Scheduling Exercises Solutions

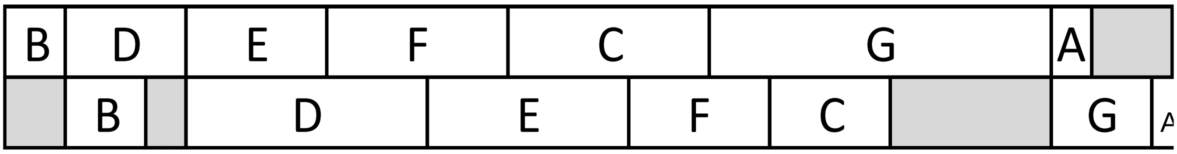
SCH_1:

a) Johnson rule yields the best scheduling for these jobs

B	D	E	F	C	G	A

The first step is to identify the lowest processing time on both centres. If the lowest time is on centre 1 (machine 1), the job is brought forward to the beginning of the schedule. If the lowest time is on centre 2 (machine 2), the job is pushed back to the end of the schedule. Each time a job is scheduled it ought to be removed from the scheduling list. The procedure is to continue until no further jobs need scheduling.

b)



	A	B	C	D	E	F	G
W1	52	0	25	3	9	16	35
P1	2	3	10	6	7	9	17
W2	3	0	3	0	5	6	0
P2	1	4	6	12	10	7	5
Time in the system	58	7	44	21	31	38	57

A

W_1- waiting time on machine 1

P_1- processing time on machine 1

W_2- waiting time on machine 2

P_2- processing time on machine 2

c) Average number of jobs in the system = (7+21+31+38+44+57+58)/58

= 4.414 jobs

Interval	**0-7**	**7-21**	**21-31**	**31-38**	**38-44**	**44-57**	**57-58**
Duration	7	14	10	7	6	13	1
Jobs	7	6	5	4	3	2	1
Average	(7*7)/58 = 0.845	1.448	0.862	0.483	0.310	0.448	0.017

d)

Utilization rate of M1 $=\frac{54}{58}=0.9310$

Utilization rate of M2 $=\frac{58-(3+2+8)}{58}=\frac{45}{58}=0.7758$

Average utilization rate of equipment =
= 0.8534

e)

Total idle cost in M1 = 4×5 = 20
Total idle cost in M2 = 13×6 = 78
Sum of processing times in M1 = 54 hours
Sum of processing times in M2 = 45 hours

	A	**B**	**C**	**D**	**E**	**F**	**G**	**Total**
Idle cost M1	0.74	1.11	3.70	2.22	2.59	3.33	6.30	20
Idle cost M1	1.73	6.93	10.40	20.80	17.33	12.13	8.67	78
Proc. cost M1	20	30	100	60	70	90	170	540
Proc. cost M2	11	44	66	132	110	77	55	495
Total Cost	**33.47**	**82.04**	**180.10**	**215.02**	**199.93**	**182.47**	**239.96**	**1133**

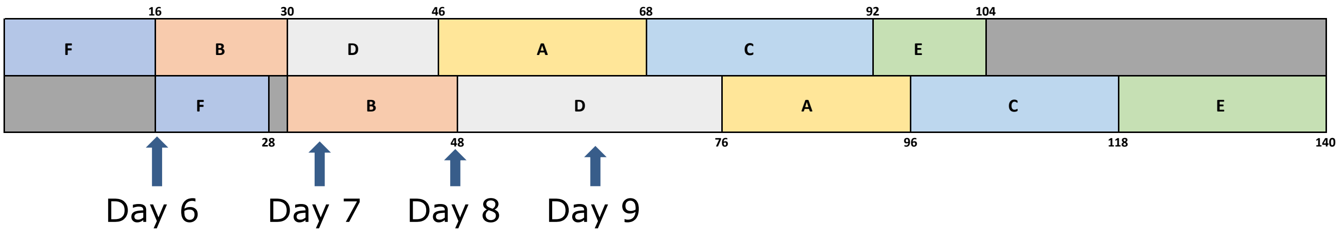
SCH_2:

Data:
Mold: Processing cost = €30,00/hour
Chroming: Processing cost = €20,00/hour
Mold: Idle cost = €15,00/hour
Chroming: Idle cost = €10,00/hour

a) The sequence that minimize the total processing time is given by the Johnson's Rule:

E	**B**	**D**	**C**	**A**	**F**

b)



Part D is not finished by the end of the 8th day, so **the production plan will not be accomplished.**

c)
Mold: Total processing time = 104 hours
Chroming: Total processing time = 122 hours
Mold: Total idle cost = 36h x €15,00 = €540,00
Chroming: Total idle cost = 18h x €10,00 = €180,00

Part F total cost: 16h × €30,00 + 12h × €20,00 + €540,00 × (16/104) + €180,00 × (12/122) = **€820,78**

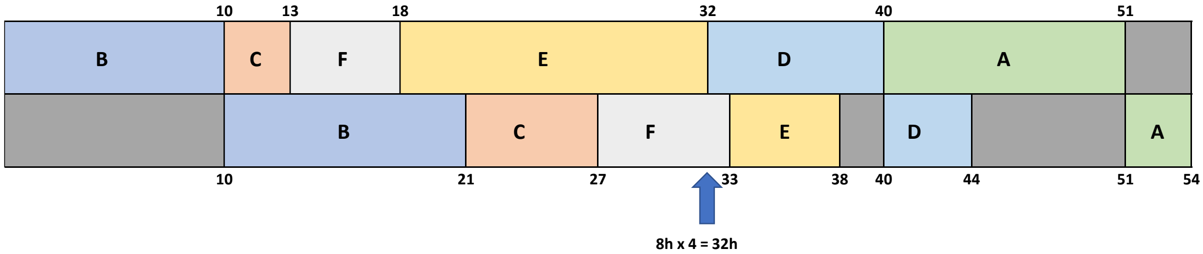
d) Part A waits = **8 hours** (76h – 68h)

SCH_3:

a) No, because the sequence that minimize the total processing time is given by the Johnson's Rule:

C	**F**	**B**	**E**	**D**	**A**

b)



At the end of the 29th day, **pieces B and C are finished**.

c)

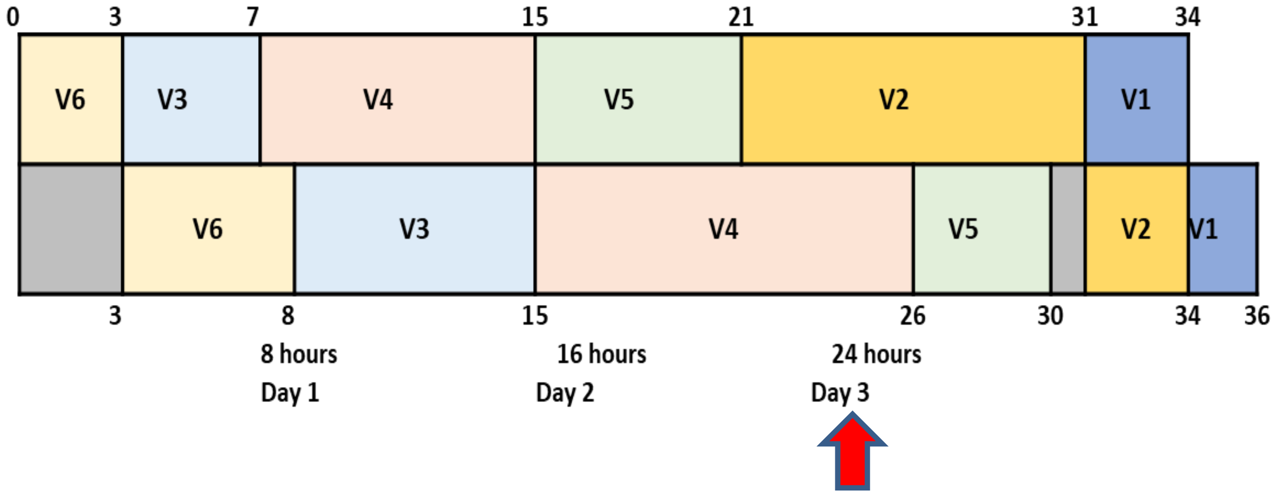
Abrasing (M1): Total idle time = 3 hours (54 – 51)
Lacquering (M2): Total idle time = 19 hours (10 + 2 + 7)
Lacquering (M2): **Idle rate** = (19/54) x 100% = **35,19%**

SCH_4:

a) The sequence that minimize the total processing time is given by the Johnson's Rule:

V6	**V3**	**V4**	**V5**	**V2**	**V1**

b)



On day 6, two vats, **Vat 6** and **Vat 3**, are ready.

c)

	V1	V2	V3	V4	**V5**	V6		
Metal Cutter	31	21	3	7	15	0	77	
Welding	0	0	1	0	5	0	6	

Idle total cost of MC = 2h x €20 = €40

Idle total cost of W = 4h x €60 = €240

Total cost of Vat 5:

€40 x 6h + €50 x 4h + €40 x (15/77) + €240 x (5/6) =

= **€647,79**

SCH_5:

a)

The Operations Manager decided to start the processing of the orders **on day 260 according** to the following sequence: SD-SA-SB-SE-SF-SC.

Order of arrival of the order	Due date	Processing time (days)
SA	310	18
SB	350	28
SC	380	25
SD	300	15
SE	375	26
SF	378	22

a)
The sequencing rule used was EDD**.**

	Due Date	**Processing time**	**Flow time**	**End date**	**Lateness**
SD	300	15	15	274*	0
SA	310	18	33	292	0
SB	350	28	61	320	0
SE	375	26	87	346	0
SF	378	22	109	368	0
SC	380	25	134	393	13
		134	439		13

*(260+15-1 =274)

Average jobs lateness = (13/6) = 2.17 days
Average number of jobs in system = (439/134) = 3.28 jobs
Utilization rate = (134/439) × 100 = 30.52%
Average completion time = (439/6) = 73.16 days

b) SD-SA-SF-SC-SE-SB

	Due Date	Processing time	Flow time		Late
SD	300	15	15	274*	0
SA	310	18	33	292	0
SF	378	22	55	314	0
SC	380	25	80	339	0
SE	375	26	106	365	0
SB	350	28	134	393	43
		134	423		43

*(260+15-1 =274)

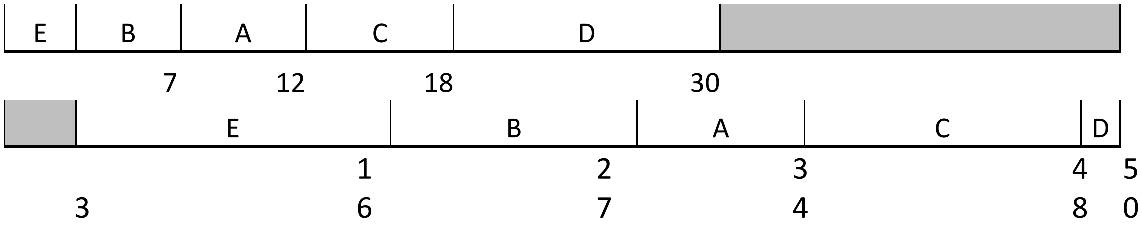
Average jobs lateness = (43/6) = 7.17 days
Average number of jobs in system = (423/134) = 3.15 jobs
Utilization rate = (134/423) × 100 = 32.39%
Average completion time = (423/6) = 70.50 days

The EDD scheduling minimizes total delay.

SCH_6:

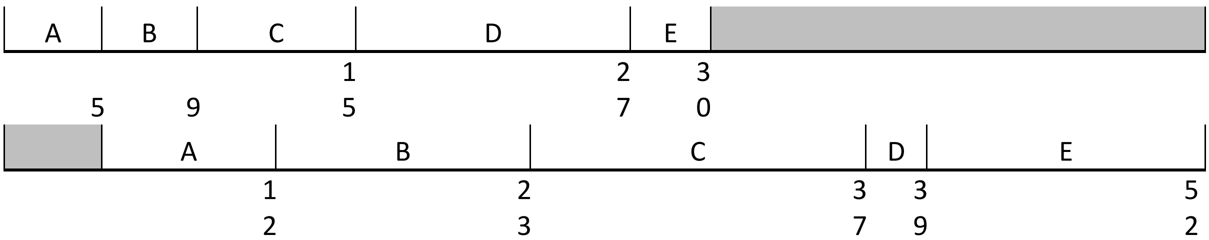
a) The Johnson rule produces the following scheduling sequence:

E	**B**	**A**	**C**	**D**



The FIFO rule produces the following scheduling sequence:

A	**B**	**C**	**D**	**E**



Using FIFO, the production assistant needed 52 hours to process the 5 jobs. Using the Johnson rule he would have required only 50 hours.

b)

	Jonhson		**FIFO**	
	M1	**M2**	**M1**	**M2**
A	7	15	0	0
B	3	9	5	3
C	12	16	9	8
D	18	18	15	10
E	0	0	27	9
	TOTAL = 98 hours		TOTAL = 86 hours	

	Johnson		**FIFO**	
A	22	336.73	0	0.00
B	12	183.67	8	139.53
C	28	428.57	17	296.51
D	36	551.02	25	436.05
E	0	0.00	36	627.91
	98	**1500.00**	86	**1500.00**

SCH_7:
a)

Project hours				
Consultants/ Project	A	B	C	D
Marie	17	13	18	13
Paul	16	14	16	15
Johnny	17	17	16	19
Sara	18	16	17	14

This is a minimisation problem, so the regular method is applied.

Step i) Find the row minimum and subtract it from the remaining row values:

	A	**B**	**C**	**D**	**row min.**
Marie	17	13	18	13	**13**
Paul	16	14	16	15	**14**
Johnny	17	17	16	19	**16**
Sara	18	16	17	14	**14**

	A	**B**	**C**	**D**
Marie	4	0	5	0
Paul	2	0	2	1
Johnny	1	1	0	3
Sara	4	2	3	0

Step ii) Find the column minimum and subtract it from the remaining column values:

	A	**B**	**C**	**D**
Marie	4	0	5	0
Paul	2	0	2	1
Johnny	1	1	0	3
Sara	4	2	3	0
col. min	**1**	**0**	**0**	**0**

	A	B	C	D
Marie	3	0	5	0
Paul	1	0	2	1
Johnny	0	1	0	3
Sara	3	2	3	0

Step iii) Draw the minimum number of lines required to cross all zeroes:

	A	B	C	D
Marie	3	0	5	0
Paul	1	0	2	1
~~Johnny~~	~~0~~	~~1~~	~~0~~	~~3~~
Sara	3	2	3	0

Step iv) subtract the smallest uncrossed value **(1)** to all other uncrossed values. Add that smallest uncrossed value to all values at the interception of lines:

	A	B	C	D
Marie	2	0	4	0
Paul	0	0	1	1
Johnny	0	2	0	4
Sara	2	2	2	0

Step v) Draw the minimum number of lines required to cross all zeroes:

	A	B	C	D
~~Marie~~	~~2~~	~~0~~	~~4~~	~~0~~
~~Paul~~	~~0~~	~~0~~	~~1~~	~~1~~
~~Johnny~~	~~0~~	~~2~~	~~0~~	~~4~~
~~Sara~~	~~2~~	~~2~~	~~2~~	~~0~~

The assignment that minimizes the total execution time for these projects is:

Marie: B
Paul: A
Johnny: C
Sara: D

b) Total number of hours required to complete all projects = 13+16+16+14= 59 hours

SCH_8:
a)

	Operations	HRM	Finance	Marketing
Chris	90	65	95	40
Steve	70	60	80	75
Juana	85	40	80	60
Rebeca	55	80	65	55

We are now facing a maximization problem so we need to identify the table maximum and subtract each cell value from it. After this step we will have a standard assignment method minimization problem.

	Operations	HRM	Finance	Marketing
Chris	5	30	0	55
Steve	25	35	15	20
Juana	10	55	15	35
Rebeca	40	15	30	40

Step i) Find the row minimum and subtract it from the remaining row values:

	Operations	HRM	Finance	Marketing	row min.
Chris	5	30	0	55	0
Steve	25	35	15	20	15
Juana	10	55	15	35	10
Rebeca	40	15	30	40	15

	Operations	HRM	Finance	Marketing
Chris	5	30	0	55
Steve	10	20	0	5
Juana	0	45	5	25
Rebeca	25	0	15	25

Step ii) Find the column minimum and subtract it from the remaining column values:

	Operations	**HRM**	**Finance**	**Marketing**
Chris	5	30	0	55
Steve	10	20	0	5
Juana	0	45	5	25
Rebeca	25	0	15	25
col. min.	0	0	0	5

	Operations	**HRM**	**Finance**	**Marketing**
Chris	5	30	0	50
Steve	10	20	0	0
Juana	0	45	5	20
Rebeca	25	0	15	20

Step iii) Draw the minimum number of lines required to cross all zeroes:

	Operations	**HRM**	**Finance**	**Marketing**
Chris	5	30	0	50
Steve	10	20	0	0
Juana	0	45	5	20
Rebeca	25	0	15	20

As the number of lines required to cross all zeros equals the number of rows (and columns) this is the optimal solution for the assignment.

Chris: Finance - 95
Steve: Marketing - 75
Juana: Operations Management - 85
Rebeca: Human Resource Management - 80

Overall teaching rating: 95 + 75 + 85 + 80 = 335

b) According to the optimal assignment Chris shouldn't teach Operations Management, so the optimal solution remains identical given this restriction.

SCH_9

a)
This is a minimisation problem, so the regular method is applied.

Step i) Find the row minimum and subtract it from the remaining row values:

	SOLD	PIC	PENT	LAS
T1	4	2	5	0
T2	3	0	2	1
T3	4	4	0	3
T4	4	1	3	0

Step ii) Find the column minimum and subtract it from the remaining column values:

	SOLD	PIC	PENT	LAS
T1	1	2	5	0
T2	0	0	2	1
T3	1	4	0	3
T4	1	1	3	0

Step iii) Draw the minimum number of lines required to cross all zeroes:

	SOLD	PIC	PENT	LAS
T1	1	2	5	0
T2	0	0	2	1
T3	1	4	0	3
T4	1	1	3	0

Step iv) subtract the smallest uncrossed value **(1)** to all other uncrossed values. Add that smallest uncrossed value to all values at the interception of lines:

	SOLD	PIC	PENT	LAS
T1	0	1	5	0
T2	0	0	3	2
T3	0	3	0	3
T4	0	0	3	0

The optimal assignment is:

T1: SOLD → 27
T2: PIC → 24
T3: PENT → 26
T4: LAS → 24

Total = 101

T1: LAS → 23
T2: SOLD → 27
T3: PENT → 26
T4: PIC → 25

Total = 101

T1: LAS → 23
T2: PIC→ 24
T3: PENT → 26
T4: SOLD→ 28

Total = 101

b) T1: PENT→ 28
T2: PIC→ 24
T3: LAS → 29
T4: SOLD→ 28

Total = 109

This assignment varies from the optimal in 8 hours.

SCH10:

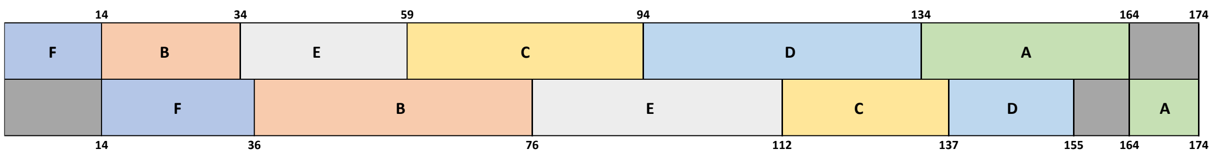
a)

The sequence that minimize the total processing time is given by the Johnson's Rule:

F	**B**	**E**	**C**	**D**	**A**

b)

	Truck						Idle cost/minute
	A	B	C	D	E	F	
Unloading (minutes)	30	20	35	40	25	14	€2,0
Storing (minutes)	10	40	25	18	36	22	€3,0



c) 14h 06m

d)

Unloading Idle Cost = 10h × €2,00 = €20,00

Storing Idle Cost = (14h + 9h) × €3,00 = €69,00

Total Idle Cost = €89,00

	Truck						
	A	B	C	D	E	F	Total
Total time in the system	174	76	137	155	112	36	690
Idle cost for each truck	**€22,44**	**€9,80**	**€17,67**	**€19,99**	**€14,45**	**€4,64**	€89,00

Multiple choice questions

1. The data below has been retrieved from the processing centres of JumboTron. Work centre 1 packages the order while work centre 2 adds a decorative ribbon to the package.

	Jobs (processing time in hours)					
	A	B	C	D	E	F
Packaging	6	8	3	5	12	2
Adding ribbon	3	2	4	1	6	6

Which of the following minimises total processing time?		
1		F-B-C-E-D-A
2		A-F-E-C-B-D
3	x	F-C-E-A-B-D
4		D-B-C-F-A-E

Assuming JumboTron follows the sequence A-F-E-C-B-D, how many jobs are completed after 21 processing hours?		
1	x	2 jobs
2		3 jobs
3		4 jobs
4		5 jobs

2. Consider the following data concerning the orders received from clients by ICEFLAVORS in the previous week:

Orders sorted by arrival date	Due date (day)	Processing Time (days)
Apple	145	30
Banana	135	25
Cherry	305	70
Apricot	230	55
Raspberry	170	40

a) Assuming the orders were processed according to their arrival order, how long does an order for Cherry ice cream spend in the system?

1		25 days
2		55 days
3		70 days
4	**X**	125 days
5		220 days

b) Assuming the orders started being processed in the beginning of day 100 and that the followed scheduling was SPT, what is the average completion time?

1		220 days
2		545 days
3	**X**	109 days
4		70 days
5		13.2 days

3. AUDIOSOND is a media content managing firm. The program's director wishes to schedule 4 shows in 4 time-slots. The goal is to maximise the overall number of viewers. The next table shows historical data for the number of shows per viewer at the different time slots:

	Viewers (in thousands)			
	PROG1	PROG2	PROG3	PROG4
14h00	150	120	130	120
17h00	140	125	140	135
19h00	150	145	140	170
21h00	160	140	150	125

a) The Program Director asked a trainee to find the optimal assignment and report back to him the next day. To do this, the trainee decided to follow the steps suggested in the assignment method. The first matrix obtained by the trainee was as follows:

1	**X**		PROG1	PROG2	PROG3	PROG4
		14h00	20	50	40	50
		17h00	30	45	30	35
		19h00	20	25	30	0
		21h00	10	30	20	45
2			PROG1	PROG2	PROG3	PROG4
		14h00	30	0	10	0
		17h00	15	0	15	10
		19h00	10	5	0	30
		21h00	35	15	25	0
3			PROG1	PROG2	PROG3	PROG4
		14h00	10	0	0	0
		17h00	0	5	10	15
		19h00	10	25	10	50
		21h00	20	20	20	5
4			PROG1	PROG2	PROG3	PROG4
		14h00	30	0	10	0
		17h00	20	5	20	15
		19h00	30	25	20	50
		21h00	40	20	30	5

b) After applying all the steps of the assignment method, the trainee obtained the following matrix:

	PROG 1	PROG 2	PROG 3	PROG 4
14h00	0	10	15	25
17h00	5	0	0	5
19h00	25	10	30	0
21h00	0	0	5	30

		The director opted for the following assignment: PROG1-19H00; PROG2-14h00; PROG3-21h00; and PROG4-17h00. What is the impact on the number of viewers, relative to the optimal assignment?
1		a gain of 65 thousand viewers
2	**X**	a loss of 45 thousand viewers
3		a gain of 50 thousand viewers
4		a loss of 60 thousand viewers

Optimal assignment: 150 + 140 + 140 + 170 = 600 thousand viewers

PROG1-19H00; PROG2-14h00; PROG3-21h00 and PROG4-17h00 =
= 150 + 120 + 150 + 135 =555 thousand viewers

Difference: 600 – 555 = **a loss of 45 thousand viewers**

4. SOLATAS received 5 orders in the previous week. The manager decided to start processing the orders in the **beginning of day 151** of the production cycle.

Orders (by arrival time)	Due date	Processing time (days)
OA	210	40
OB	301	25
OC	160	5
OD	169	15
OE	225	20

a) If the manager uses EDD scheduling, what is the delay of order OA?		
1		1 day
2	X	0 day
3		20 day
4		45 day

b) What is the average number of orders in the system if the manager schedules the processing as OC-OD-OE-OB-OA?		
1		5 orders
2		10 orders
3	X	2.2 orders
4		2.6 orders

5. RESTAURARBEM, an antique renovation company has received six orders last week. Antique renovation is a two-stage process in which the antiques are first processed on an abrasing machine and then lacquered on a second machine. The table below describes the processing hours on each machine:

	Jobs (processing hours)					
	A	B	C	D	E	F
Abrasing (M1)	2	5	8	1	5	7
Lacquering (M2)	6	2	4	4	9	3

Which of the following sequences minimises the total processing time?		
1		D-B-A-F-E-C
2		D-C-A-B-F-E
3		D-A-B-E-F-C
4	x	D-A-E-C-F-B

If the followed processing sequence was: F-E-D-C-A-B, what is the waiting time for job C on machine 2 (lacquering)?		
1		25 hours
2	x	4 hours
3		21 hours
4		0 hours

Assuming the processing sequence was: F-E-D-C-A-B, what is the inactivity time on machine 2 after 15 hours?		
1	x	9 hours
2		2 hours
3		7 hours
4		4 hours