

```
/* This is a SAS program for analyzing
data from a nested or heirarchical
experiment. This program is posted as
```

```
pigment.sas
```

```
The data are measurements of moisture
content of a pigment taken from Box,
Hunter and Hunter (page 574). */
```

```
data set1;
  infile 'c:\stat504\pigment.dat';
  input batch sample test y;
run;
```

```
proc print data=set1;
run;
```

```
/* The "random" statement in the
following GLM procedure prints
formulas for expectations of
mean squares. */
```

```
proc glm data=set1;
  class batch sample;
  model y = batch sample(batch) / e1;
  random batch sample(batch) / q test;
run;
```

# The GLM Procedure

## Class Level Information

Class	Levels	Values
batch	15	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
sample	2	1 2

Number of Observations Read 60  
Number of Observations Used 60

# The GLM Procedure

Dependent Variable: y

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	29	2080.683333	71.747701	78.27	<.0001
Error	30	27.500000	0.916667		
Corrected Total	59	2108.183333			

R-Square 0.986956  
Coeff Var 3.574712  
Root MSE 0.957427  
y Mean 26.78333

Source	DF	Type I SS	Mean Square	F Value	Pr > F
batch	14	1210.933333	86.495238	94.36	<.0001
sample(batch)	15	869.750000	57.983333	63.25	<.0001

# The GLM Procedure

Source	Type I Expected Mean Square
batch	$\text{Var}(\text{Error}) + 2 \text{ Var}(\text{sample}(\text{batch})) + 4 \text{ Var}(\text{batch})$
sample(batch)	$\text{Var}(\text{Error}) + 2 \text{ Var}(\text{sample}(\text{batch}))$

# The GLM Procedure

## Tests of Hypotheses for Random Model Analysis of Variance

Dependent Variable: y

Source	DF	Type I SS	Mean Square	F Value	Pr > F
batch	14	1210.933333	86.495238	1.49	0.2256
Error Error: MS(sample(batch))	15	869.750000	57.983333		

Source	DF	Type I SS	Mean Square	F Value	Pr > F
sample(batch)	15	869.750000	57.983333	63.25	<.0001
Error: MS(Error)	30	27.500000	0.916667		

```

/* Alternatively, REML estimates of variance
   components are produced by the MIXED
   procedure in SAS. Note that there are
   no terms on the right of the equal sign in
   the model statement because the only
   non-random effect is the intercept.      */

```

```

proc mixed data=set1;
  class batch sample test;
  model y = ;
  random batch sample(batch);
run;

```

```

/* Use the MIXED procedure in SAS to compute
   maximum likelihood estimates of variance
   components */

```

```

proc mixed data=set1 method=ml;
  class batch sample test;
  model y = ;
  random batch sample(batch);
run;

```

## The Mixed Procedure

### Model Information

Data Set	WORK.SET1
Dependent Variable	y
Covariance Structure	Variance Components
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Containment

### Class Level Information

Class	Levels	Values
batch	15	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
sample	2	1 2
test	2	1 2

### Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	382.51571298	
1	1	292.26233543	0.00000000

Convergence criteria met.

### Covariance Parameter Estimates

Cov Parm	Estimate
batch	7.1280
sample(batch)	28.5333
Residual	0.9167

### Fit Statistics

-2 Res Log Likelihood	292.3
AIC (smaller is better)	298.3
AICC (smaller is better)	298.7
BIC (smaller is better)	300.4

## The Mixed Procedure

### Model Information

Data Set	WORK.SET1
Dependent Variable	y
Covariance Structure	Variance Components
Estimation Method	ML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Containment

### Iteration History

Iteration	Evaluations	-2 Log Like	Criterion
0	1	383.82686282	
1	1	294.43106422	0.00000000

Convergence criteria met.

### Covariance Parameter Estimates

Cov Parm	Estimate
batch	5.6864
sample(batch)	28.5333
Residual	0.9167

### Fit Statistics

-2 Log Likelihood	294.4
AIC (smaller is better)	302.4
AICC (smaller is better)	303.2
BIC (smaller is better)	305.3

```

> # This file is stored as pigment.r
>
> pigment <- read.table("pigment.dat",
+   col.names=c("Batch","Sample","Test","Y"))
> pigment$Batch <- as.factor(pigment$Batch)
> pigment$Sample <- as.factor(pigment$Sample)
>
> # Random effects analysis using lme()
> library(nlme)
> pigment.lme <- lme(Y ~ 1, random = ~1 | Batch/Sample, data=pigment)
> summary(pigment.lme)
Linear mixed-effects model fit by REML
Data: pigment
      AIC      BIC    logLik
300.2623 308.5725 -146.1312

Random effects:
Formula: ~1 | Batch
      (Intercept)
StdDev:    2.669827

      Formula: ~1 | Sample %in% Batch
      (Intercept) Residual
StdDev:    5.341659 0.9574273

Fixed effects: Y ~ 1
              Value Std.Error DF   t-value p-value
(Intercept) 26.78333   1.200661 30 22.30716      0

Standardized Within-Group Residuals:
      Min      Q1      Med      Q3      Max
-1.732600891 -0.464992584  0.009751556  0.522792863  1.582429596

Number of Observations: 60
Number of Groups:
      Batch Sample %in% Batch
      15      30

>
> # Confidence intervals for fixed effects
> # and estimated standard deviations (REML)
> intervals(pigment.lme)
Approximate 95% confidence intervals

Fixed effects:
      lower      est.      upper
(Intercept) 24.33126 26.78333 29.23541
attr(,"label")

```

```

[1] "Fixed effects:"

Random Effects:
Level: Batch
      lower    est.    upper
sd((Intercept)) 0.7001028 2.669827 10.18133
Level: Sample
      lower    est.    upper
sd((Intercept)) 3.713376 5.341659 7.68393

Within-group standard error:
      lower    est.    upper
0.7428726 0.9574273 1.2339492
>
> # ML estimation
> pigment.ml <- lme(Y ~ 1, random = ~1 | Batch/Sample, data=pigment, method="ML")
> summary(pigment.ml)
Linear mixed-effects model fit by maximum likelihood
Data: pigment
      AIC      BIC    logLik
302.4311 310.8084 -147.2155

Random effects:
Formula: ~1 | Batch
      (Intercept)
StdDev:    2.384560

Formula: ~1 | Sample %in% Batch
      (Intercept) Residual
StdDev:    5.341682 0.957427

Fixed effects: Y ~ 1
      Value Std.Error DF  t-value p-value
(Intercept) 26.78333  1.169733 30 22.89695      0

Standardized Within-Group Residuals:
      Min      Q1      Med      Q3      Max
-1.73796449 -0.46739215  0.01465911  0.52143218  1.57706562

Number of Observations: 60
Number of Groups:
      Batch Sample %in% Batch
      15      30
> intervals(pigment.ml)
Approximate 95% confidence intervals

Fixed effects:

```



```

              lower    est.    upper
(Intercept) 24.41441 26.78333 29.15226
attr(,"label")
[1] "Fixed effects:"

Random Effects:
Level: Batch
              lower    est.    upper
sd((Intercept)) 0.4996879 2.384560 11.37935
Level: Sample
              lower    est.    upper
sd((Intercept)) 3.713624 5.341682 7.683483

Within-group standard error:
      lower    est.    upper
0.7431152 0.9574269 1.2335454

```