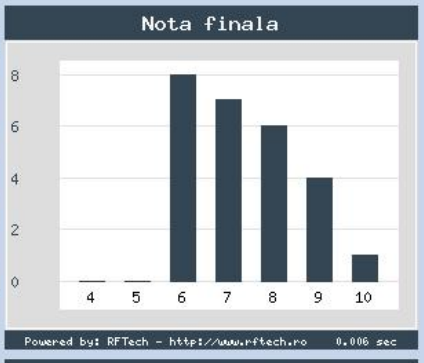
Aggregate Results

Lists

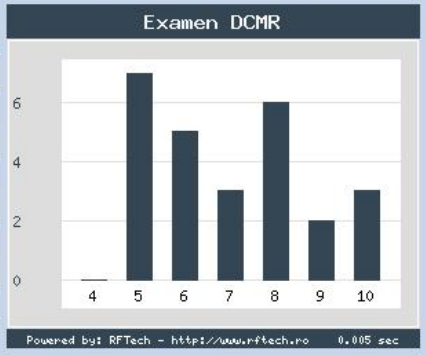
Bonus points (final)

Statistici

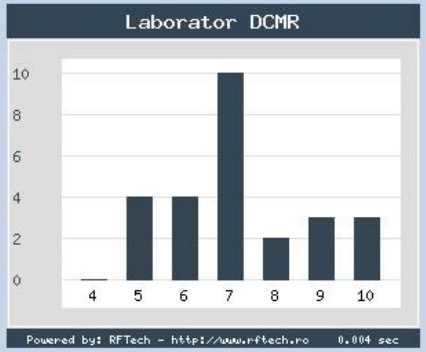
Nota.	Numar
4	0
5	0
6	8
7	7
8	6
9	4
10	1
TOTAL	26



Exam.	Numar
4	0
5	7
6	5
7	3
8	6
9	2
10	3
TOTAL	26

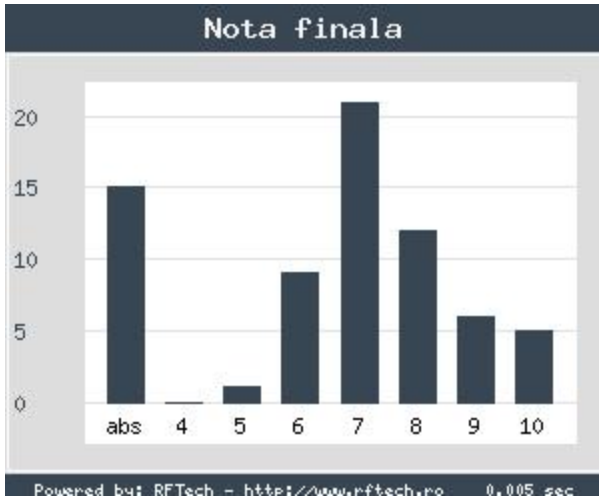


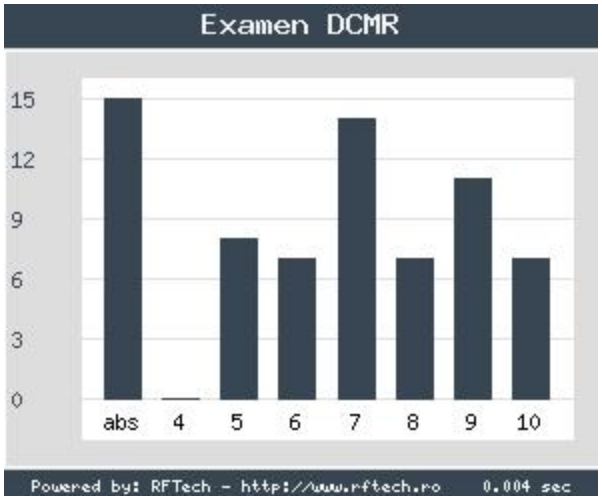
Labo.	Numar
4	0
5	4
6	4
7	10
8	2
9	3
10	3
TOTAL	26

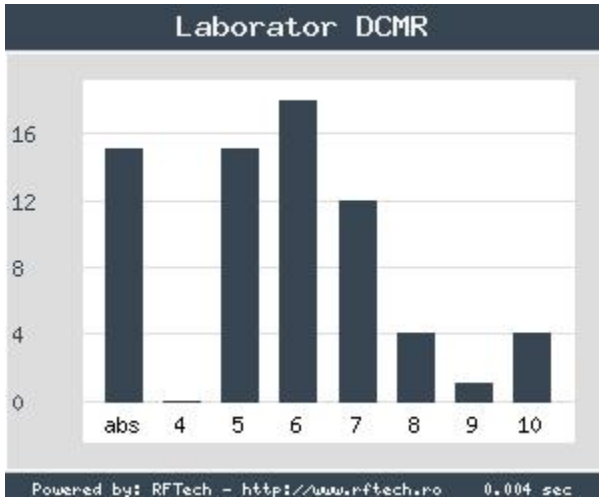


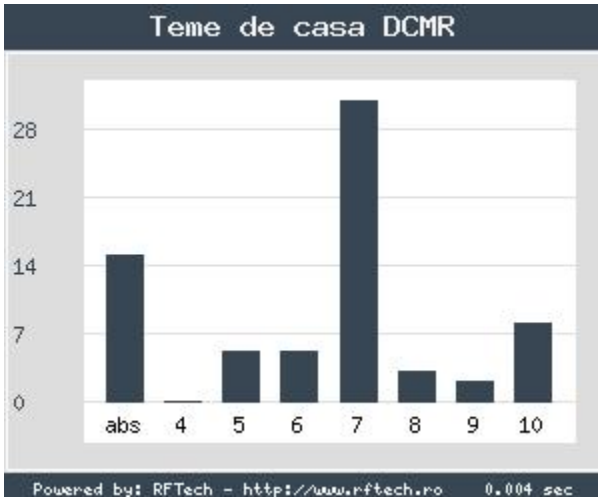
Grades

- 2019/2020



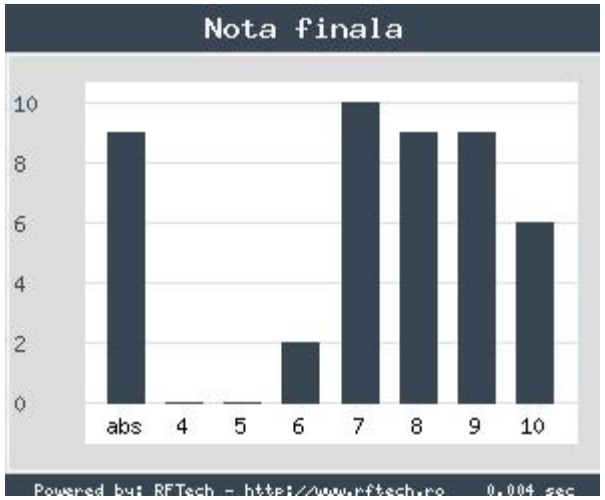


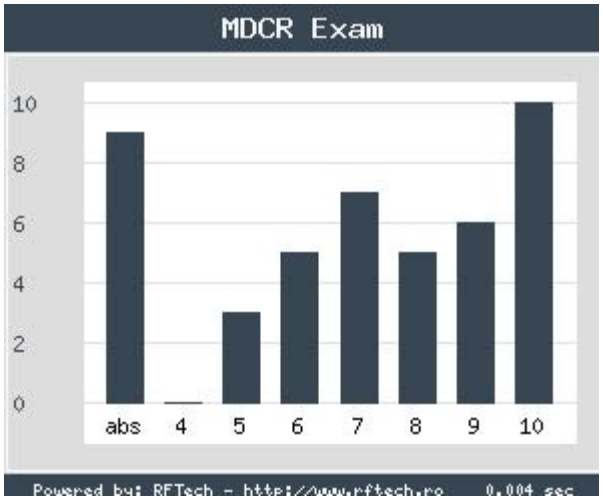


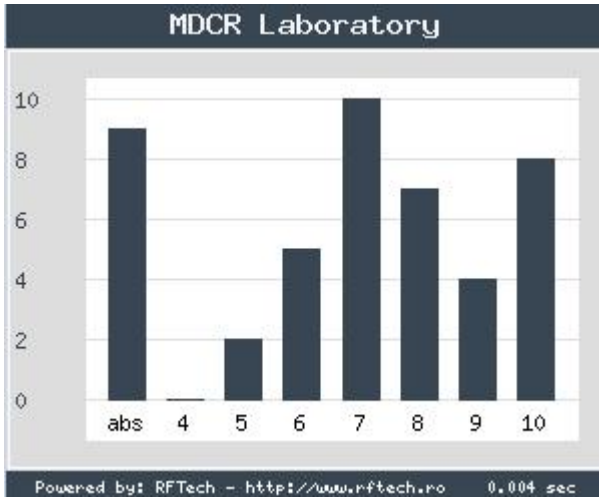


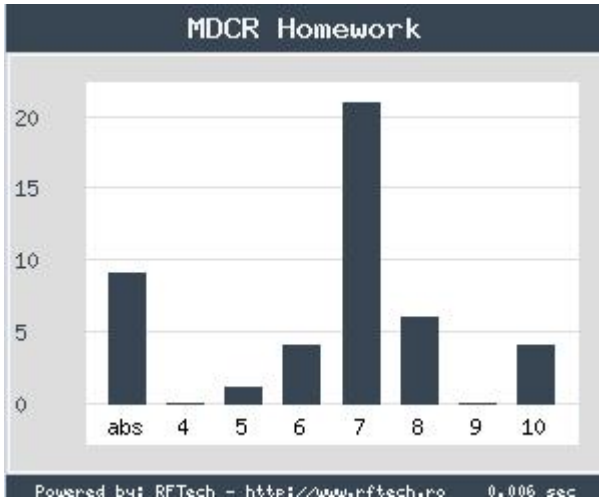
Grades

- 2019/2020 - eng



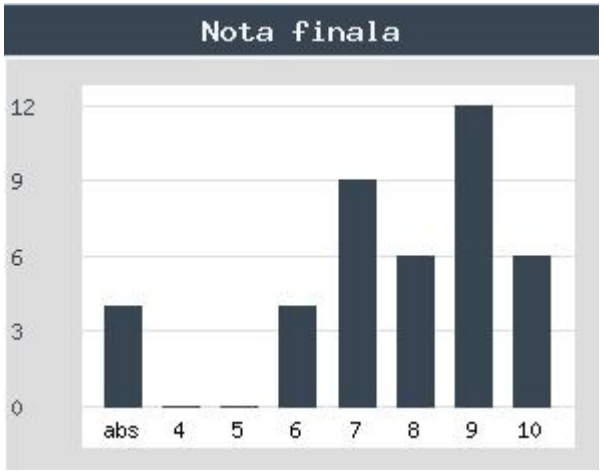


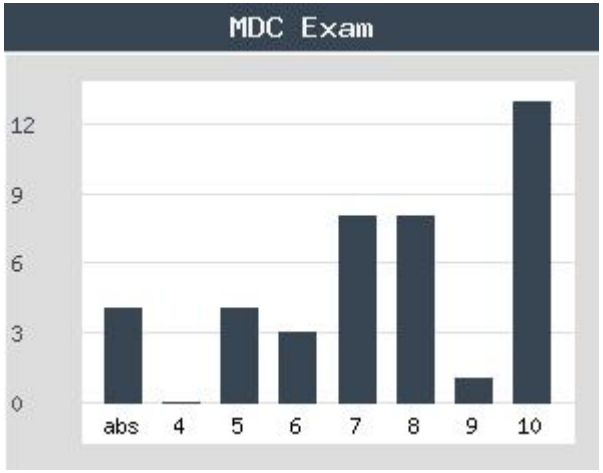


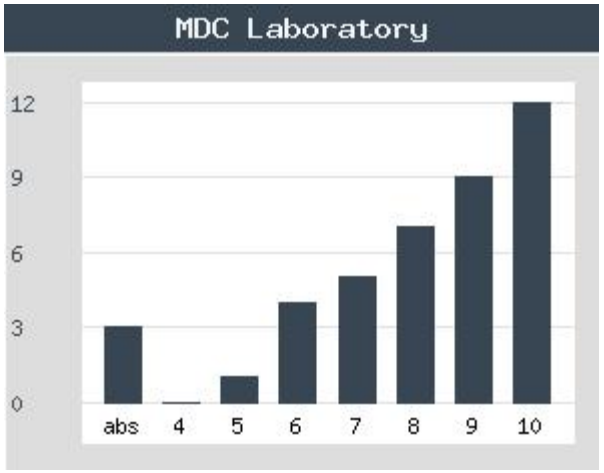


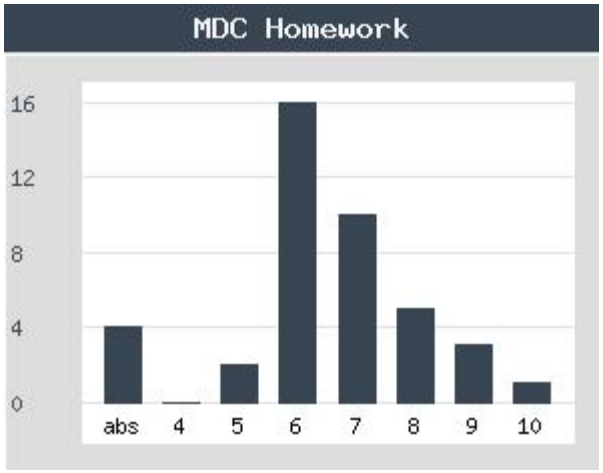
Grades

- 2020/2021 - eng

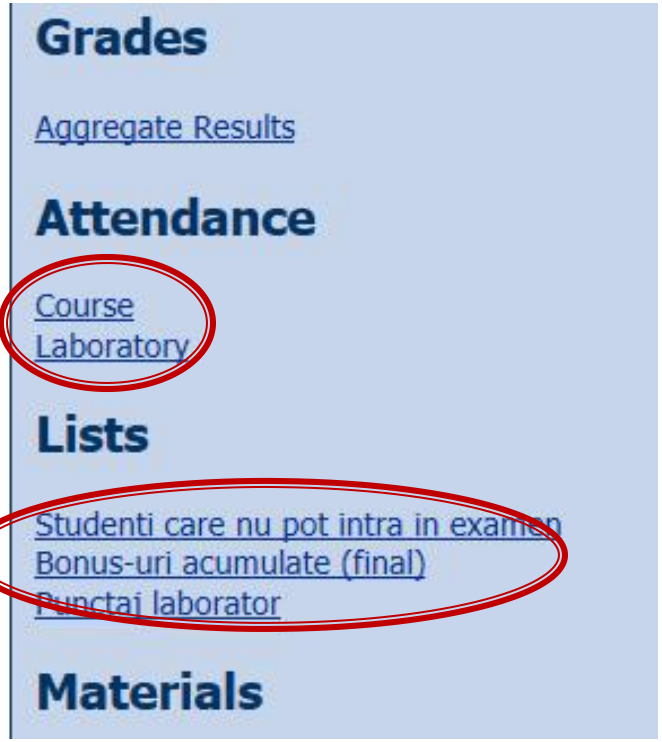








Attendance, Lists

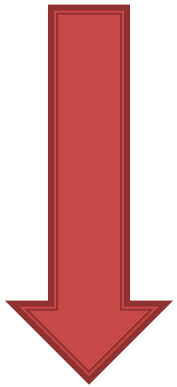


- Attendance
- minimum 7 sessions
- Activity bonus
- Homework individual data
- etc.

Bonus

Group	Course attendance	B. attendance	B. supplemental	B. photo	B. T1	B. T2	B. T3	Total Bonus	Obs.
5411	4.6	0.5		1		0	0.1	1.6	-
5411	17	2.5		1	0.75	0	0.5	4.75	-
5411	12.6	2		1		0	0.1	3.1	-
5411	9.6	1.5		1	0.25		0	2.75	-
5411	5.2	0.5		1		0	0	1.5	-
5411	12	2		0.5		0		2.5	-
5411	16.15	2.5		0.5	0.5	0.3		3.8	-
5411	18	2.5	1.5	1	0		0.1	5.1	-
5411	15.725	2.5		1	0.75	0	0	4.25	-
5411	18	2.5	1.75	1	0.63	0	1	6.88	-
5411	1.2	0		1				1	-
5411	13	2	0.5	1	0.13	0	0	3.63	-
5411	15.375	2.5		1	1	0		4.5	-
5411	5.075	0.5	0.05	0				0.55	-
5411	1.8	0		0.5			0.1	0.6	-
5411	17.5	2.5	0.4	1	1		0.2	5.1	-

Previous years



Optoelectronics

Course: OPTO (2019-2020)

Course Coordinator: Assoc.P. Dr. Radu-Florin Damian
Code: DID405M
Discipline Type: DID; Required, Domain
Credits: 4
Enrollment Year: 4, **Sem.** 8

Activities

Course: Instructor: Assoc.P. Dr. Radu-Florin Damian, 2 Hours/Week, Specialization Section, Timetable:
Laboratory: Instructor: Assist.P. Dr. Petre-Daniel Matasaru, 1 Hours/Week, Group, Timetable:

Evaluation

Type: **Colloquium**

A: 50%, (Test/Colloquium)
B: 30%, (Seminary/Laboratory/Project Activity)
C: 20%, (Tests during semester)

Previous years

2018-2019 | 2017-2018 | 2016-2017 | 2015-2016 | 2014-2015 | More years...

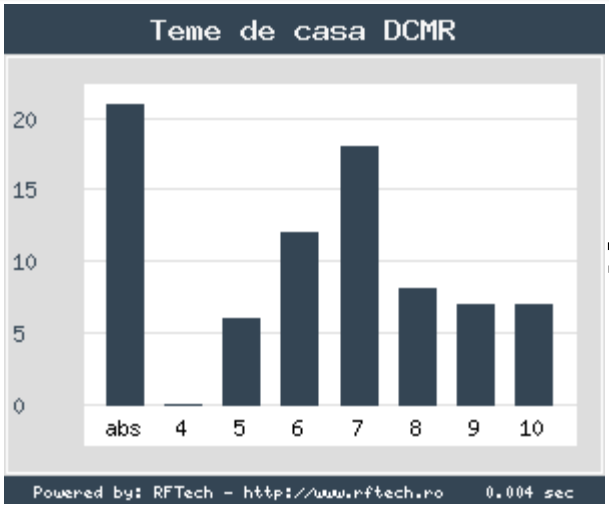
Server-ul "rf-opto" pastreaza istoricul materialelor pentru anii anteriori
Alegeti anul recent corespunzator pentru vizualizare sau "More years" pentru a afisa mai multi ani din istoric

Previous years

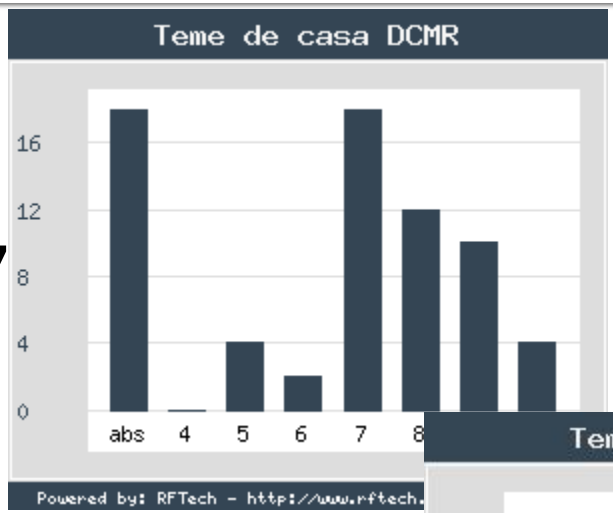
Previous years, 2004-2023

Effect? – "andrei" factor

15/6

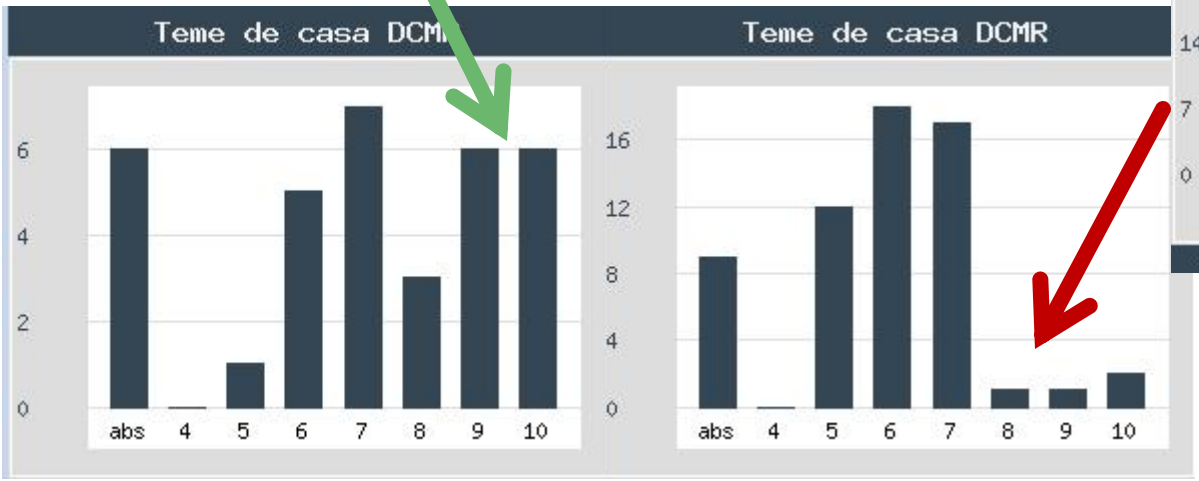


16/7



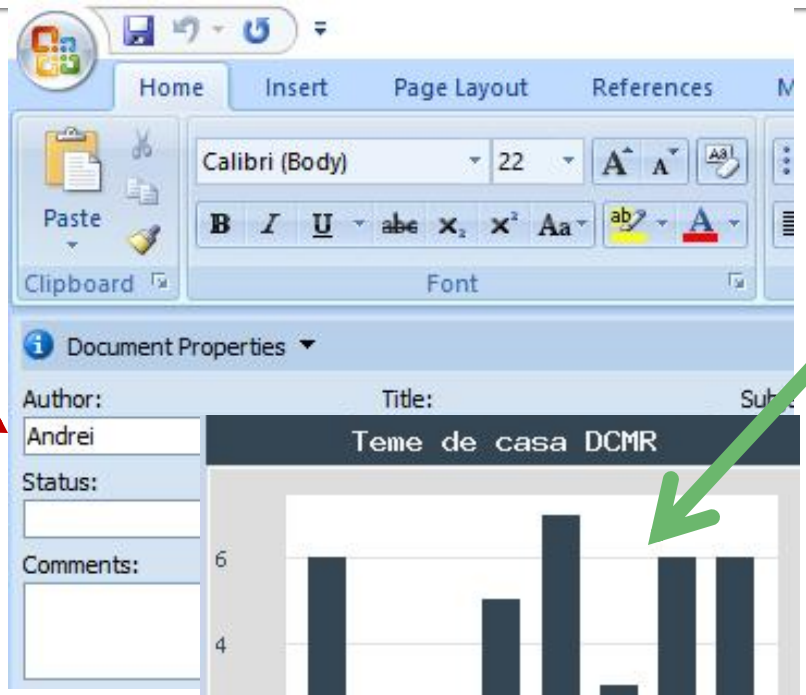
17/8

18/9

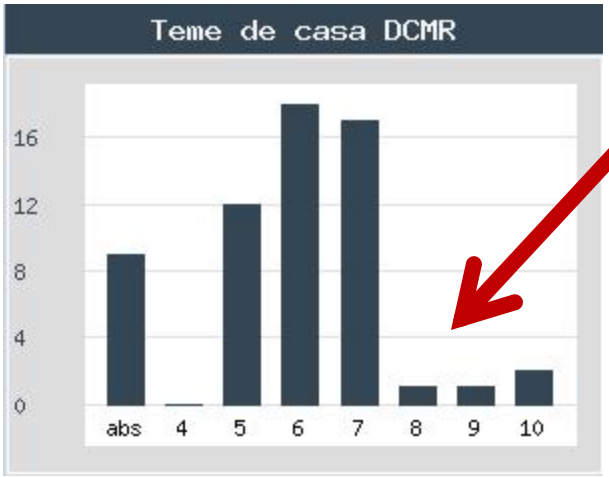


Project 2019/2020

- factorul “andrei” = **-2p**

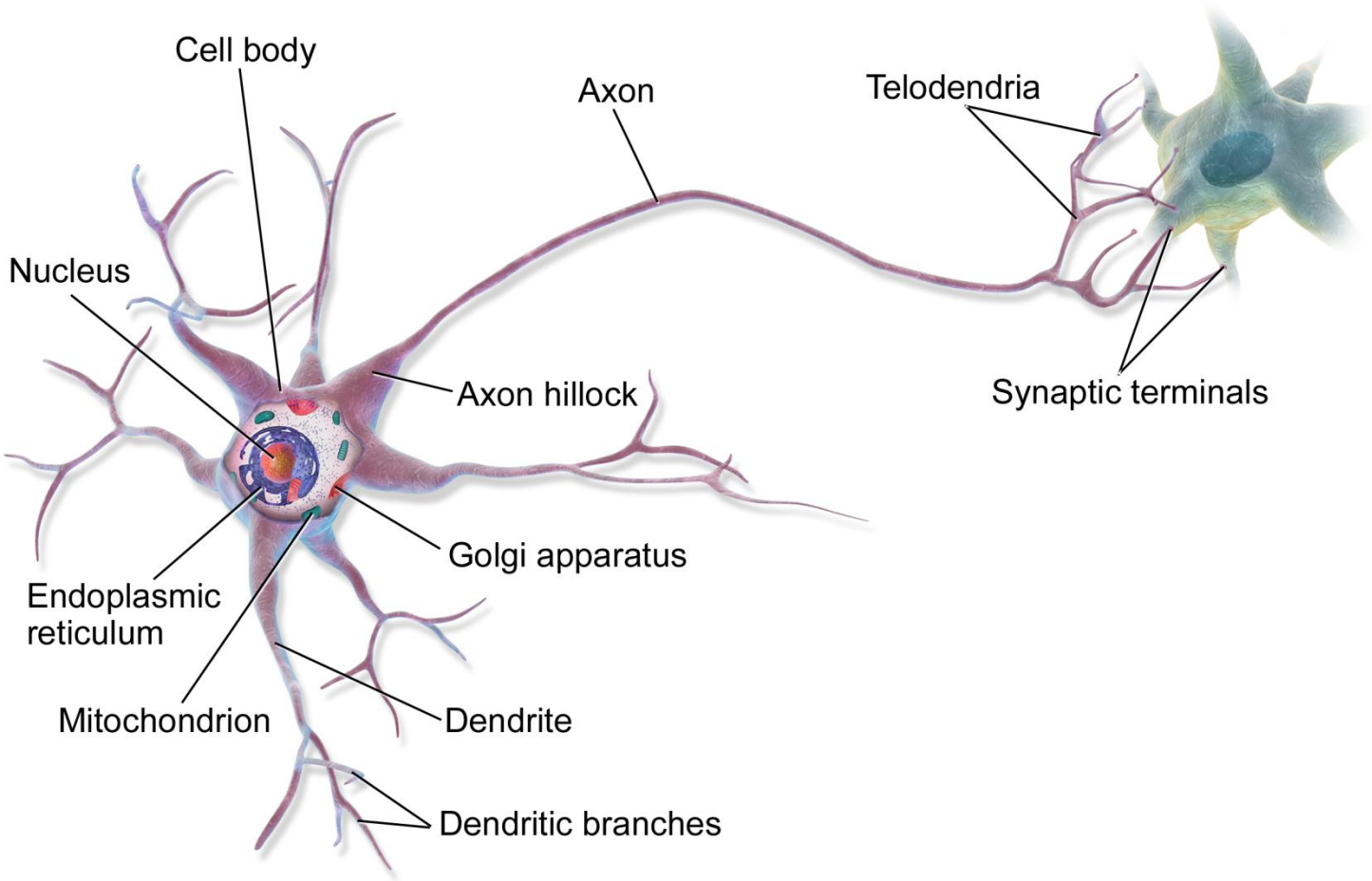


2018/9

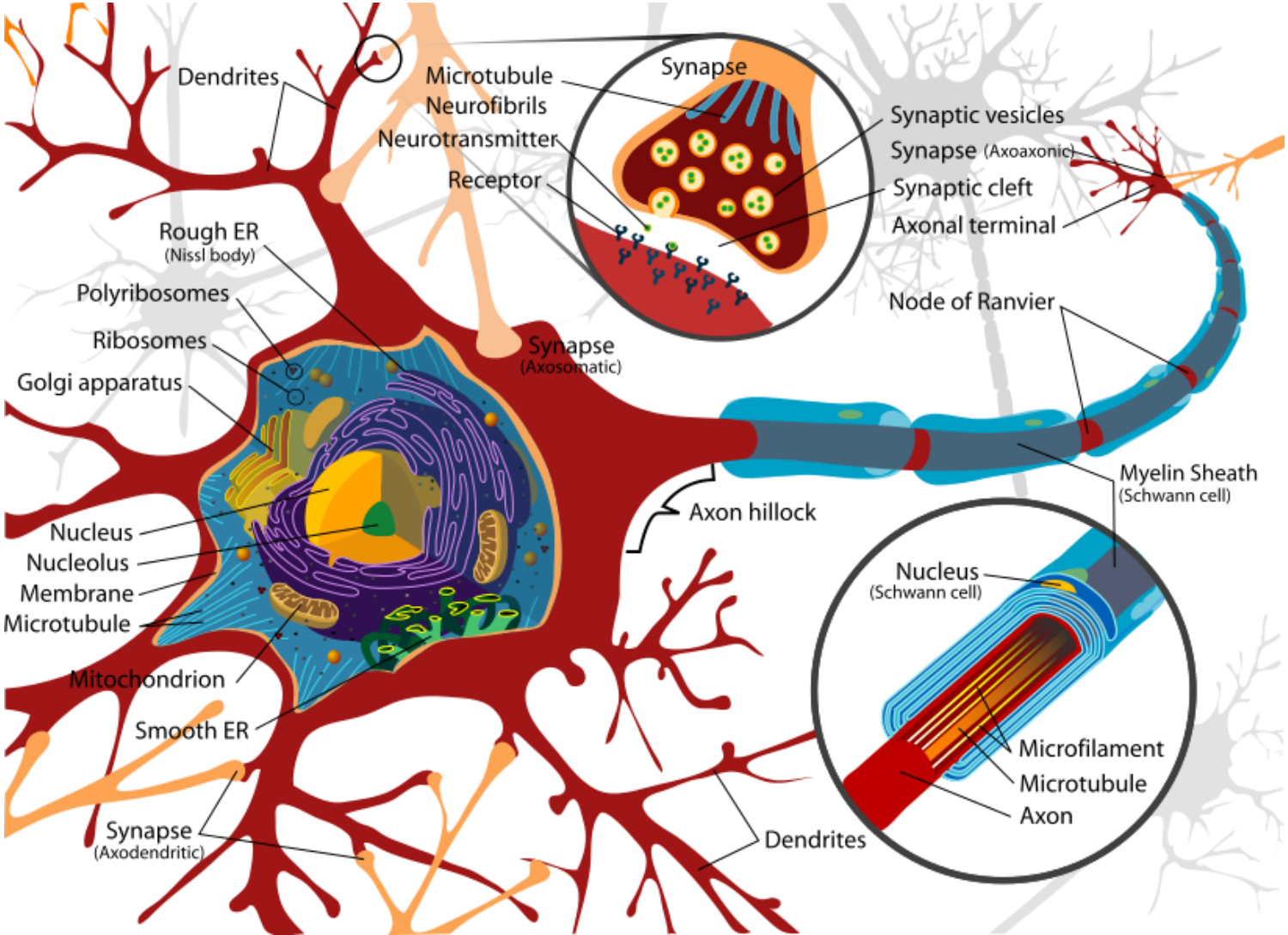


2018/9 (e)

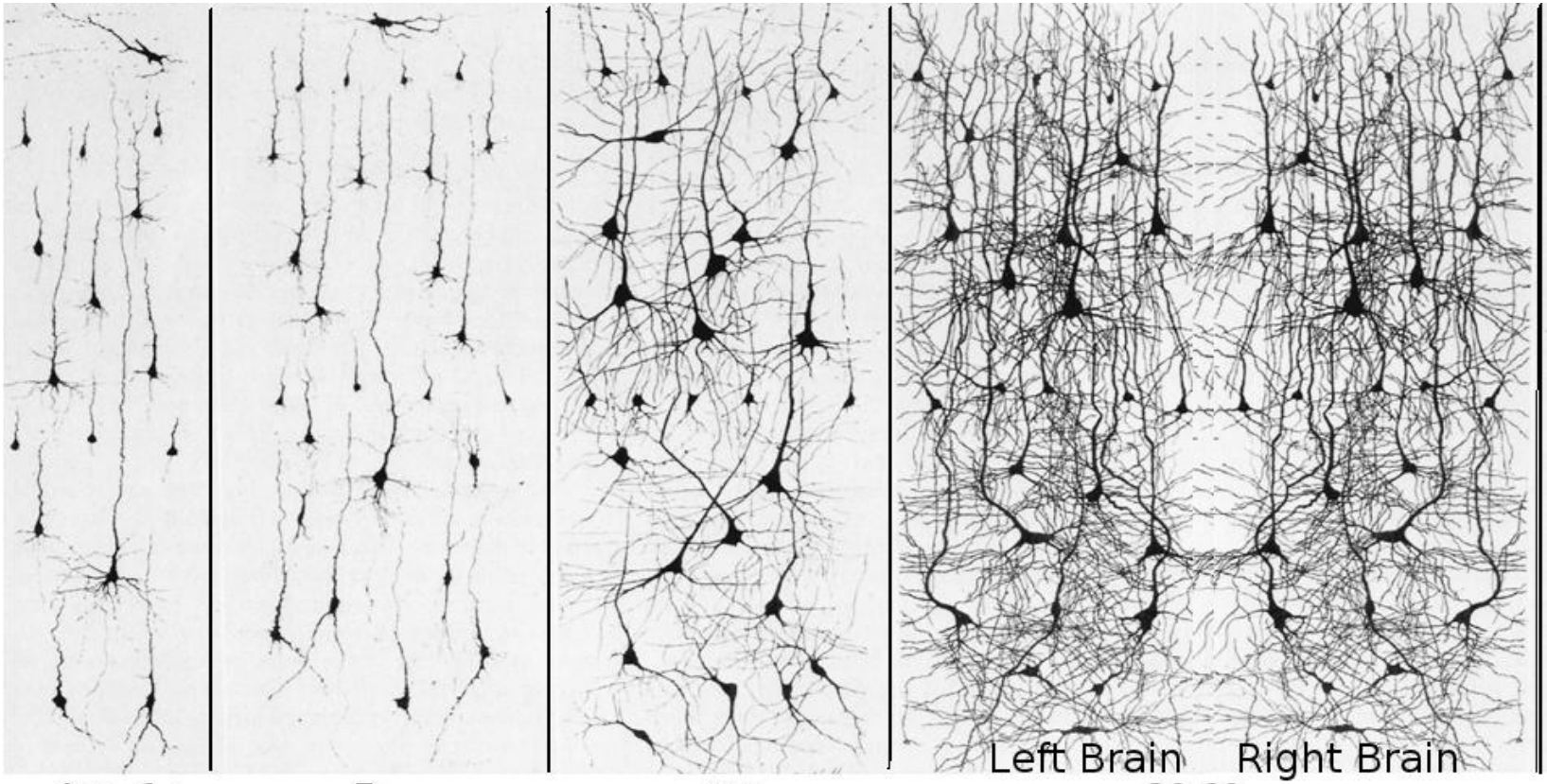
Course Objectives 1



Course Objectives 2



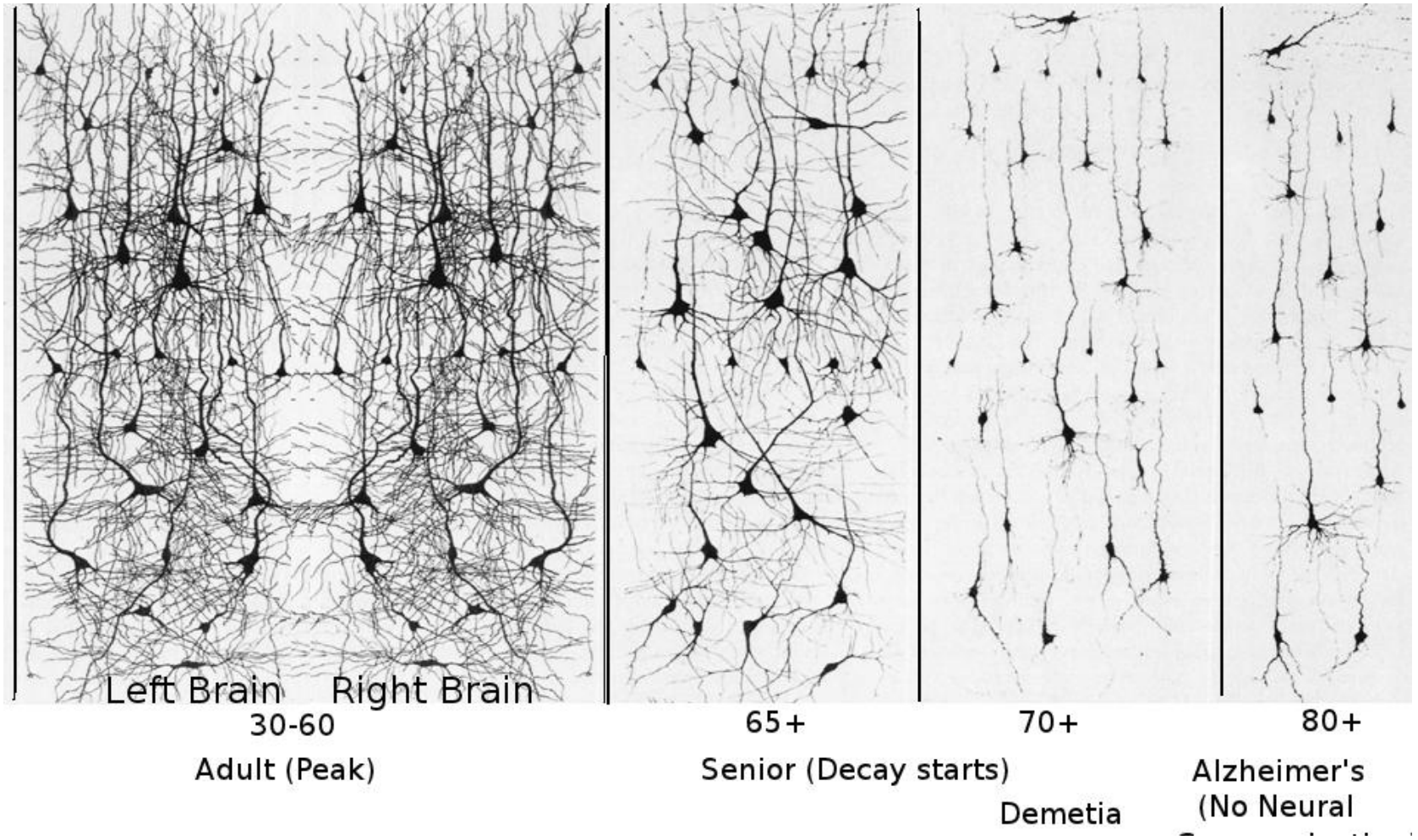
Course Objectives 3



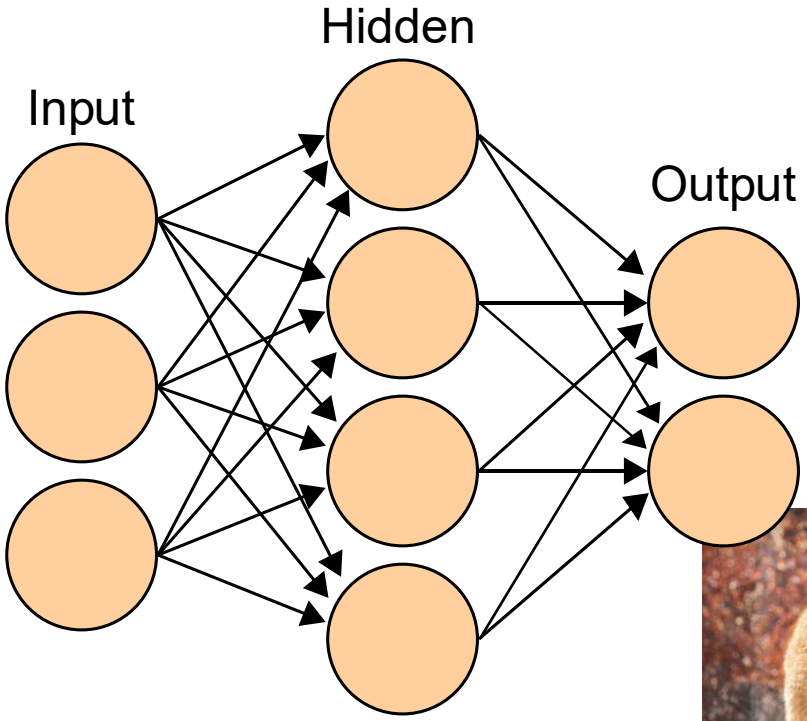
Course Objectives 4

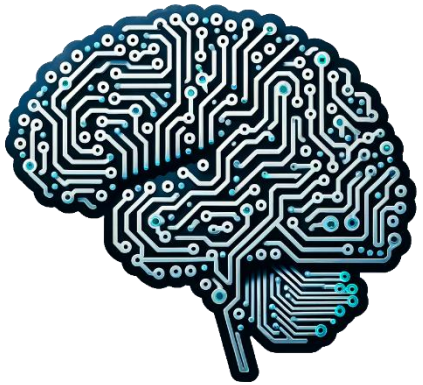
"Engineering" Sinapses

Deadline


Left Brain
Right Brain
30-60
Adult (Peak)
65+
Senior (Decay starts)
70+
Demetia
80+
Alzheimer's
(No Neural

IA/AI





IA/AI+ IN/NI

SUPERVISED LEARNING

UNSUPERVISED LEARNING

REINFORCEMENT LEARNING

Course Topics

- Transmission lines
- Impedance matching and tuning
- Directional couplers
- Power dividers
- Microwave amplifier design
- Microwave filters
- ~~Oscillators and mixers~~ ?

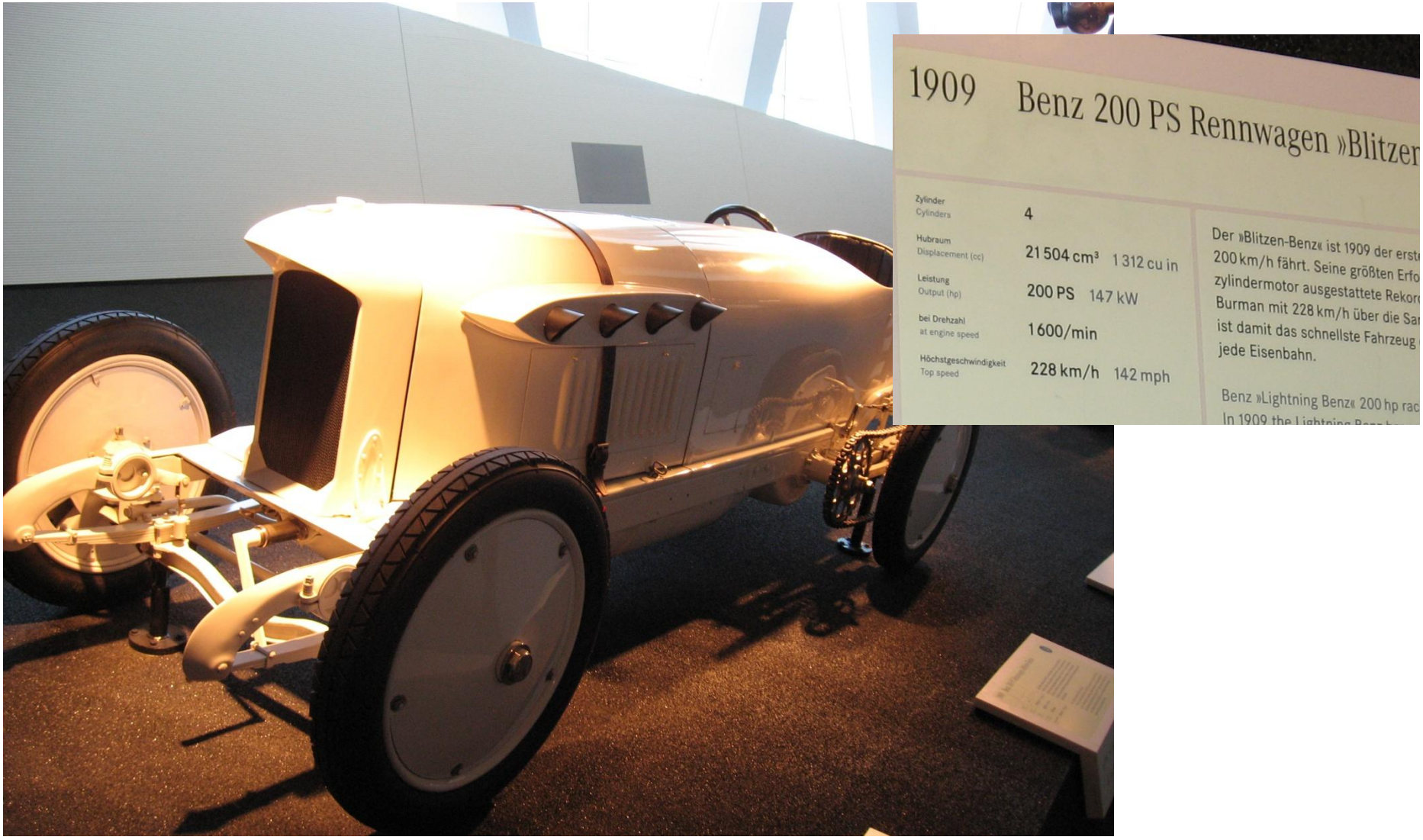
Textbooks

- https://rf-opto.etti.tuiasi.ro
- Irinel Casian-Botez: "Microunde vol. 1: Proiectarea de circuit", Ed. TEHNOPRES, 2008
- David Pozar, Microwave Engineering, Wiley; 4th edition , 2011, ISBN : 978-1-118-29813-8 (E), ISBN : 978-0-470-63155-3 (P)

~1930

~1930

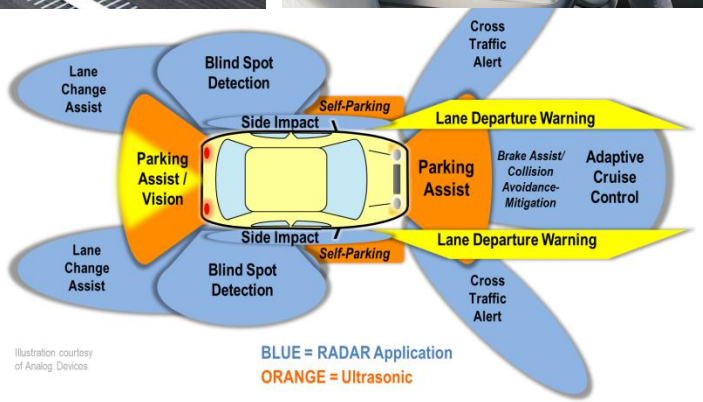
1909


1909 Benz 200 PS Rennwagen »Blitzen
Zylinder
Cylinders
4
Hubraum
Displacement (cc)
21 504 cm³ 1 312 cu in
Leistung
Output (hp)
200 PS 147 kW
bei Drehzahl
at engine speed
1 600/min
Höchstgeschwindigkeit
Top speed
228 km/h 142 mph
Der »Blitzen-Benz« ist 1909 der erste
200 km/h fährt. Seine größten Erfo
zylindermotor ausgestattete Rekor
Burman mit 228 km/h über die Sa
ist damit das schnellste Fahrzeug
jede Eisenbahn.
Benz »Lightning Benz« 200 hp rac

1930-1950

Technology

> 2010



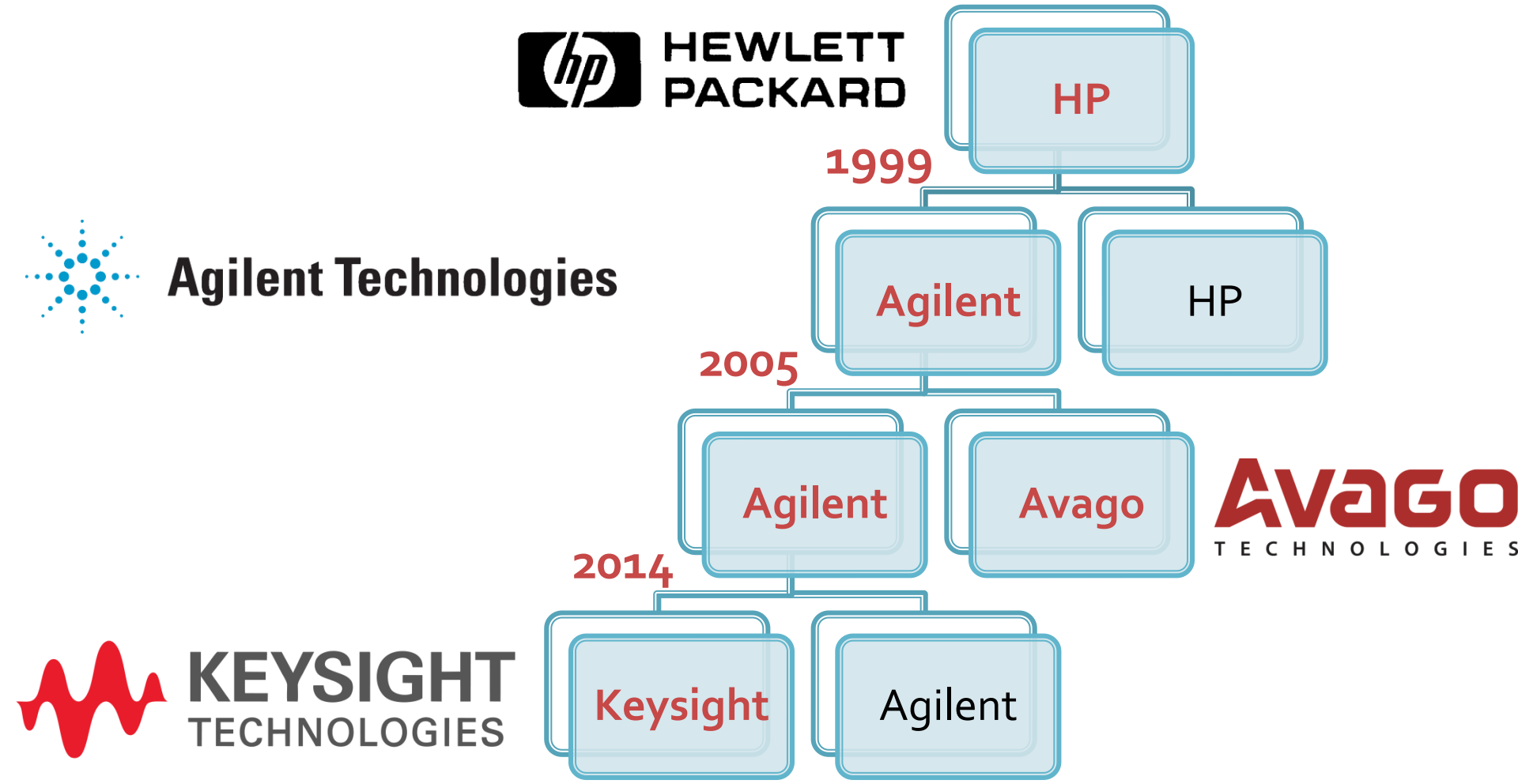
< 1950

Technology

1x1 = 1 1x2 = 2 1x3 = 3 1x4 = 4 1x5 = 5 1x6 = 6 1x7 = 7 1x8 = 8 1x9 = 9 1x10 = 10	2x1 = 2 2x2 = 4 2x3 = 6 2x4 = 8 2x5 = 10 2x6 = 12 2x7 = 14 2x8 = 16 2x9 = 18 2x10 = 20	3x1 = 3 3x2 = 6 3x3 = 9 3x4 = 12 3x5 = 15 3x6 = 18 3x7 = 21 3x8 = 24 3x9 = 27 3x10 = 30	4x1 = 4 4x2 = 8 4x3 = 12 4x4 = 16 4x5 = 20 4x6 = 24 4x7 = 28 4x8 = 32 4x9 = 36 4x10 = 40	5x1 = 5 5x2 = 10 5x3 = 15 5x4 = 20 5x5 = 25 5x6 = 30 5x7 = 35 5x8 = 40 5x9 = 45 5x10 = 50
6x1 = 6 6x2 = 12 6x3 = 18 6x4 = 24 6x5 = 30 6x6 = 36 6x7 = 42 6x8 = 48 6x9 = 54 6x10 = 60	7x1 = 7 7x2 = 14 7x3 = 21 7x4 = 28 7x5 = 35 7x6 = 42 7x7 = 49 7x8 = 56 7x9 = 63 7x10 = 70	8x1 = 8 8x2 = 16 8x3 = 24 8x4 = 32 8x5 = 45 8x6 = 48 8x7 = 56 8x8 = 64 8x9 = 72 8x10 = 80	9x1 = 9 9x2 = 18 9x3 = 27 9x4 = 36 9x5 = 45 9x6 = 54 9x7 = 63 9x8 = 72 9x9 = 81 9x10 = 90	10x1 = 10 10x2 = 20 10x3 = 30 10x4 = 40 10x5 = 50 10x6 = 60 10x7 = 70 10x8 = 80 10x9 = 90 10x10 = 100

Most used!!

2x1 = 2
2x2 = 4
2x3 = 6
2x4 = 8
2x5 = 10
2x6 = 12
2x7 = 14
2x8 = 16
2x9 = 18
2x10 = 20

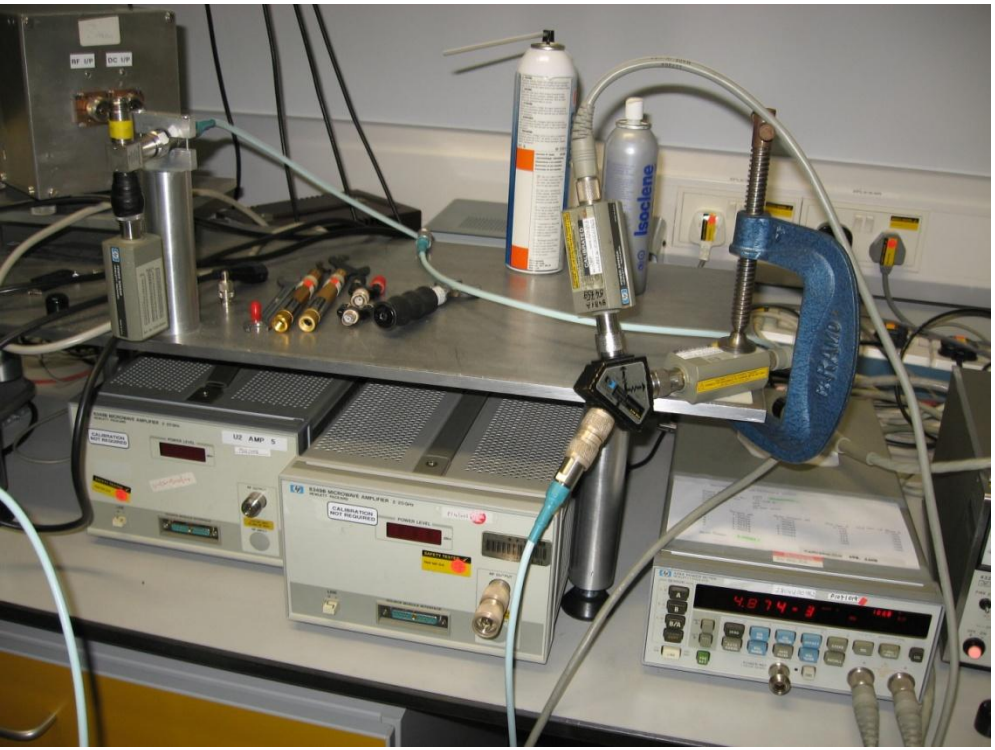

HEWLETT PACKARD
HP
1999
Agilent Technologies
Agilent
HP
2005
Agilent
Avago
AVAGO TECHNOLOGIES
2014
KEYSIGHT TECHNOLOGIES
Keysight
Agilent

NPL, London


HEWLETT PACKARD 8510


NATIONAL PHYSICAL LABORATORY
HEWLETT PACKARD
NETWORK ANALYZER
8510
SAFETY TESTED

NPL, London


Isoclene


8349B MICROWAVE AMPLIFIER 2-20 GHz
HEWLETT-PACKARD
CALIBRATION NOT REQUIRED
POWER LE


438A POWER METER
HEWLETT-PACKARD
SENSOR
A
B


8349B MICROWAVE AMPLIFIER 2-20 GHz
CALIBRATION NOT REQUIRED
POWER LEVEL

Examen: Logarithmic scales

dB $= 10 \cdot \log_{10}(P_2 / P_1)$

0 dB	= 1
+ 0.1 dB	= 1.023 (+2.3%)
+ 3 dB	= 2
+ 5 dB	= 3
+ 10 dB	= 10
-3 dB	= 0.5
-10 dB	= 0.1
-20 dB	= 0.01
-30 dB	= 0.001

dBm $= 10 \cdot \log_{10}(P / 1\ \text{mW})$

0 dBm	= 1 mW
3 dBm	= 2 mW
5 dBm	= 3 mW
10 dBm	= 10 mW
20 dBm	= 100 mW
-3 dBm	= 0.5 mW
-10 dBm	= 100 µW
-30 dBm	= 1 µW
-60 dBm	= 1 nW

[dBm] + [dB] = [dBm]

[dBm/Hz] + [dB] = [dBm/Hz]

[x] + [dB] = [x]

Computing Loss/Gain in circuits

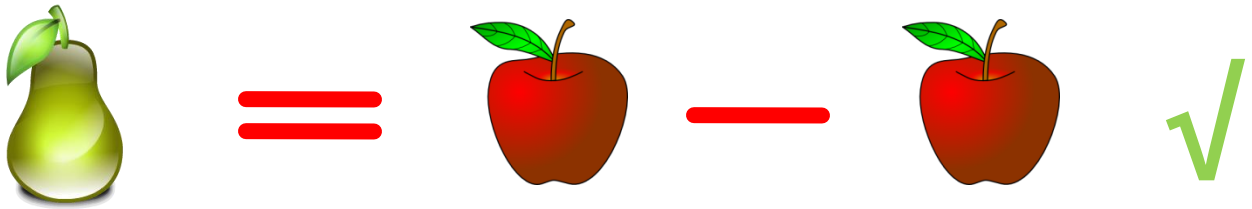
$$\text{Gain/Loss} = \frac{P_{out}}{P_{in}}$$

$$\text{Loss[dB]} = [-]\ 10 \cdot \log_{10}\left(\frac{P_{out}}{P_{in}}\right)$$

$$\text{Loss[dB]} = [-]\ 10 \cdot \log_{10}\left(\frac{P_{out}}{P_0} \cdot \frac{P_0}{P_{in}}\right)$$

$$\text{Loss[dB]} = [-]\ 10 \cdot \left[\log_{10}\left(\frac{P_{out}}{P_0}\right) - \log_{10}\left(\frac{P_{in}}{P_0}\right)\right]$$

$$\text{Loss[dB]} = [-]\ (P_{out}[\text{dBm}] - P_{in}[\text{dBm}])$$



Computing Loss/Gain in circuits

$$\text{Loss} = \frac{P_{out}}{P_{in}} < 1 \qquad \text{Loss[dB]} = 10 \cdot \log_{10}\left(\frac{P_{out}}{P_{in}}\right) < 0$$

$$\text{Loss/Attenuation[dB]} = [-]\ 10 \cdot \log_{10}\left(\frac{P_{out}}{P_{in}}\right)$$

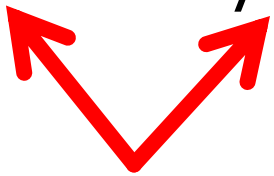
$$\text{Gain} = \frac{P_{out}}{P_{in}} > 1 \qquad \text{Gain[dB]} = 10 \cdot \log_{10}\left(\frac{P_{out}}{P_{in}}\right) > 0$$

$$\text{Attenuation[dB/km]} = \frac{\text{Loss[dB]}}{\text{Length[km]}}$$

Computing Loss/Gain in circuits

Loss/Attenuation $\rightarrow P_{out} < P_{in} \rightarrow P_{out}[\text{dBm}] < P_{in}[\text{dBm}]$

$$P_{out}[\text{dBm}] = P_{in}[\text{dBm}] - \text{Loss/Attenuation}[\text{dB}]$$



Gain/Amplification $\rightarrow P_{out} > P_{in} \rightarrow P_{out}[\text{dBm}] > P_{in}[\text{dBm}]$

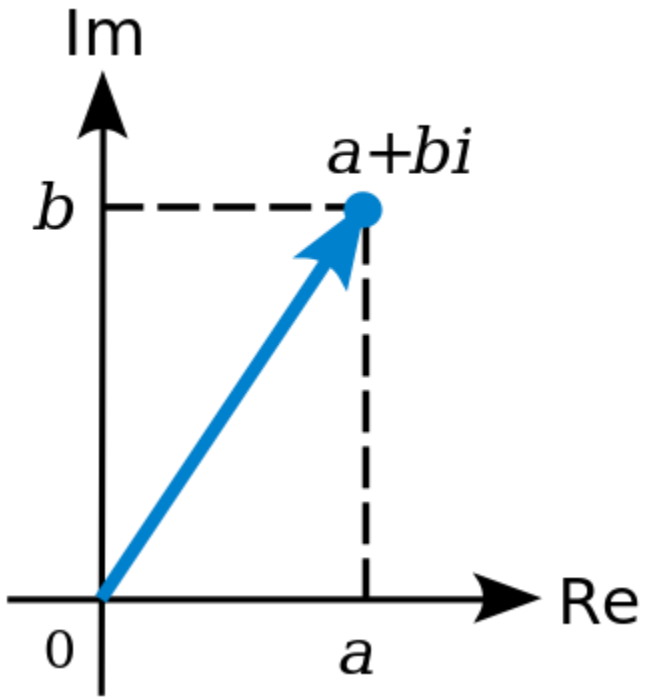
$$P_{out}[\text{dBm}] = P_{in}[\text{dBm}] + \text{Gain/Amplification}[\text{dB}]$$

Exam

- Complex numbers arithmetic!!!!
- $z = a + j \cdot b$; $j^2 = -1$

Complex plane

- abscissa – real part
- ordinate – imaginary part
- any of them can be negative, whole plane, 4 quadrants



Elementary operations

- Addition

$$z+w=(a+j\cdot b)+(c+j\cdot d)=(a+c)+j\cdot(b+d)$$

- Subtraction

$$z-w=(a+j\cdot b)-(c+j\cdot d)=(a-c)+j\cdot(b-d)$$

- Multiplication

$$z\cdot w=(a+j\cdot b)\cdot(c+j\cdot d)=(a\cdot c-b\cdot d)+j\cdot(b\cdot c+a\cdot d)$$

- Division

$$z/w=\frac{a+j\cdot b}{c+j\cdot d}=\frac{(a+j\cdot b)\cdot(c-j\cdot d)}{(c+j\cdot d)\cdot(c-j\cdot d)}=\left(\frac{a\cdot c+b\cdot d}{c^2+d^2}\right)+j\cdot\left(\frac{b\cdot c-a\cdot d}{c^2+d^2}\right)$$

Conjugate

- z $z = a + j \cdot b$
- z^* $z^* = a - j \cdot b$
- Symmetry over the real axis

$$\mathrm{Re}(z) = a = \frac{1}{2} \cdot (z + z^*)$$

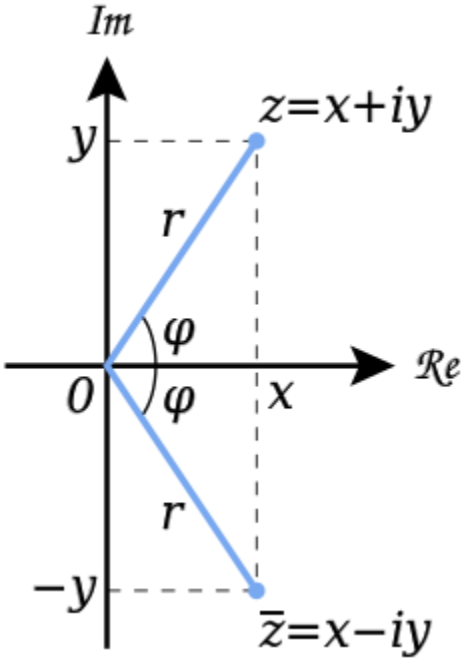
$$\mathrm{Im}(z) = b = \frac{1}{2 \cdot j} \cdot (z - z^*) = \frac{j}{2} \cdot (z^* - z)$$

$$(z + w)^* = z^* + w^*$$

$$(z - w)^* = z^* - w^*$$

$$(z \cdot w)^* = z^* \cdot w^*$$

$$(z / w)^* = z^* / w^*$$



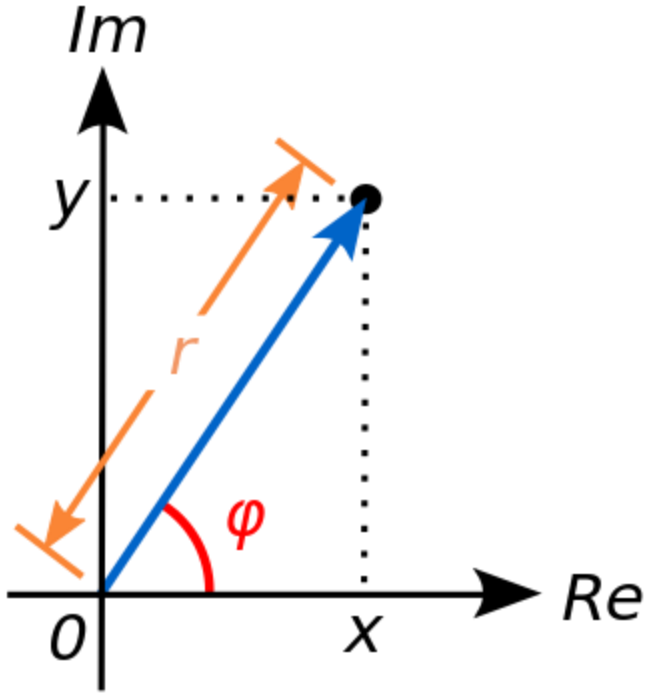
Polar representation

- Polar representation
  - modulus
  - phase relative to the real axis

$$z = a + j \cdot b = |z| \cdot (\cos\varphi + j \cdot \sin\varphi)$$

$$|z| = \sqrt{a^2 + b^2}$$

$$\varphi = \arg(z) = \begin{cases} \arctan\left(\frac{b}{a}\right), & a > 0 \\ \arctan\left(\frac{b}{a}\right) + \pi, & a < 0, b \geq 0 \\ \arctan\left(\frac{b}{a}\right) - \pi, & a < 0, b < 0 \\ \frac{\pi}{2}, -\frac{\pi}{2}, nedefinit & a = 0 \end{cases}$$

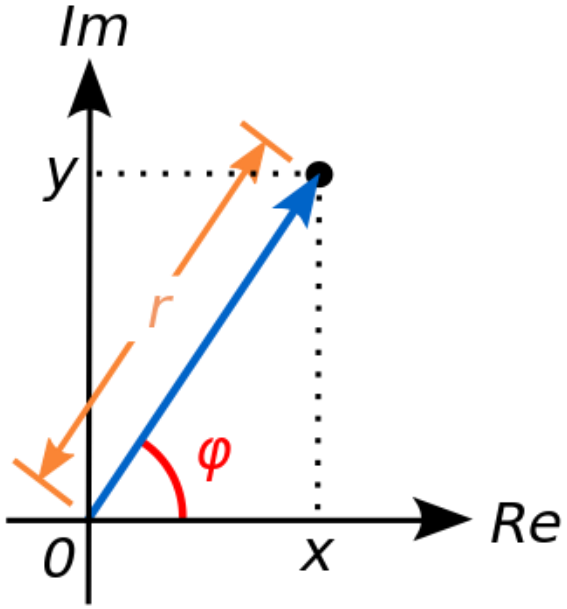


Polar representation

- Euler's formula

$$e^{j\cdot x} = \cos x + j\cdot \sin x; \forall x \in R$$

- Polar representation



$$z = a + j\cdot b = |z|\cdot e^{j\cdot\varphi}$$

$$z = a + j\cdot b = |z|\cdot(\cos\varphi + j\cdot\sin\varphi)$$

$$z^n = \left(|z|\cdot e^{j\cdot\varphi}\right)^n = |z|^n \cdot e^{j\cdot n\cdot\varphi} = |z|^n \cdot [\cos(n\cdot\varphi) + j\cdot\sin(n\cdot\varphi)]$$

$$\sqrt{z} = \left(|z|\cdot e^{j\cdot\varphi}\right)^{1/2} = \sqrt{|z|}\cdot e^{j\cdot\frac{\varphi}{2}} = \sqrt{|z|}\cdot\left(\cos\frac{\varphi}{2} + j\cdot\sin\frac{\varphi}{2}\right)$$

$$z\cdot w = |z|\cdot e^{j\cdot\varphi}\cdot|w|\cdot e^{j\cdot\theta} = |z|\cdot|w|\cdot e^{j\cdot(\varphi+\theta)} = |z|\cdot|w|\cdot[\cos(\varphi+\theta) + j\cdot\sin(\varphi+\theta)]$$

$$z/w = \frac{|z|\cdot e^{j\cdot\varphi}}{|w|\cdot e^{j\cdot\theta}} = \frac{|z|}{|w|}\cdot e^{j\cdot\varphi}\cdot e^{-j\cdot\theta} = \frac{|z|}{|w|}\cdot[\cos(\varphi-\theta) + j\cdot\sin(\varphi-\theta)]$$

Polar representation

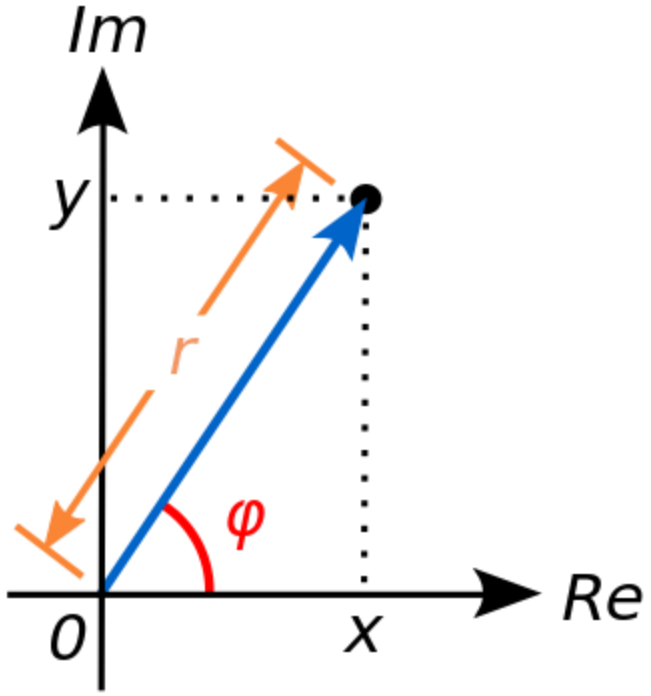
- Polar representation

$$|z| = \sqrt{a^2 + b^2}$$

$$|z|^2 = z \cdot z^*$$

$$\left|e^{j \cdot x}\right| = \left|\cos x + j \cdot \sin x\right| = \sqrt{\cos^2 x + \sin^2 x} = 1$$

$$\left|e^{j \cdot x}\right| = 1; \quad \forall x \in R$$



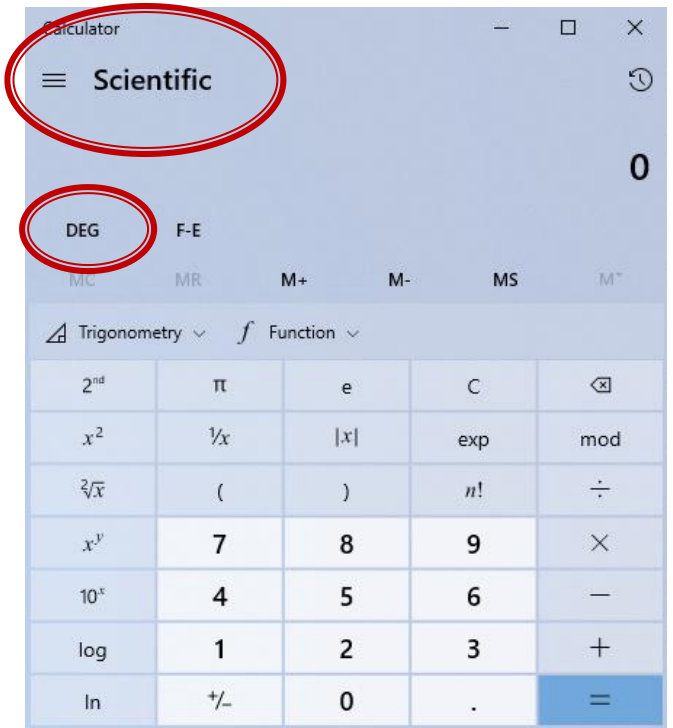
$$z^* = \left(|z| \cdot e^{j \cdot \varphi}\right)^* = |z| \cdot \left(\cos\varphi + j \cdot \sin\varphi\right)^* = |z| \cdot \left(\cos\varphi - j \cdot \sin\varphi\right) =$$

$$= |z| \cdot \left[\cos(-\varphi) + j \cdot \sin(-\varphi)\right] = |z| \cdot e^{-j \cdot \varphi}$$

Polar representation

- standard unit for angles – radians
- microwaves traditional unit for angles – **degrees in decimal form** (55.89°)

$$\varphi = \arg(z) = \begin{cases} \arctan\left(\frac{b}{a}\right), & a > 0 \\ \arctan\left(\frac{b}{a}\right) + \pi, & a < 0, b \geq 0 \\ \arctan\left(\frac{b}{a}\right) - \pi, & a < 0, b < 0 \\ \frac{\pi}{2}, -\frac{\pi}{2}, nedefinit & a = 0 \end{cases}$$



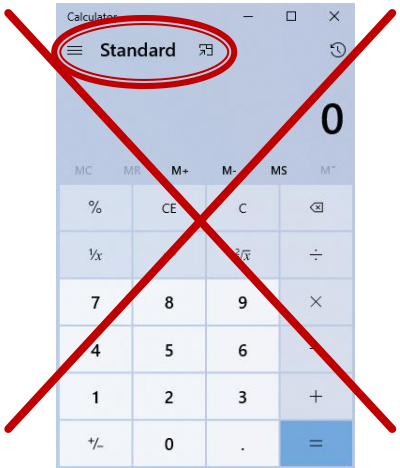
$$\varphi[^\circ] = 180^\circ \cdot \frac{\varphi[rad]}{\pi} \qquad \varphi[rad] = \pi \cdot \frac{\varphi[^\circ]}{180^\circ}$$

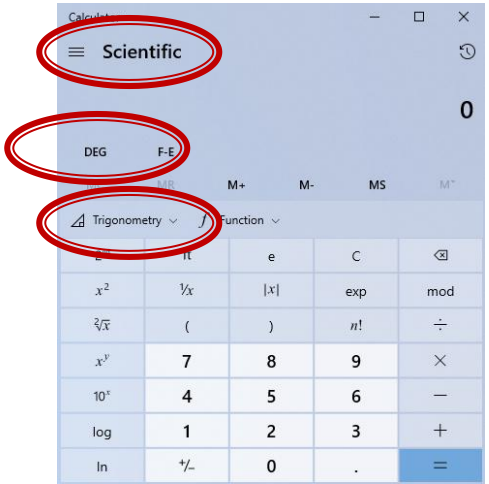
Polar representation

- **Attention to angle numerical values!!**
  - math software – work in standard unit: radians
    - a **conversion** is necessary before and after using a trigonometric function (sin, cos, tan, atan, tanh)
  - scientific calculators have the built-in option of choosing the angle unit
    - always **double check** current working unit

$$\varphi[^\circ] = 180^\circ \cdot \frac{\varphi[rad]}{\pi}$$

$$\varphi[rad] = \pi \cdot \frac{\varphi[^\circ]}{180^\circ}$$





Contact

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- rdamian@etti.tuiasi.ro