

**Final examination, 20. April 2004**

All aids are allowed, except personal computer and personal assistance. The exam consists of 3 questions, which have equal weight (*10 points each*) and should all be answered; further detail about the points is given for specific parts of each question. The duration of the exam is 3 hours. Generally, all statistical models used should be specified, and to such detail that it is clear which terms are present and in which form.

**Questions 1-2.**

Not shown.

**Question 3.**

A study was designed to compare the average access times of five brands (types) of half-height computer disk drives (denoted A through E). It was desirable to compare the disk drives in several computers, in order to eliminate computer specific behaviour. Five computers were used; each computer could however only hold four drives. The study design and the observed average access times (in *ms*) are given in the table below (e.g., the average access time for drive A in computer 1 was 35 *ms*):

		Computer				
		1	2	3	4	5
A	35	A 41	B 40	A 32	A 40	
B	42	B 45	C 42	C 33	B 38	
C	31	D 32	D 33	D 35	C 35	
D	30	E 40	E 39	E 36	E 37	

The organization of these data for statistical analysis is shown in the Minitab listing below.

```
MTB > Print 'type' 'computer' 'time'.
Data Display
```

Row	type	computer	time
1	A	1	35
2	B	1	42
3	C	1	31
4	D	1	30
5	A	2	41
6	B	2	45
7	D	2	32
8	E	2	40
9	B	3	40
10	C	3	42
11	D	3	33
12	E	3	39

13	A	4	32
14	C	4	33
15	D	4	35
16	E	4	36
17	A	5	40
18	B	5	38
19	C	5	35
20	E	5	37

Use this description of the data and the design to answer to the following points.

- A) (*4 points*) Describe the statistical design and motivate the choice of such a design for the problem described above. Suggest a suitable statistical model for the data.

The data have been analyzed in Minitab and Stata, and the following pages give the complete listing from the session window in Minitab, and a corresponding do-file for Stata and the additional output produced by the Stata analysis.

- B) (*6 points*) Carry out a statistical analysis on the basis of the listings given. Summarize the conclusions that can be drawn about the five brands of disk drives. Include in your discussion suggestions and motivations for additional analyses you would want to carry out, if any.

```
MTB > GLM 'time' = type computer;
SUBC> Brief 2 ;
SUBC> Means type computer.
General Linear Model: time versus type, computer
```

```
Factor      Type Levels Values
type        fixed      5 A B C D E
computer    fixed      5 1 2 3 4 5
```

Analysis of Variance for time, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
type	4	168.700	139.200	34.800	3.58	0.042
computer	4	65.700	65.700	16.425	1.69	0.222
Error	11	106.800	106.800	9.709		
Total	19	341.200				

Least Squares Means for time

type	Mean	SE Mean
A	37.47	1.599
B	40.80	1.599
C	35.87	1.599
D	32.40	1.599
E	37.47	1.599
computer		
1	34.67	1.599
2	39.27	1.599
3	38.67	1.599
4	35.00	1.599
5	36.40	1.599

(continues on next page)

Stata do-file and additional listing:

```
* do-file for VHM 802, exam 2004, Q3
* dataset computer.dta has 20 observations and 3 variables: type computer time
anova time type computer
xi: regress time i.type i.computer
adjust _Icomputer_2=0.2 _Icomputer_3=0.2 _Icomputer_4=0.2 _Icomputer_5=0.2, by(type) se
adjust _Itype_2=0.2 _Itype_3=0.2 _Itype_4=0.2 _Itype_5=0.2, by(computer) se
```

```
. xi: regress time i.type i.computer
i.type          _Itype_1-5          (_Itype_1 for type==A omitted)
i.computer      _Icomputer_1-5      (naturally coded; _Icomputer_1 omitted)
```

Source	SS	df	MS	Number of obs =	20
Model	234.4	8	29.3	F( 8, 11) =	3.02
Residual	106.8	11	9.70909091	Prob > F =	0.0466
Total	341.2	19	17.9578947	R-squared =	0.6870
				Adj R-squared =	0.4593
				Root MSE =	3.1159

time	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
_Itype_2	3.333333	2.275562	1.46	0.171	-1.675145	8.341811
_Itype_3	-1.6	2.275562	-0.70	0.497	-6.608478	3.408478
_Itype_4	-5.066667	2.275562	-2.23	0.048	-10.07514	-.0581888
_Itype_5	1.08e-15	2.275562	0.00	1.000	-5.008478	5.008478
_Icomputer_2	4.6	2.275562	2.02	0.068	-.4084779	9.608478
_Icomputer_3	4	2.275562	1.76	0.107	-1.008478	9.008478
_Icomputer_4	.3333333	2.275562	0.15	0.886	-4.675145	5.341811
_Icomputer_5	1.733333	2.275562	0.76	0.462	-3.275145	6.741811
_cons	35.33333	2.090237	16.90	0.000	30.73275	39.93391