Problem description

An investigator is interested in comparing the cardiovascular fitness of elite runners on three different training courses, each of which covers 10 miles. The courses differ in terms of terrain, Course 1 is flat, Course 2 has graded inclines, and Course 3 includes steep inclines. Each runner's heart rate is monitored at mile 5 of the run on each course. Ten runners are involved, and their heart rates measured on each course are shown below.

| Runner number | Course1 | Course2 | Course3 |
|---|---|---|---|
| 1 | 132 | 135 | 138 |
| 2 | 143 | 148 | 148 |
| 3 | 135 | 138 | 141 |
| 4 | 128 | 131 | 139 |
| 5 | 141 | 141 | 150 |
| 6 | 150 | 156 | 161 |
| 7 | 131 | 134 | 138 |
| 8 | 150 | 156 | 162 |
| 9 | 142 | 145 | 151 |
| 10 | 139 | 165 | 160 |

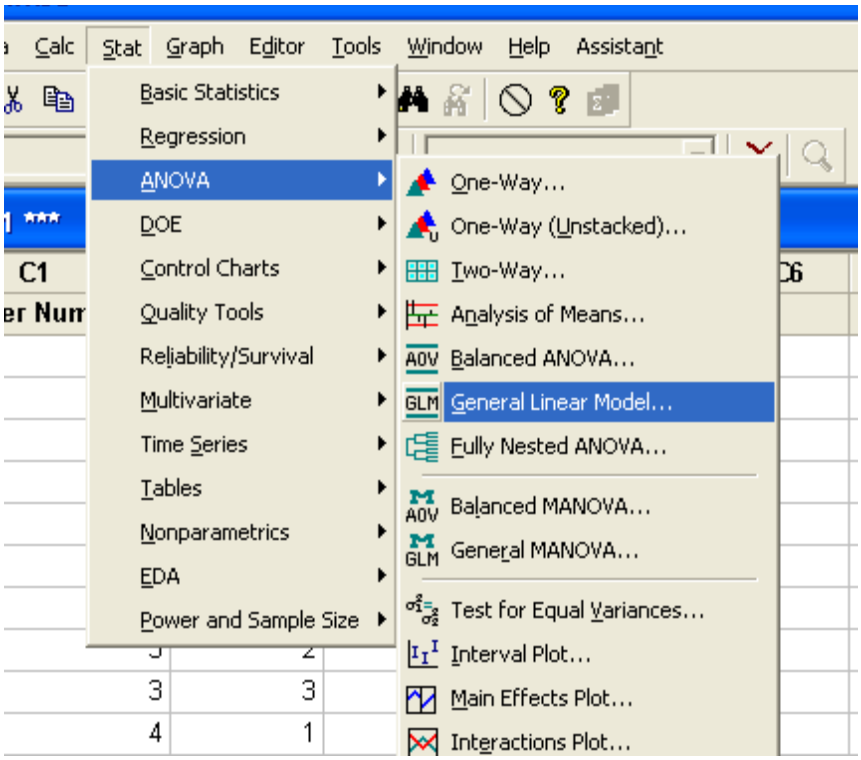
In Minitab, the data should be entered as picture below.

Worksheet 1 ***

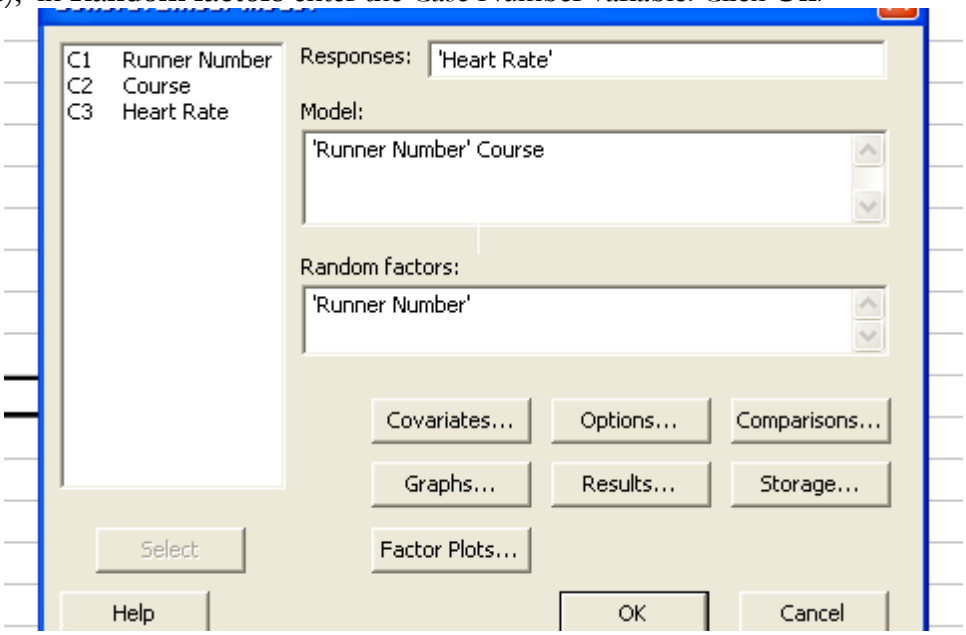
| ↓ | C1 | C2 | C3 |
|---|---|---|---|
| | Runner Number | Course | Heart Rate |
| 1 | 1 | 1 | 132 |
| 2 | 1 | 2 | 135 |
| 3 | 1 | 3 | 138 |
| 4 | 2 | 1 | 143 |
| 5 | 2 | 2 | 148 |
| 6 | 2 | 3 | 148 |
| 7 | 3 | 1 | 135 |
| 8 | 3 | 2 | 138 |
| 9 | 3 | 3 | 141 |
| 10 | 4 | 1 | 128 |
| 11 | 4 | 2 | 131 |
| 12 | 4 | 3 | 139 |

Repeated Measure ANOVA

Click on **Stat-ANOVA- General Linear Model** in the pull down menus to start the process.




We need to define which of our variables is the dependent variable and which is the factor variable. In the window for the test, in **Responses** enter the dependent variable (Heart Rate), in **Model** enter the Case Number variable (Runner Number), the Factor variable (Course), in **Random factors** enter the Case Number variable. Click **Ok**.



Output

Recall that the null hypothesis in ANOVA is that the means of all the groups are the same and the alternative is that at least one is different. So for our example with 3 treatment groups

$H_0: \mu_1 = \mu_2 = \mu_3$

$H_A$: At least one mean is different

Session

**General Linear Model: Heart Rate versus Runner Number, Course**

```
Factor          Type    Levels  Values
Runner Number   random      10  1, 2, 3, 4, 5, 6, 7, 8, 9, 10
Course          fixed        3  1, 2, 3


Analysis of Variance for Heart Rate, using Adjusted SS for Tests

Source          DF   Seq SS   Adj SS  Adj MS      F      P
Runner Number    9  2224.53  2224.53  247.17  16.19  0.000
Course           2   476.47   476.47  238.23  15.60  0.000
Error           18   274.87   274.87   15.27
Total           29  2975.87


S = 3.90773   R-Sq = 90.76%   R-Sq(adj) = 85.12%


Unusual Observations for Heart Rate

Obs  Heart Rate      Fit  SE Fit  Residual  St Resid
 28     139.000  149.500   2.471   -10.500     -3.47 R
 29     165.000  155.300   2.471     9.700      3.20 R
R denotes an observation with a large standardized residual.
```

We will use the Runner Number line, as that is the Factor of interest. Here SSb is 476.47 and SSw is 274.87. The p-value is .000 and thus we reject the null hypothesis and conclude that there is significant difference in runner's heart rate among the courses.