Answers

1. a. The F-statistic for light in the mixed effects case is MS(light)/MS(light*worker) = 110.45/13.575 = 8.14.

b. The F-statistic for light in the fixed effects case is MS(light)/MS(error) = 110.45/3.850 = 28.69

c. The mixed effects analysis would probably be more appropriate because the workers were selected randomly from a population of workers.

2. The solution is contained in the "Annotated mixed code and analysis".

3. Here is the code for the MIXED analysis of the agronomy data.

```
data;
input block $ treatment yield;
datalines;
West  1     40.5
West  2     39.4
West  3     38.3
West  4     38.1
Mid   1     45.4
Mid   2     44.1
Mid   3     43.0
Mid   4     42.0
East  1     48.3
East  2     47.0
East  3     46.2
East  4     46.1
;
proc mixed;
class treatment block;
model yield = treatment;
random block treatment*block;
lsmeans treatment/pdiff;
run;
```

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Here is the an edited output that has the analysis of variance and the lsmeans. We see that the treatment effect is significant with F = 46.13 and p = .0002

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
treatment	3	6	46.13	0.0002

Least Squares Means

Effect	treatment	Estimate	Standard Error	DF	t Value	Pr > |t|
treatment	1	44.7333	2.2738	6	19.67	<.0001
treatment	2	43.5000	2.2738	6	19.13	<.0001
treatment	3	42.5000	2.2738	6	18.69	<.0001
treatment	4	42.0667	2.2738	6	18.50	<.0001

Here are the differences of means with p-values. We see that all of the differences are significant at the 5% except for 3 vs 4 which has a p = .1297.

Differences of Least Squares Means

Effect	treatment	_treatment	Estimate	Standard Error	DF	t Value	Pr > |t|
treatment	1	2	1.2333	0.2468	6	5.00	0.0025
treatment	1	3	2.2333	0.2468	6	9.05	0.0001
treatment	1	4	2.6667	0.2468	6	10.80	<.0001
treatment	2	3	1.0000	0.2468	6	4.05	0.0067
treatment	2	4	1.4333	0.2468	6	5.81	0.0011
treatment	3	4	0.4333	0.2468	6	1.76	0.1297

b. Here is the GLM code. The data step is the same as that with the MIXED procedure.

```
proc glm;
class treatment block;
model yield = treatment block/ss3;
lsmeans treatment block/stderr pdiff;
run;
```

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Here is the fixed effects analysis of variance. Note that the F-statistic for treatment is 46.13 and the p-value is p = .0002 which is identical to that we obtained with the MIXED analysis.

Dependent Variable: yield

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	136.1916667	27.2383333	298.05	<.0001
Error	6	0.5483333	0.0913889		
Corrected Total	11	136.7400000			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
treatment	3	12.6466667	4.2155556	46.13	0.0002
block	2	123.5450000	61.7725000	675.93	<.0001

Here are the lsmeans and pairwise p-values for treatments. The p-values for the for comparing means are the same as those for the MIXED analysis. For instance, for 1 vs 2 the p-value in both cases is .0025.

treatment	yield LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	44.7333333	0.1745364	<.0001	1
2	43.5000000	0.1745364	<.0001	2
3	42.5000000	0.1745364	<.0001	3
4	42.0666667	0.1745364	<.0001	4

Least Squares Means for effect treatment
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: yield

i/j	1	2	3	4
1		0.0025	0.0001	<.0001
2	0.0025		0.0067	0.0011
3	0.0001	0.0067		0.1297
4	<.0001	0.0011	0.1297	

c. The means, F-statistics, and p-values for comparing treatments using either the mixed effects analysis (PROC MIXED) or the fixed effects analysis (PROC GLM) are the same. However the standard errors of the means are not the same. For the mixed effects analysis the standard error of the lsmeans is 2.2738 but for the fixed effects analysis it is .1745364. This is because there is random variability in the mixed analysis due to both blocks and error, but in the fixed effects analysis blocks are regarded as fixed (not random) so the only random variability is error.