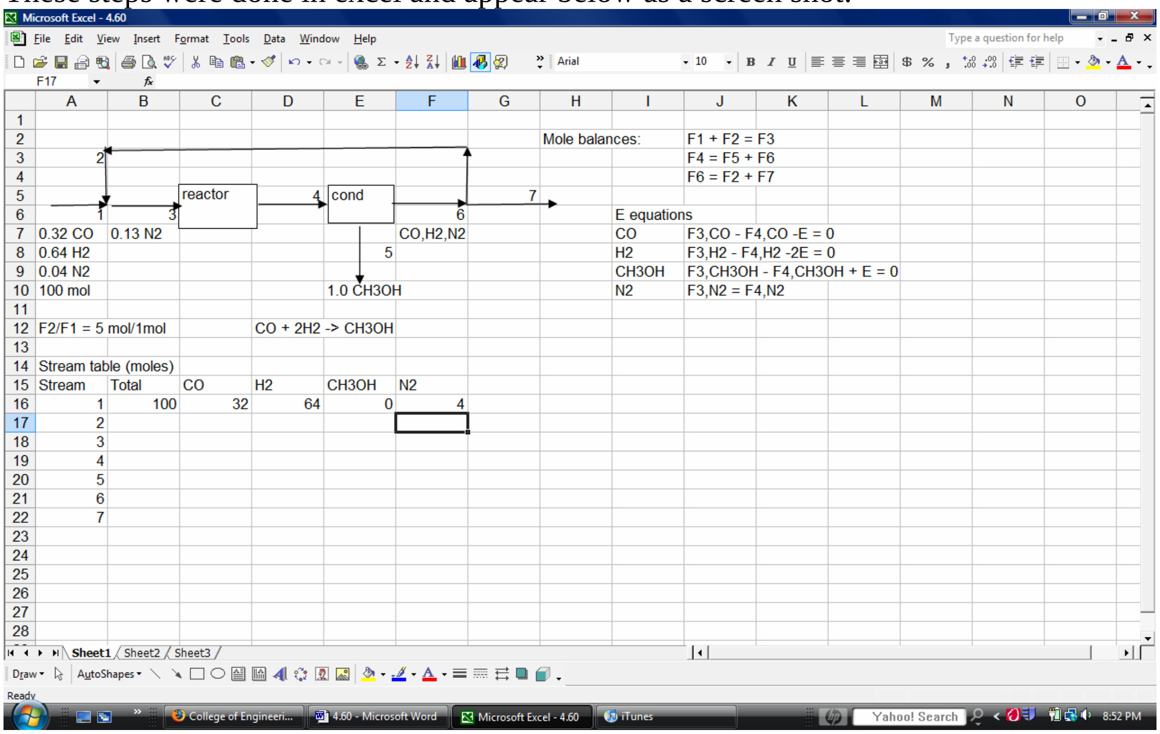
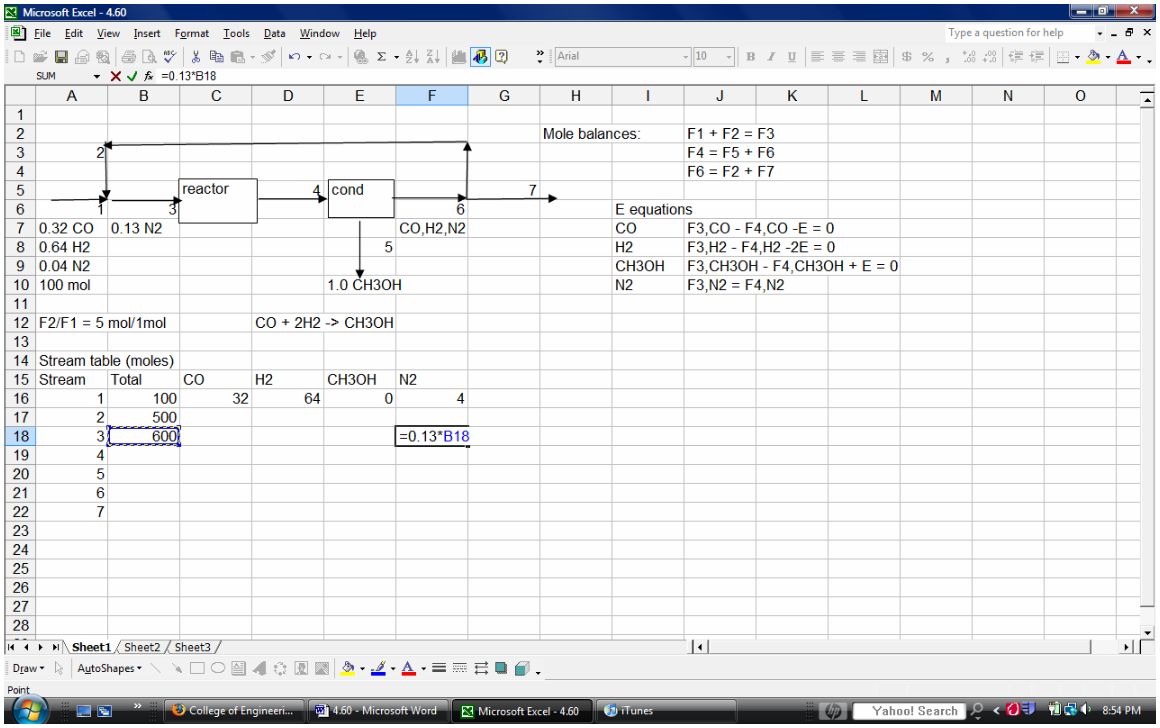
Problem 4.60
Do like we always do:
1) read
2) draw
3) label
4) reread
5) transform to math
6) write equations
7) solve

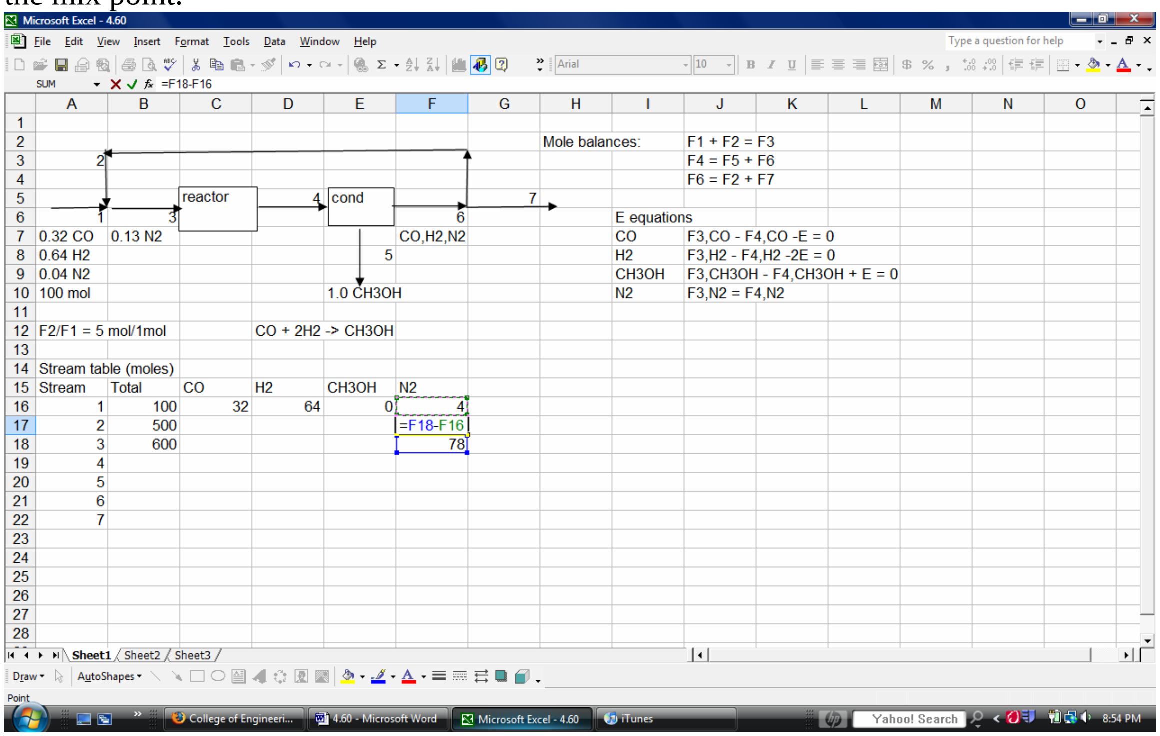
These steps were done in excel and appear below as a screen shot:



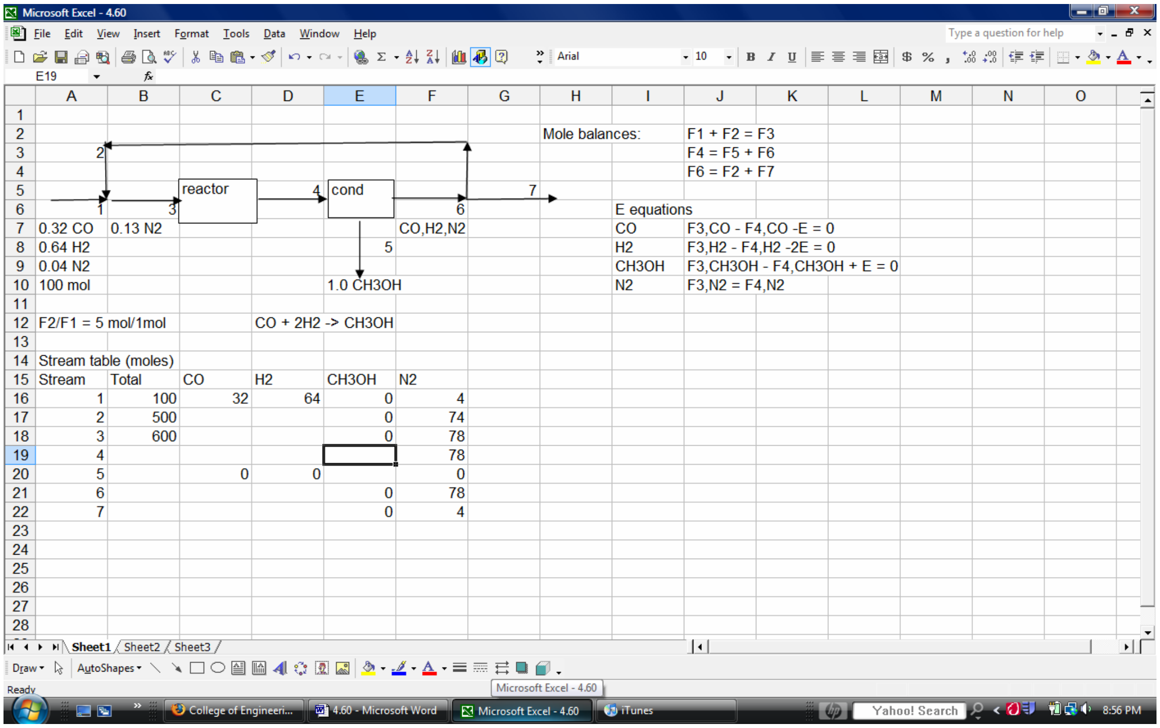
Let's find F2 using the subsidiary relationship given in the problem statement: F2/F1 = 5
F2 = 500 moles
Using our mass/mole balance equations, F3 then is 600 moles
And we know F3 is 0.13 N2 so that is 78 moles of N2.



This then tells us that 74 moles of N2 were in stream 2, using a nitrogen balance around the mix point.



We also fill in all the zeroes in the table and finish the nitrogen balances to get:



Stream	Total	CO	H2	CH3OH	N2
1	100	32	64	0	4
2	500			0	74
3	600			0	78
4					78
5		0	0		0
6				0	78
7				0	4

This is pretty much where we got bogged down in class on Monday. Let's pick up here and try writing some other things that we know are true (our goal is to get to a point where the number of equations equals the number of unknowns):

We know that for stream 3,

F3,CO + F3,H2 = 600 – 78 = 522 moles (equation 1)

This is one equation with 2 unknowns. Now look at our E equations and rewrite those to see what we get:

F3,CO - F4,CO -E = 0 (equation 2)

F3,H2 - F4,H2 - 2E = 0 (equation 3)

At this point, we have three equations with the following 5 unknowns: F3,CO, F3,H2, F4,CO, F4,H2, E

Let's also add the balance around the mix point for CO and H2:

F3,CO = 32 + F2,CO (equation 4)

F3,H2 = 64 + F2,H2 (equation 5)

So, now we are at 5 equations with seven unknowns (the two new ones are F2,CO and F2,H2.

Hmmm…Are we going to end up going in circles here? Maybe. Let's be patient and keep going.

We know that all the CO and H2 in stream 4 goes to stream six so let's replace equations 2 and 3 by:

F3,CO – F6,CO -E = 0 (equation 2)

F3,H2 – F6,H2 - 2E = 0 (equation 3)

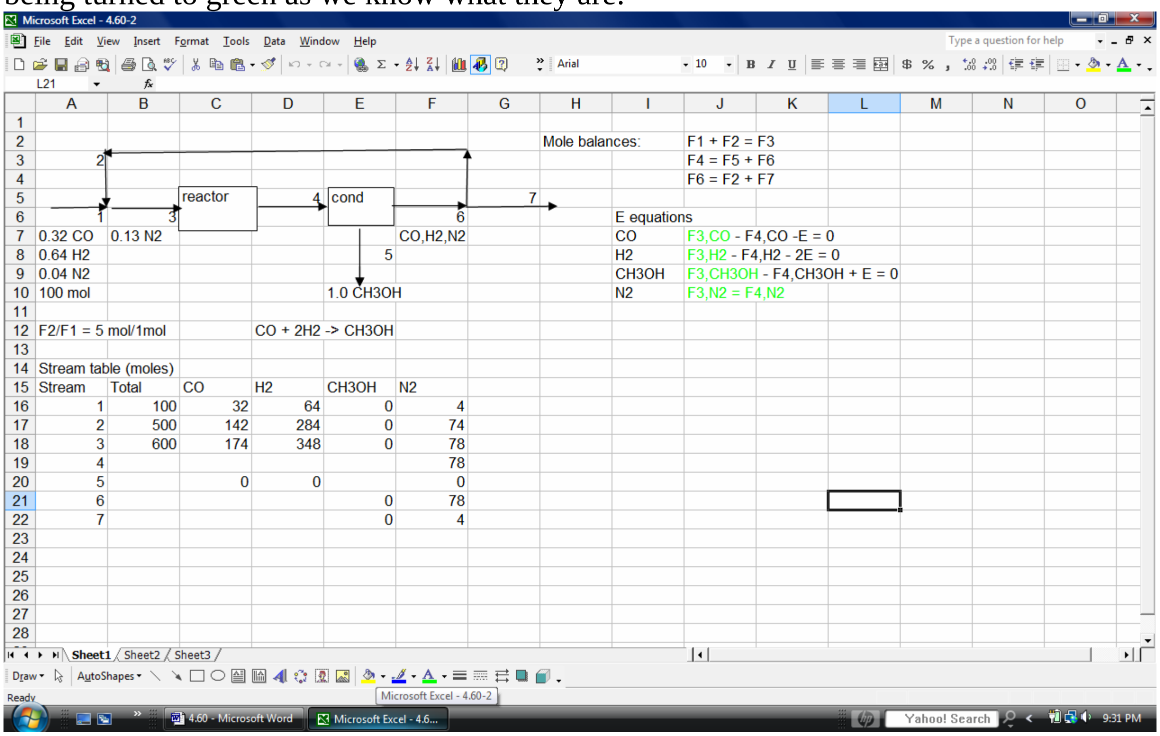
We can stall and also write that F2,CO + F2, H2 = 500-74 = 426 (equation 6)

We'll combine equations 2, 3, 4 and 5 above to get:

32 + F2,CO – F6,CO -E = 0 (equation 2’)
64 + F2,H2 – F6,H2 - 2E = 0 (equation 3’)
We can sum these two together and rearrange to get:
F2,CO = F6,CO +E -32 (equation 2’)
F2,H2 = F6,H2 + 2E -64 (equation 3’)
522 = F6,CO + F6,H2 + 3E

We seem to be at an impasse still.
There is twice as much H2 as CO in stream 1. For every 1 mole of CO we use, we use 2 moles of H2, so this ratio will stay 2:1 consistently as we move past the reaction. So, F4,H2/F4,CO = 2 and F2,H2/F2,CO = 2…Hey. A little logic in this case suggests that we can go back up to equation 6 to find:
F2,CO + 2F2,CO = 426 -> F2,CO = 142 mole and F2,H2 = 284.

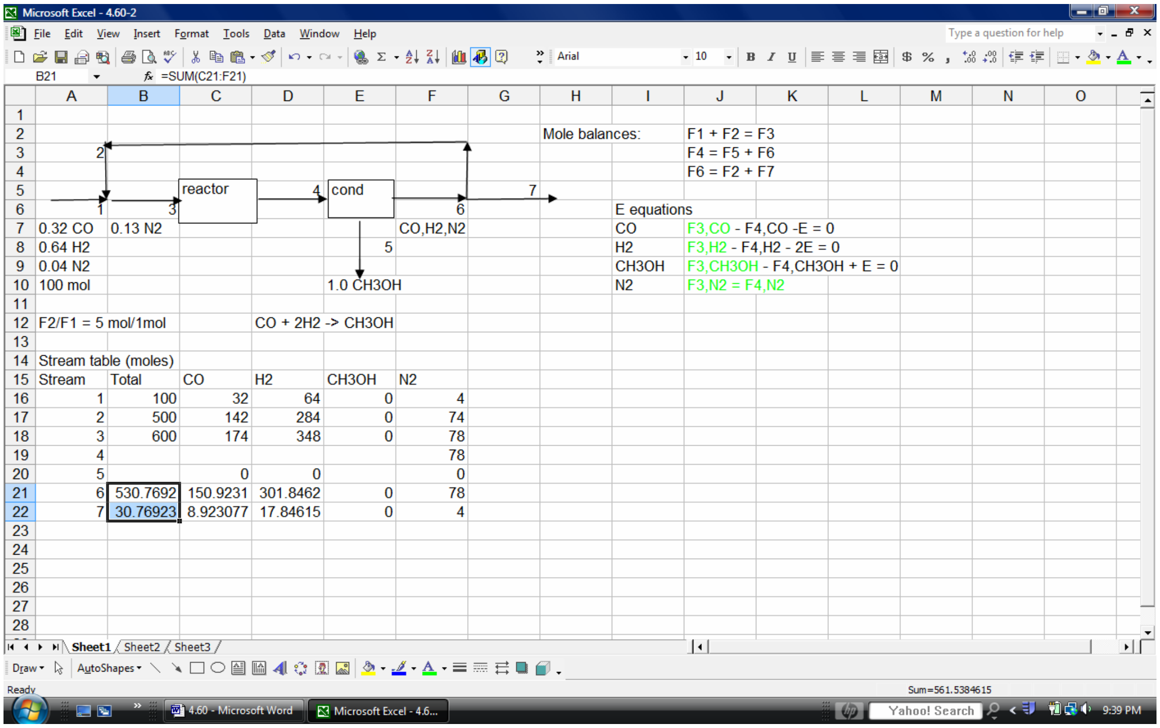
Let’s place that in our table and start following that information around to fill in F3 completely and see what else we know. The variables we know in the equations are now being turned to green as we know what they are:



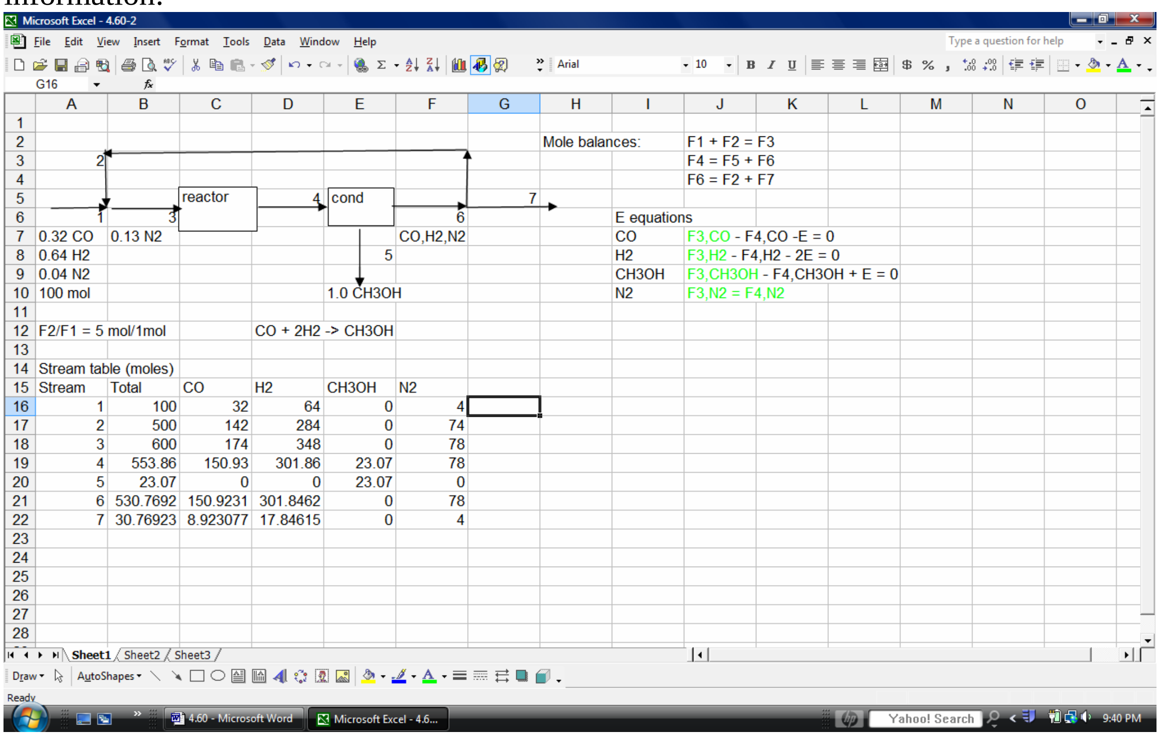
Stream	Total	CO	H2	CH3OH	N2
1	100	32	64	0	4
2	500	142	284	0	74
3	600	174	348	0	78
4					78
5		0	0		0
6				0	78
7				0	4

And we could continue with the logic that F6,H2/F6,CO = 2
522 = F6,CO + 2F6,CO + 3E
174 = F6,CO + E
Here is one equation with two unknowns…So close!

Hey! Wait a minute. Go back and look at the nitrogen information around streams 2, 6, and 7… We know that 78/4 = F2/F7. And since this is a split point where compositions remain constant, we can then find F7 of CO and H2 are 8.92 and 17.85 moles, respectively. And then we fill in F6 to get the following table:



And now that we know F6,CO, we find E = 23.07 and we can then find the rest of the information:



Let's say we are a little doubtful that everything worked out. We can do an external check to see if the number of carbon atoms in is equal to the number of carbon atoms out using streams 1, 5 and 7 (much like we were contemplating last Monday):

C balance: 32(1) should equal 23.07(1) + 8.92 (1)…Answer is…yes.

O balance: 32(1) should equal 23.07(1) + 8.92(1) …yes.

H balance: 64(2) should equal 23.07(4) + 17.85(2)…answer is?...yes!
We have external confirmation that our numbers all worked out. Whew!