

## IT-305 INDUSTRIAL SAFETY TWA and PEL EXERCISES

The student should become familiar with Appendix A beginning on page 458 of the text and the “notes” to the Appendix at the top of page 473. The two most important are “b” and “c” that define parts per million (ppm) and milligrams per milliliter ( $\text{mg}/\text{m}^3$ ). These two measurements and how the measurements are taken are essential to understanding the Appendix.

Please look at Appendix A on page 458. The definition of a PEL limit is defined as; “The permissible exposure levels (PELs) are 8-hour time-weighted averages (TWAs) unless otherwise noted....” These are the two terms we will use to describe exposure and the amount of exposure a worker receives.

On page 458 look at the substance Acetone, its PEL is 1000 ppm OR 2400  $\text{mg}/\text{m}^3$ . It is NOT BOTH; it depends on how the measurement is taken as defined on page 473.

Lets do some easy problems. There are several types of exposures the text introduces. The first is single chemical exposures for an entire 8-hour shift, or different concentrations of the chemical exposure during multiple time periods. The second is multiple chemical exposures and multiple time segments.

### Single Chemical Exposure for an 8-hour workday.

Example #1. Suppose a worker is exposed to Carbon Dioxide for an 8-hour workday. The level of exposure is 4000 ppm. Has the PEL been exceeded?

The answer is NO. The 8-hour permissible exposure level for Carbon Dioxide listed on page 460 is either 5000 ppm or 9000  $\text{mg}/\text{m}^3$ . He was exposed to only a 4000 time weighted average (TWA). The TWA is the 8-hour time-weighted average of a worker’s exposure. However an addition question must be asked.... Has the action limit (AL) been reached? This answer is YES.

The AL is arbitrarily set by OSHA at 50% of the PEL therefore  $4000/5000 = 80\%$  of the PEL meaning the AL has been exceeded. What is the reason for the AL? Answer see page 186 and 194. However the AL is used by OSHA as a decision step that requires organizations to provide personal protection equipment (PPS) once the AL is reached or take steps to reduce the exposure.

Example #2. Suppose the next shift the same worker was exposed to Carbon Dioxide for an 8-hour workday but the concentrations were:

From/To	Chemical	Exposure (ppm’s)
8:00 till 10:00	Carbon Dioxide	4000
10:00 till noon	“	4500
Noon till 4:00	“	3500

Has the PEL been exceeded for this worker? In other words does this worker's TWA exceed OSHA's PEL for this concentration of chemical?

The answer requires you to compute a weighted average for the exposure. To do that you must use the formula identified on page 183 of the text and used in the Case Study 9.3.

Solution:

Step 1: Convert time to hours. Make certain there are 8 hours accounted for.

From/To	Hours	Chemical	Exposure (ppm's)
8:00 till 10:00	2	Carbon Dioxide	4000
10:00 till noon	2	"	4500
Noon till 4:00	4	"	3500
Total	<u>8</u>		

Step 2: Multiply hours (Ti) by concentration (Ci) of the chemical and total. Make certain to round to two decimal places if required.

From/To	Hours	Exposure	CiTi
8:00 till 10:00	2 x's	4000	8000
10:00 till noon	2 x's	4500	9000
Noon till 4:00	4 x's	3500	14000
Total	<u>8</u>		<u>31000</u>

Step 3: Divide the total weighted concentration (CiTi) by the total hours (Ti). This is the worker's TWA for this exposure. Make certain to round to two decimal places if required.

$$\text{TWA} = 31000/8 = 3875 \text{ ppm}$$

Now compare the TWA to the PEL. Does an exposure of 3875 ppm of Carbon Dioxide exceed OSHA's PEL of 5000 ppm? The answer is NO. However the AL is exceeded which means the employer must provide PPE for this employee.

Example #3. Look at Case Study 9.3 on page 183 in the text. Assume the chemical this worker is exposed to is Nitric Acid. Has the PEL been exceeded? How about the AL?

The answer is the PEL is not exceeded but the AL is. What does the organization have to do now that he knows the AL is exceeded? The organization must reduce the exposure or provide the worker with PPE. Please read on page 184 some clarification concerning this Case Study, it states the PEL is  $5 \text{ mg/m}^3$  thus not all PEL's are in ppm.

Example #4. Suppose a worker was exposed to Dioxane for an 8-hour workday and the concentrations were as follows.

From/To	Hours	Exposure	CiTi
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8:00 till 10:00	2 x's	115	230
10:00 till noon	2 x's	95	190
Noon till 4:00	4 x's	97	388
Total	<u>8</u>		<u>808</u>

$TWA = 808/8 = 101 \text{ ppm}$

Now compare the TWA to the PEL. Does an exposure of 101 ppm of Dioxane exceed OSHA's PEL of 100 ppm? The answer is YES. Is the AL exceeded? Obviously YES since the PEL is exceeded the AL is also.

Multiple Chemical Exposures for an 8-hour workday.

Multiple chemical exposures are similar to single chemical exposures, in that you compute a TWA for each chemical and then convert the TWA into a ratio or percentage of the PEL. It is the combined percentage or ratio that OSHA is interested. OSHA is concerned if the combined percentages exceed 100%, if so, the combined exposures exceed the permissible exposure limit for this employee for this combination of chemicals. An example will help clarify.

Example #5. Go to page 184 in the text Case Study 9.4. These instructions will deviate a little from what the text states but I think it will make it more understandable. Notice a worker is exposed to three chemicals; Nitric Acid, Sulfuric Acid and Acetic Acid during a 8-hour workday.

Chem.	Hours	8-hour Exposure is the TWA in mg/m <sup>3</sup>	TWA/PEL as a percentage
Nitric Acid	8	4	4/5 = 80%
Sulfuric Acid	8	0.9	.9/1 = 90%
Acetic Acid	8	22	22/25 = 88%
		Total	<u>258%</u>

What you can see by using percentages in lieu of the example >1 is that 258% is greater than 100% therefore the PEL has been exceeded. In this example if the percentage is greater than 50% the AL has been reached also.

Example #6. Suppose a worker was exposed to Ammonia and Carbon Dioxide during an 8-hour workday and the concentrations were as follows.

Chem.	Hours	8-hour Exposure is the TWA in ppm	TWA/PEL as a percentage
Ammonia	8	13	13/50 = 26%
Carbon Dioxide	8	4000	4000/5000 = 80%
		Total	<u>106%</u>

It should be easy to see the PEL has been exceeded.

Example #7. Suppose a worker was exposed to Cumene, Ethyl Ether and Vinyl Toluene during an 8-hour workday and the concentrations were as follows.

Chem.	Hours	8-hour Exposure is the TWA in ppm	TWA/PEL as a percentage
Cumene	8	30	$30/50 = 60\%$
Ethyl Ether	8	250	$250/400 = 62.5\%$
Vinyl Toluene	8	70	$70/100 = 70\%$
		Total	<u>192.5%</u>

Yea its this easy. The PEL has ben exceeded.

Example #8. Suppose a worker was exposed to Dioxane and Carbon Dioxide during an 8-hour workday. The concentrations and exposure times are as follows. Notice this example has multiple chemicals and multiple times. The goal is to compute the 8-hour TWA for each chemical and express it as a percentage and total the percentages as in the previous example.

From/To	Hours	Chemical/ exposure Dioxane	CiTi	Hours	Chemical/ exposure Carbon Dioxide	CiTi
8:00 till 10:00	2	70	140	2	4000	8000
10:00 till noon	2	75	150	2	4500	9000
Noon till 4:00	4	50	200	4	3500	14000
Total	<u>8</u>		<u>490</u>	<u>8</u>		<u>31000</u>

Dioxane's TWA =  $490/8 = 61.25 =$  TWA/PEL =  $61.25/100 = 61.25\%$   
 Carbon Dioxide's TWA =  $31000/8 = 3875 =$  TWA/PEL =  $3875/5000 = 77.50\%$   
 Total %'s = 138.75%.

Yes the PEL has been exceeded by some 38.75%, a citation can and most likely be issued.

Example #9. Suppose a worker was exposed to Ammonia and Carbon Dioxide during an 8-hour workday. The concentrations and exposure times are as follows. Notice, once again, this example has multiple chemicals and multiple times. The goal is to compute the 8-hour TWA for each chemical and express it as a percentage and total the percentages as in the previous example.

From/To	Hours	Chemical/ exposure Ammonia	CiTi	Hours	Chemical/ exposure Carbon Dioxide	CiTi
8:00 till 9:30	1.5	45	67.5	1.5	1500	2250
9:30 till 11:30	2	28	56	2	1650	3300
11:30 till 2:00	2.5	36	90	2.5	1800	4500

2:00 till 4:00	<u>2</u>	40	<u>80</u>	2	1400	<u>2800</u>
Total	8		293.5	8		12850

Ammonia's TWA =  $293.5/8 = 36.69 =$  TWA/PEL =  $36.69/50 = 73.38\%$   
 Carbon Dioxide's TWA =  $12850/8 = 1606.25 =$  TWA/PEL =  $1606.25/5000 = 32.13\%$   
 Total %'s = 105.51%

Yes the PEL has been exceeded.

Notice that for simplicity we have only used ppm's as the measure for PEL's. Please keep in mind that  $\text{mg}/\text{m}^3$  can also be used and some chemicals do not have ppm's as a PEL, only  $\text{mg}/\text{m}^3$ . For example go to page 459 and look at the PEL for Ammonia Sulfate, Asbestos, Boron Oxide as "dust" and notice there is no ppm PEL listed.

Now try these on your own. Answers and work are included at the end of this packet. The student may expect to see these type questions on the comprehensive portion of the test.

HW# 1: Page 196 Question 9.16

CO is the symbol for Carbon Monoxide

CO<sub>2</sub> is the symbol for Carbon Dioxide

HW# 2: Page 197 Question 9.27

Assume that Methanol has a PEL of 200 ppm.

HW# 3: Page 198 Question 9.36

Assume the PEL for Isopropyl Ether is 500 ppm.

Assume the PEL for Ethyl Benzene is 100 ppm.

Assume the PEL for Chlorobenzene is 75 ppm.

Assume the PEL for Chlorobromomethane is 200 ppm.

HW# 4: Page 198 Question 9.39

Answer the question: Has the PEL has been exceeded?

Assume that the PEL for Ammonium Sulfide is 15 ppm.

Assume the PEL for Acetic Anhydride is 5 ppm.

Assume the PEL for Sodium Hydroxide is  $5 \text{ mg}/\text{m}^3$ .

Assume the PEL for is Carbon Disulfide is 20 ppm..

Assume the PEL for Calcium Bisulfide is 20 ppm.

Assume the PEL for Sodium Sulfide is  $5 \text{ mg}/\text{m}^3$ .

Assume the PEL for Sodium Sulfite is  $5 \text{ mg}/\text{m}^3$ .

HW# 5: Suppose a worker was exposed to Ammonia, Carbon Dioxide and Cychohexanol during an 8-hour workday. The concentrations and exposure times are as follows.

From/To	Hours	Chemical/ exposure	Chemical/ exposure	Chemical/ exposure
		Ammonia	Carbon Dioxide	Cychohexanol

8:00 till 9:30	1.5	40	1500	35
9:30 till noon	2	30	1650	30
noon till 2:30	2.5	25	2000	35
2:30 till 4:00	2	20	1800	30
Total	<u>8</u>			

What are the TWA's for each chemical exposure? Has the PEL has been exceeded for any individual chemical? Has the PEL has been exceeded for the combination of chemicals? What about the AL, has it been exceeded?

HW# 6. Suppose a worker is exposed to Ammonia during an 8-hour workday with the times and concentrations listed below.

From/To	Exposure (ppm's)
8:00 till 8:45	35
8:45 till 10:00	40
10:00 till noon	50
Noon till 2:30	40
2:30 till 4:00	45

Has the PEL been exceeded for this worker?

HW# 7. Suppose a worker is exposed to Dioxane and Carbon Dioxide during an 8-hour workday with the times and concentrations listed below.

From/To	Dioxane Exposure (ppm's)	Carbon Dioxide Exposure (ppm's)
8:00 till 9:30	55	3500
9:30 till 10:00	80	5000
10:00 till 11:00	60	2500
11:00 till Noon	60	2400
noon till 3:00	45	3600
3:00 till 4:00	60	4200

What are the TWA's for each chemical exposure? Has the PEL has been exceeded for any individual chemical? Has the PEL has been exceeded for the combination of chemicals? What about the AL, has it been exceeded?

### Noise

So far we have only considered hazardous chemicals however noise has an OSHA mandated PEL as well. The text considers two types of noise scenarios, single and multiple noise sources. Turn to page 215 in the text and acquaint yourself with Table 10.2. Please note that the left hand column "A-weighted sound level" is also the heading for column 3, therefore the chart is continuous for 80 through 130. The A-weighted sound level is the amount to noise a worker is exposed to during an 8-hour day. The "Reference duration time (hr)" column is the OSHA PEL.

For example a worker who is exposed to 92 decibels (DBA's) during a work shift can only work in that environment for 6.2 hours without exceeding the PEL. The chart is simple to use. However OSHA computes its PELs in DBA's NOT hours. This is somewhat awkward therefore the following examples will deviate from the precise definition of PELs but only for educational purposes.

Example #10. Suppose a worker was exposed to the following levels of noise. How many hours can he work in that environment without exceeding the PEL?

Exposed to 95 DBA's	OSHA's PEL is 4 hours
Exposed to 85 DBA's	OSHA's PEL is 16 hours
Exposed to 100 DBA's	OSHA's PEL is 2 hours
Exposed to 75 DBA's	OSHA's PEL is none listed
Exposed to 87 DBA's	OSHA's PEL is 12.1 hours
Exposed to 89 DBA's	OSHA's PEL is 9.2 hours

The reason at 75 DBA's there is no PEL listed is because the exposure to less than 80 DBA's is minimal and therefore OSHA has chosen not to have a PEL for that value. In other words a worker can work an infinite number of hours at that level of noise. Also note how the PEL is easier to understand if it is listed in the number of hours a worker can be exposed to a designated level of noise.

Next lets look at multiple noise levels and varying time exposures.

Suppose a worker is exposed to a work environment that has a noise level that varies over the 8-hour work shift. The different noise levels are the result of various machines being operated then shut down. An example might be an air compressor that runs intermittently or a punch press or saw that create noise for short periods of time.

The following example will illustrate how time (measured in hours) will become the variable in computing exposure levels for noise and identifying the PEL.

Example #11. Suppose a worker is exposed to the following.

From/To	Noise level (DBA)
8:00 till 10:00	90
10:00 till noon	90
Noon till 2:00	90
2:00 till 4:00	90

The solution is similar to chemical exposure in that you must convert the exposure time into a proportion of PEL. Therefore, step 1 is to convert the time into hours, next express the time as a ratio of the appropriate PEL, as shown below. The PEL for 90 DBA of exposure is 8 hours according to Table 10.2.

From/To	Hours	Noise level (DBA)	Time Exposure/PEL
8:00 till 10:00	2	90	$2/8 = 25\%$

10:00 till noon	2	90	$2/8 = 25\%$
Noon till 2:00	2	90	$2/8 = 25\%$
2:00 till 4:00	2	90	$2/8 = 25\%$
Total	<u>8</u>		<u>100%</u>

Make sure to total the “Hours” column to verify that an 8-hour TWA is being computed. Notice in the last column how the hours of exposure (for each time period) are divided by the PEL (for that exposure) and computed as a percentage. If the total percentage exceeds 100% the PEL for the total exposure has been exceeded.

In this example the noise level is a constant 90 DBA for each time period, and it is not hard to see how you could you have combined the segments of “like” exposure into an 8-hour exposure of 90 DBA. The percentage,  $8/8 = 100\%$ , would have been the same and the PEL would not have been “exceeded.”

What about AL’s for noise. Yes it is safe to say the same criteria apply to noise that applies to chemical exposure; if the exposure is more than 50% of the PEL the employer must supply PPE’s to its workers.

It may be safe to say but now you may have identified why it is easier to think of the PEL for noise as “time” rather than exposure.

Example #11. Turn to page 215 in the text and review Case Study 10.3. Suppose a worker is exposed to the following levels of noise for varying periods of time. First convert time to hours and then convert the time to a percentage of the appropriate PEL as identified in Table 10.2 on page 215 in the text.

From/To	Hours	Noise level (DBA)	Time Exposure/PEL
8:00 till 10:00	2	90	$2/8 = 25.00\%$
10:00 till 11:00	1	95	$1/4 = 25.00\%$
11:00 till 12:30	1.5	75	na
12:30 till 1:30	1	85	$1/16 = 6.25\%$
1:30 till 2:00	.5	95	$.5/4 = 12.50\%$
2:00 till 4:00	2	90	$2/8 = 25.00\%$
Total	<u>8</u>		<u>93.75%</u>

Make sure to total the “Hours” column to verify that an 8-hour TWA is being computed. Notice how you “ignore” the percentage for noise levels less than 80 DBA. Also notice in the last column how the hours of exposure (for each time period) are divided by the PEL (for that exposure) and expressed as a percentage. The text combines like exposures and expresses them as a single percentage; either way is OK. Just remember that if the total percentage exceeds 100% the PEL for the total exposure has been exceeded. If it exceeds 50% the AL is exceeded and the employer must provide PPEs for the workers.

Example #12. Suppose a worker is exposed to the following levels of noise for varying periods of time. Has the PEL been exceeded for this worker exposed to this environment?

From/To	Hours	Noise level (DBA)	Time Exposure/PEL
8:00 till 9:00	1	87	$1/12.1 = 8.26\%$
9:00 till 10:30	1.5	90	$1.5/4 = 37.50\%$
10:30 till 12:30	2	80	$2/32 = 6.25\%$
12:30 till 2:00	1.5	95	$1.5/4 = 37.50\%$
2:00 till 4:00	2	80	$2/32 = 6.25\%$
Total	8		95.76%

Since the exposure percentage is less than 100% the PEL has not been exceeded, however the AL has.

Example #13. Suppose a worker is exposed to the following levels of noise for varying periods of time. Has the PEL been exceeded for this worker exposed to this environment?

From/To	Hours	Noise level (DBA)	Time Exposure/PEL
8:00 till 11:30	3.5	98	$3.5/2.6 = 134.62\%$
11:30 till 1:30	2	95	$2/4 = 50.00\%$
1:30 till 2:00	.5	98	$.5/2.6 = 19.23\%$
2:00 till 3:30	1.5	85	$1.5/16 = 9.38\%$
3:30 till 4:00	.5	75	na
Total	8		213.23%

The computed percentage is much greater than 100% therefore the PEL has been exceeded. In this example not how the exposure in the first time bucket is greater than 100%. Regardless of what levels of noise the worker might have been exposed to for the remainder of the day the total PEL would have been exceeded. Therefore for noise if any time segment the PEL is greater than 100% the PEL is exceeded for the 8-hour workday.

Example #14. Suppose a worker is exposed to the following levels of noise for varying periods of time. Has the PEL been exceeded for this worker exposed to this environment?

From/To	Hours	Noise level (DBA)	Time Exposure/PEL
8:00 till 9:30	1.5	90	$1.5/4 = 37.50\%$
9:30 till 12:00	2.5	85	$2.5/16 = 15.63\%$
12:00 till 1:00	1	95	$1/4 = 25.00\%$
1:00 till 2:30	1.5	90	$1.5/8 = 18.75\%$
2:30 till 4:00	1.5	95	$1.5/4 = 37.50\%$
Total	8		134.38%

The computed percentage is greater than 100% therefore the PEL has been exceeded.

Next consider how multiple machines (multiple noise levels) combine to influence the PEL. Turn to page 212 in the text. Review Figure 10.11 and note the four machines and their individual noise levels. In this example you must compute a combined TWA for the noise levels of these machines.

Noise is somewhat fickle, in that, the closer the decibel level of two machines are, the combined “resonance” is greater than it would be for only one machine. The more different the noise levels of two machines the less impact it has on the combined noise.

Review Table 10.1 on page 212 in the text. The left column’s description states, “Difference between two decibel levels...”, the right column states, “Amount to be added to larger level to obtain...” note if the difference is zero how 3 is added but if the difference is 12 very little is added. This has to do with the characteristics of sound waves, their amplitude and pitch.

Example #15. Turn to page 212 in the text and review Case Study 10.2. Suppose a worker is exposed to the following noise levels for various machines. Has the PEL been exceeded for this worker exposed to this environment?

For multiple machines the author of the text chose a simplistic approach in that he wanted the student exposed to the mechanics of how to compute the exposure. However understand this is a very simplistic approach and not the most precise.

To answer the question a decibel level must be calculated that combines the noise level for all four machines. To do this requires a systematic comparison of calculating the noise between the first and second machines, then the third, and finally the fourth.

The process is to compute the difference between the DBAs of the Machine A and Machine B, in the following example that difference is zero therefore according to Table 10.1, three (3) DBA’s is the “Amount to be added to larger level to obtain decibel sum”.

	DBA level	Difference between two machine’s DBA levels	Therefore add to larger...	
Machine A	86			
Machine B	<u>86</u>	0	3	86 + 3 = 89 DBA

Next compare the combined decibels from Machine A and B with Machine C.

	DBA level	Difference between two machine’s DBA levels	Therefore add to larger...	
Machine A & B	89			
Machine C	<u>82</u>	7	.8	89 + .8 = 89.8 DBA

Next compare the combined decibels from Machine A, B and C (89.8) with Machine D.

DBA level	Difference between two machine’s DBA levels	Therefore add to larger...
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Machine A, B & C	89.8			
Machine D	<u>78</u>	11.8	approx. .2	$89.8 + .2 = 90$ DBA

As you can see this is not very difficult. The 8-hour TWA for the three machines is 90 DBA's. How long can a worker be exposed to this level of noise? Go to Table 10.2 and note that the worker can be exposed for 8 hours at this noise level, therefore the PEL has not been exceeded.

It is important to caution the student NOT to rearrange the order of the machines in order to get a lower TWA. As mentioned earlier the author chose a simplistic approach. The order is actually based on the distance (measured in feet) the worker is from the machine. However the computations are somewhat complex and he chose not to introduce those computations into this text.

Example #16. A worker has been exposed to the following four machines and noise levels for an 8-hour work shift. Has the PEL been exceeded for this environment?

	DBA level	Difference	Therefore add	Combined DBA
Machine A	82			
Machine B	95	$82 - 95 = 7$	.8	$95 + .8 = 95.8$
Machine C	90	$95.8 - 90 = 5.8$	approx. 1.0	$95.8 + 1.0 = 96.8$
Machine D	90	$96.8 - 90 = 6.8$	approx. .8	$96.8 + .8 = 97.6$

Refer to Table 10.2 for the PEL that corresponds to an 8-hour TWA for 97.6 DBA's. The PEL is about 2.6 hours. The worker has worked 8 hours therefore the PEL has been exceeded.

Example #17. A worker has been exposed to the following five machines and noise levels for an 8-hour work shift. Has the PEL been exceeded for this environment?

	DBA level	Difference	Therefore add	Combined DBA
Machine A	90			
Machine B	95	$90 - 95 = 5$	1.2	$95 + 1.2 = 96.2$
Machine C	85	$96.2 - 85 = 11.2$	.3	$96.2 + .3 = 96.5$
Machine D	90	$96.5 - 90 = 6.5$	.9	$96.5 + .9 = 97.4$
Machine E	75	$97.4 - 75 = 22.4$	0	$97.4 + 0 = 97.4$

Refer to Table 10.2 for the PEL that corresponds to an 8-hour TWA for 97.4 DBA's. The PEL is about 3 hours. The worker has worked 8 hours therefore the PEL has been exceeded.

It is important to note the more machines running in a work environment the easier it is to exceed the PEL even though individual machines may not be very loud. Consider the following example.

Example #18. A worker has been exposed to the following five machines and noise levels for an 8-hour work shift. Has the PEL been exceeded for this environment?

	DBA level	Difference	Therefore add	Combined DBA
Machine A	85			
Machine B	85	$85 - 85 = 0$	3	$85 + 3 = 88$
Machine C	85	$88 - 85 = 3$	1.8	$88 + 1.8 = 89.8$
Machine D	85	$89.8 - 85 = 4.8$	1.2	$89.8 + 1.2 = 91.0$
Machine E	85	$91.0 - 85 = 6$	1.0	$91.0 + 1.0 = 92$

Refer to Table 10.2 for the PEL that corresponds to an 8-hour TWA for 92.0 DBA's. The PEL is about 6.2 hours. The worker has worked 8 hours therefore the PEL has been exceeded. Even though each machine's noise level is modest the combined level is considerable.

Now try these on your own. Answers and work are included at the end of this packet. The student may expect to see these type questions on the comprehensive portion of the test.

HW# 8: Page 225 Question 10.12 (a only)

HW# 9: Page 226 Question 10.18

HW# 10: A worker has been exposed to the following machines and noise levels for an 8-hour work shift. Has the PEL been exceeded for this environment? Make certain you compute the TWA, this is not a "yes/no" question.

	DBA level	Difference	Therefore add	Combined DBA
Machine A	84			
Machine B	80			
Machine C	86			
Machine D	90			
Machine E	75			

HW# 11: A worker has been exposed to the following machines and noise levels for an 8-hour work shift. Has the PEL been exceeded for this environment? Make certain you compute the TWA, this is not a "yes/no" question.

	DBA level	Difference	Therefore add	Combined DBA
Machine A	85			
Machine B	90			
Machine C	85			
Machine D	80			

## ANSWERS TO THE HOMEWORK ASSIGNMENTS.

HW# 1:

CO is the symbol for Carbon Monoxide

CO<sub>2</sub> is the symbol for Carbon Dioxide

From/To	Hrs.	Exp. CO	CiTi	Exp. CO <sub>2</sub>	CiTi	Exp. IO.	CiTi	Exp. Mg.	CiTi
8:00 till 10:00	2	10	20	1000	2000	1	2	1	2
10:00 till 12:00	2	20	40	1000	2000	4	8	1	2
12:00 till 1:00	1	25	25	1000	1000	2	2	0	0
1:00 till 4:00	3	30	90	1000	3000	3	9	1	3
Total	8		175		8000		21		7

Carbon Monoxide's TWA  $175/8 = 21.88 =$

Carbon Dioxide's TWA  $= 8000/8 = 1000 =$

Iron Oxide fume's TWA  $= 21/8 = 2.625 =$

Manganese fume's TWA  $= 7/8 = .875 =$

Total %'s =

TWA/PEL  $= 21.88/50 = 43.76\%$

TWA/PEL  $= 1000/5000 = 20.00\%$

TWA/PEL  $= 2.6/10 = 26.25\%$

TWA/PEL  $= .875/5 = 17.50\%$

107.51%

Yes the PEL has been exceeded.

HW# 2: Methanol has a PEL of 200 ppm.

From/To	Hrs.	Exp. Methanol	CiTi	Exp. Nitric Oxide	CiTi	Exp. Sulfur Dioxide	CiTi
8:00 till 10:00	2	50	100	5	10	0	0
10:00 till 11:00	1	150	150	10	10	1	1
11:00 till 1:00	2	100	200	5	10	1	2
1:00 till 4:00	3	200	600	10	30	1	3
Total	8		1050		60		6

Methanol's TWA  $1050/8 = 131.25 =$

Nitric Oxide's TWA  $= 60/8 = 7.5 =$

Sulfur Dioxide's TWA  $= 6/8 = .75 =$

Total %'s =

TWA/PEL  $= 131.25/200 = 65.63\%$

TWA/PEL  $= 7.5/25 = 30.00\%$

TWA/PEL  $= .75/5 = 15.00\%$

110.63%

Yes the PEL has been exceeded.

HW# 3: Assume the PEL for Isopropyl Ether is 500 ppm.

Assume the PEL for Ethyl Benzene is 100 ppm.  
 Assume the PEL for Chlorobenzene is 75 ppm.  
 Assume the PEL for Chlorobromomethane is 200 ppm.

Contaminant	TWA	PEL	TWA/PEL as a percentage
Isopropyl Ether	200	500	200/500 = 40.00%
Ethyl Benzene	40	100	40/100 = 40.00%
Chlorobenzene	25	75	25/75 = 33.33%
Chlorobromomethane	50	200	50/200 = 25.00%
Total			<u>138.33%</u>

Yes the PEL has been exceeded.

HW# 4: Assume the PEL for Ammonium Sulfide is 15 ppm.  
 Assume the PEL for Acetic Anhydride is 5 ppm.  
 Assume the PEL for Sodium Hydroxide is 5 mg/m<sup>3</sup>.  
 Assume the PEL for is Carbon Disulfide is 20 ppm..  
 Assume the PEL for Calcium Bisulfide is 20 ppm.  
 Assume the PEL for Sodium Sulfide is 5 mg/m<sup>3</sup>.  
 Assume the PEL for Sodium Sulfite is 5 mg/m<sup>3</sup>.

Contaminant	8 hour TWA	TWA	TWA/PEL as %
Acetic Anhydride	4 * .5 = 2.0 4 * 1 = 4.0	6/ 8 = .75	.75/5 = 15.00%
Sodium Hydroxide	4 * .2 = .8 4 * .3 = 1.2	2/8 = .25	.25/5 = 5.00%
Ammonium Sulfide	4 * 3 = 12 4 * 4 = 16	28/8 = 3.5	3.5/15 = 23.33%
Calcium Bisulfide	4 * 5 = 20 4 * 8 = 32	52/8 = 6.5	6.5/20 = 32.50%
Carbon Disulfide	4 * 4 = 16 4 * 6 = 24	40/8 = 5	5/20 = 25.00%
Sodium Sulfide	4 * .7 = 2.8 4 * .8 = 3.2	6/8 = .75	.75/ 5 = 15.00%
Sodium Sulfite	4 * .5 = 2.0 4 * .5 = 2.0	4/8 = .5	.5/5 = 10.00%
Total			<u>125.83%</u>

Yes the PEL has been exceeded.

HW# 5: Suppose a worker was exposed to Ammonia, Carbon Dioxide and Cychohexanol during an 8-hour workday. The concentrations and exposure times are as follows.

Hours	Exp. Ammonia	CiTi	Exp. Carbon Dioxide	CiTi	Exp. Cychonhexanol	CiTi
1.5	40	60	1500	2250	35	52.5

2	30	60	1650	3300	30	60
2.5	25	62.5	2000	5000	35	87.5
2	20	40	1800	3600	30	60
8		160		14150		260

Ammonia's TWA =  $160/8 = 20 =$  TWA/PEL =  $20/50 = 40.00\%$   
 Carbon Dioxide's TWA =  $14150/8 = 1768.75 =$  TWA/PEL =  $1768.75/5000 = 35.38\%$   
 Cychohexanol TWA =  $260/8 = 32.5 =$  TWA/PEL =  $32.5/50 = 65.00\%$   
 Total %'s = 140.38%

Yes the PEL and AL have been exceeded.

HW# 6: Suppose a worker is exposed to Ammonia during an 8-hour workday with the times and concentrations listed below.

From/To	Hours	Exposure (ppm's)	CiTi
8:00 till 8:45	.75	35	26.25
8:45 till 10:00	1.25	40	50
10:00 till noon	2	50	100
Noon till 2:30	2.5	40	100
2:30 till 4:00	1.5	45	67.50
Total			<u>343.75</u>

Ammonia's TWA =  $343.75/8 = 42.97 =$  TWA/PEL =  $42.97/50 = 85.94\%$

In this example the PEL is not exceeded. It should be noted that the TWA is 42.97 and the PEL is 50 ppm. The percentage did not have to be computed but for clarification it was done. If the 8-hour TWA is less than the PEL it has not been exceeded. In this case the AL has been exceeded.

HW# 7: Suppose a worker is exposed to Dioxane and Carbon Dioxide during an 8-hour workday with the times and concentrations listed below.

From/To	Hours	Dioxane Exp.	CiTi	Carbon Dioxide Exp.	CiTi
8:00 till 9:30	1.5	55	82.50	3500	5250
9:30 till 10:00	.5	80	40	5000	2500
10:00 till 11:00	1	60	60	2500	2500
11:00 till Noon	1	60	60	2400	2400
noon till 3:00	3	45	135	3600	10800
3:00 till 4:00	1	60	60	4200	4200
Total	8		<u>437.50</u>		<u>27650</u>

Dioxane's TWA =  $437.50/8 = 54.69 =$  TWA/PEL =  $54.69/100 = 54.69\%$   
 Carbon Dioxide TWA =  $27650/8 = 3456.25 =$  TWA/PEL =  $3456.25/5000 = 69.13\%$   
 Total 123.82%

The PEL has been exceeded for this combination of chemicals, and the AL also.

HW# 8:

	DBA level	Difference	Therefore add	Combined DBA
Machine 1	80			
Machine 2	86	$80 - 86 = 6$	1.0	$86 + 1 = 87$
Machine 3	93	$93 - 87 = 6$	1.0	$93 + 1.0 = 94$
Machine 4	70	$94 - 75 = 19$	0	$0 + 94 = 94$

Refer to Table 10.2 for the PEL that corresponds to an 8-hour TWA for 94.0 DBA's. The PEL is about 4.6 hours. The worker has worked 8 hours therefore the PEL has been exceeded.

HW# 9:

From/To	Hours	Noise level (DBA)	Time Exposure/PEL as a %
8:00 till 9:00	1	86	$1/13.9 = 7.19\%$
9:00 till 11:00	2	84	$2/18.4 = 10.87\%$
11:00 till 12:00	1	81	$1/27.9 = 3.58\%$
12:00 till 1:00	1	101	$1/1.7 = 58.82\%$
1:00 till 4:00	3	75	na
Total	8		80.46%

The computed percentage is less than 100% therefore the PEL has not been exceeded.

HW# 10:

	DBA level	Difference	Therefore add	Combined DBA
Machine A	84			
Machine B	80	$84 - 80 = 4$	1.4	$84 + 1.4 = 85.4$
Machine C	86	$85.4 - 86 = .6$	about 2.8	$86 + 2.6 = 88.6$
Machine D	90	$90 - 88.6 = 1.4$	about 2.4	$90 + 2.4 = 92.4$
Machine E	75	na	0	$0 + 92.4 = 92.4$

The TWA for this environment is 92.4 DBA. This worker worked 8 hrs, the PEL is 6.2 hours, therefore the PEL has been exceeded.

HW# 11:

	DBA level	Difference	Therefore add	Combined DBA
Machine A	85			
Machine B	90	$90 - 85 = 5$	1.2	$90 + 1.2 = 91.2$

Machine C	85	$91.2 - 85 = 6.2$	1.0	$91.2 + 1 = 92.2$
Machine D	80	$92.2 - 80 = 12.2$	.1	$92.2 + .1 = 92.3$

The TWA for this environment is 92.3 DBA. This worker worked 8 hrs, the PEL is 6.2 hours, therefore the PEL has been exceeded.