Chemical Engineering 4310
Fall Semester, 2006
Homework Assignment #1
Chapters 1 and 2
(For return in marked box in hall of 2nd floor
Chemical Sciences by noon on Friday, September 15)

Work problems 1-1, 1-4, 1-8, 1-18, 1-20, 1-25, 2-2, 2-3 and 2-17 in the text

1. The following data was found on the CNN website on August 29, 2005. It does not reference a source! The data are for 2004.

Occupation	Total Deaths	Deaths/100,000 workers
Logging workers:	85	92.4
Aircraft pilots:	109	92.4
Fishers and fishing workers:	38	86.4
Structural iron and steel:	31	47.0
Refuse:	35	43.2
Farmers:	307	37.5
Roofers:	94	34.9
Electrical power line:	36	30.0
Truck and other drivers:	905	27.6
Taxi drivers:	67	24.2

Calculate an FAR for each type of worker and compare to any existing data. Also compute an OSHA incident rate based on fatalities. Assume that each worker works 40 hours per week for 50 weeks per year.

Credits

1-1:	5	1-25:	10
1-4:	10	2-2:	20
1-8:	10	2-3:	10
1-18:	5	2-17:	10
1-20:	5	1:	15
			100 Total

$\boxed{1\text{-}1}$ FAR = 4 @ 10^8 exposed hours

Deaths per person per year

$$= \left(\frac{4 \text{ hrs}}{\text{shift}}\right)\left(\frac{200 \text{ shifts}}{\text{year}}\right)\left(\frac{4 \text{ deaths}}{10^8 \text{ hrs}}\right)$$

$$= \underline{3.2 \times 10^{-5}} \text{ deaths/person-year}$$

$\boxed{1\text{-}4}$ Normal working hours are approximately 2000 hours per year. For 500 years, we have

$$(500 \text{ years})\left(\frac{2000 \text{ hrs}}{\text{year}}\right) = 1 \times 10^6 \text{ hours}$$

We can assume 1 death every 10^6 exposed hours. But FAR's are based on 10^8 exposed hours. This means

$$\frac{10^8}{10^6} = 100 \text{ deaths per } 10^8 \text{ hours} \quad \therefore \text{FAR} = 100$$

The workers should be alarmed! For an average chemical plant, $\underline{\text{FAR} = 4}$ deaths/10^8 hrs

$$\text{Deaths per year} = (2000 \text{ hrs})\left(\frac{4 \text{ deaths}}{10^8 \text{ hrs}}\right) = \underline{8 \times 10^{-5}}$$

$$\text{Years per death} = \frac{1}{8 \times 10^{-5}} = 12{,}500$$

Chances should be <u>1 in 12,500</u> years of exposure.

$\boxed{1\text{-}8}$ Airline industry has fewest deaths per passenger mile, <u>but</u>, due to high rate of speed of the aircraft, many miles are accumulated. From Table 1-4, FAR for:

Car - 57
Bicycle - 96
Air - 240

Thus, on a <u>per hour</u> basis, travelling by plane is almost <u>5 times</u> more dangerous than travelling by car.

To compute the FAR, we need the total hours exposed. This would require an average speed. Suppose the average speed is 200 MPH.

$$\text{Total hours exposed} = \frac{10 \times 10^6 \text{ miles}}{200 \text{ mi/hr}}$$

$$= 50{,}000 \text{ hrs}$$

$$\text{FAR} = \frac{4 \times 10^8}{50{,}000 \text{ hrs}} = \underline{8{,}000}$$ which is larger than the 240 reported in Table 1-4.

A fatality rate would require the total number of passengers in the 10^7 miles, Suppose each trip averaged 300 miles.

$$\text{Total passengers} = \frac{10^7 \text{ miles}}{300 \text{ mi/person}} = 33{,}333 \text{ passengers}$$

$$\text{Fatality rate} = \frac{4}{33{,}333} = 1.2 \times 10^{-4}$$, which is high

Solution Problem 1-20

1-20) Loosen bolts but do not remove. The pry up cover. If liquid comes out retighten bolts to stop flow.

Solution Problem 1-18

1-18) Operator depended on alarm to alert him/her to high level rather than pay attention to actual level. Failure rate of high level alarm was higher than operator.

1-25 Another way of measuring accident performance is by the LTIR or Lost Time Injury Rate. This is identical to the OSHA incidence rate based on incidents in which the employee is unable to continue their normal duties.

A plant site has 1200 full-time employees working 40 hours per week and 50 weeks per year. If it had two lost time incidents last year, what is the LTIR?

Solution:

$$LTIR = \frac{(\text{No. of lost time incidents})}{\text{Total hours worked}} (200{,}000 \text{ hrs})$$

$$\text{Total hours worked} = (1200 \text{ employees})\left(40 \frac{\text{hrs}}{\text{wk}}\right)\left(50 \frac{\text{wk}}{\text{yr}}\right)$$

$$= 2.4 \times 10^6 \text{ Hrs}$$

$$LITR = \frac{(2)(200{,}000)}{2.4 \times 10^6} = 0.167$$

This is low; 2 or 3 is typical

$\boxed{2\text{-}2}$

Dose (mg/ℓ)	Log (Dose)	No. of Insects	No. Affected	%	Probit
10.2	1.01	50	44	88.0	6.18
7.7	0.886	49	42	85.7	6.07
5.1	0.708	46	24	52.2	5.06
3.8	0.580	48	16	33.3	4.57
2.6	0.415	50	6	12.0	3.82
0	—	49	0	0	—

The probit variables were read from Table 2-3.
Plots are given on the next page.
The straight line on the probit plot was "eyeball" best fit.

Slope of the probit curve is $\frac{1.2}{0.30} = 4.0$

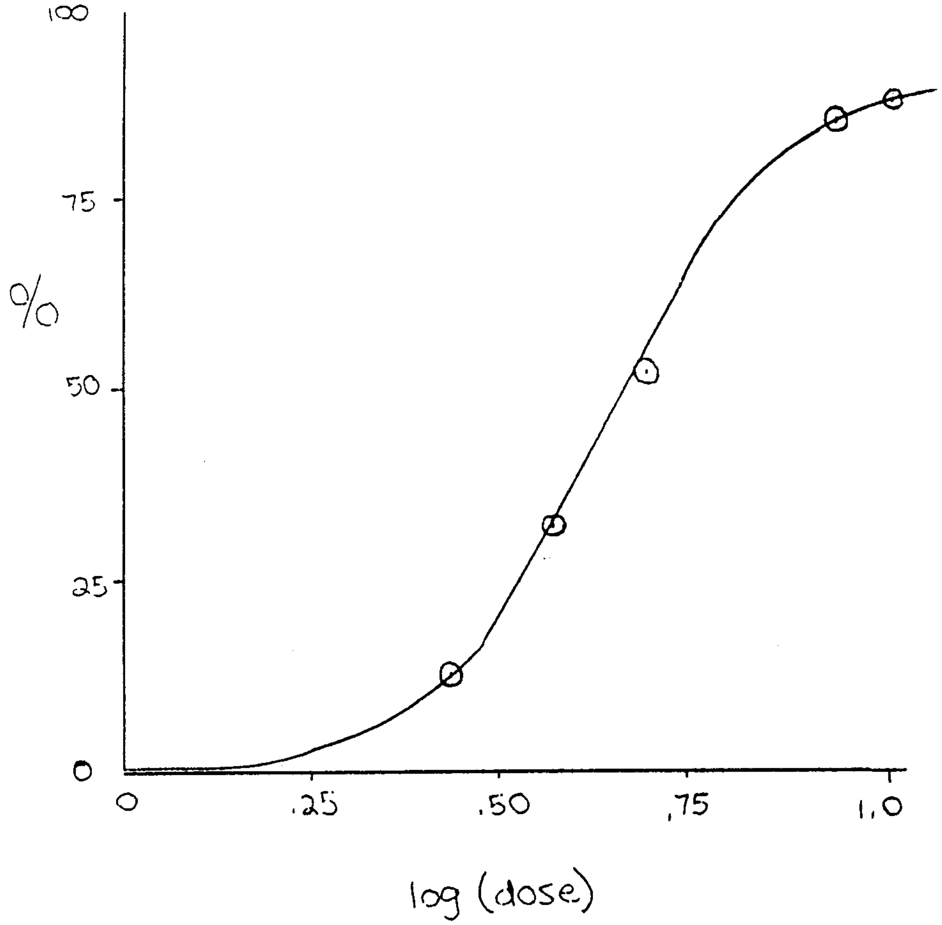
Then $y = 4 \log(\text{dose}) + \text{intercept}$

@ $Y = 5.2$, $\log(\text{dose}) = 0.75$, so

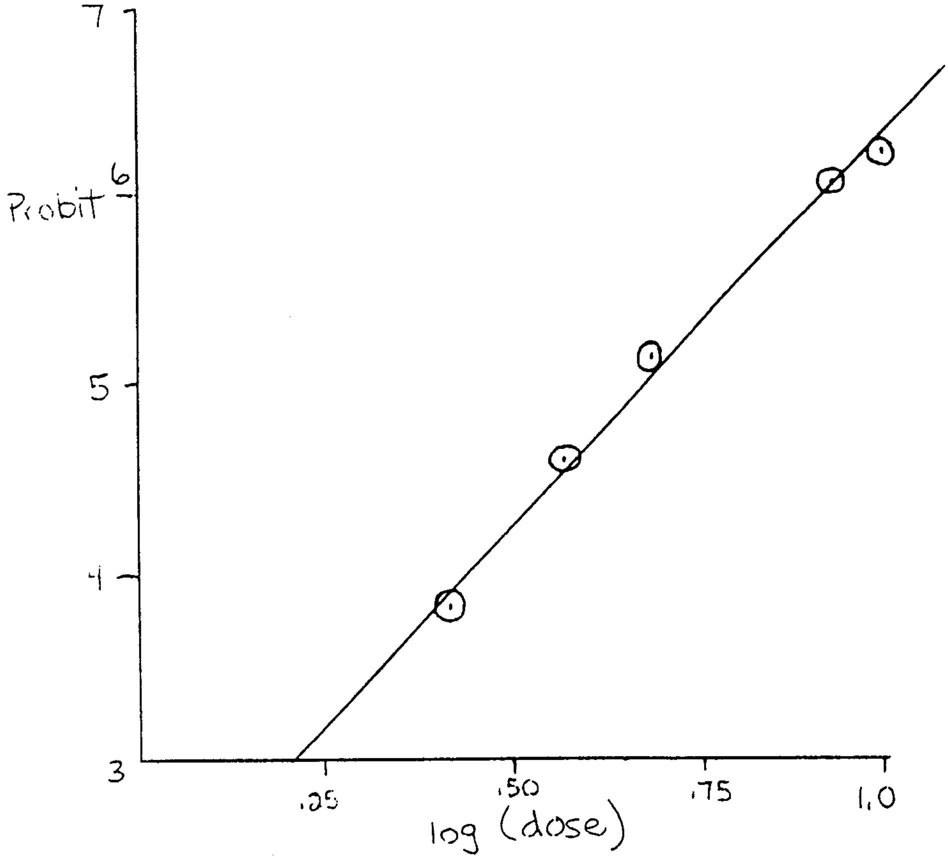
$\text{intercept} = 5.2 - 4(0.75) = 2.2$

$\boxed{Y = 4 \log\left(\frac{mg}{\ell}\right) + 2.2}$ OR

$Y = 1.74 \ln\left(\frac{mg}{\ell}\right) + 2.2$ (since $\ln = 2.3 \log$)


100
75
%
50
25
0
0
.25
.50
.75
1.0
log (dose)

(a)


7
Probit
6
5
4
3
.25
.50
.75
1.0
log (dose)

(b)

Comparison

Dose (mg/l)	Probit	No. Affected	Predicted Probit	Predicted %	Predicted No. Affected
10.2	6.18	44	6.23	89	44.5
7.7	6.07	42	5.74	77	37.7
5.1	5.06	24	5.03	51	23.5
3.8	4.57	16	4.52	31.5	15.1
2.6	3.82	6	3.86	12.8	6.4

$\boxed{2\text{-}3}$ Overpressure = 47,000 N/m^2

From Table 2-4:

Structural damage: $Y = -23.8 + 2.92 \ln p^{\circ}$

Deaths from lung hemorrhage: $Y = -77.1 + 6.91 \ln p^{\circ}$

Eardrums: $Y = -15.6 + 1.93 \ln p^{\circ}$

For $p^{\circ} = 47{,}000 \ N/m^2$

Structural damage: $Y = 7.61$

Deaths (lung hem): $Y = -2.76$

Eardrums: $Y = 5.163$

From Table 2-~~5~~4

	Percent Affected
Structural damage:	99.6
Deaths (lung hem):	0 (Y is negative)
Eardrums	56

The blast is not serious enough to expect fatalities, but is serious enough to cause extensive damage to surrounding structures and to rupture the eardrums of more than half of the people exposed. Additional injuries from debris might be expected.

$\boxed{2\text{-}17.}$ Solution:

$$50\% \equiv 5 \text{ probits}$$

$$Y = -6.18 + \ln CT$$

$$Y = -6.18 + \ln C(30)$$

$$5 + 6.18 = \ln C(30)$$

$$11.18 = \ln C(30)$$

$$e^{11.18} = C(30) = 71682$$

$$C = 71682/30 = 2389 \text{ ppm}$$

This is higher than the IDLH.

①

SOLUTION ~ Problem 1

1.) Use as a basis 100,000 workers. Compute total time worked by these 100,000 workers.

$$(100{,}000 \text{ workers})\left(\frac{2000 \text{ hours}}{\text{worker}}\right) = 2 \times 10^8 \text{ hours.}$$

FAR is based on 1×10^8 hours.

Thus $\boxed{FAR = \frac{\text{Deaths}/100{,}000 \text{ workers}}{2}}$

The OSHA incident rate is based on 200,000 hours of exposure

Thus $\boxed{\text{OSHA rate} = \frac{\text{Deaths}/100{,}000 \text{ workers}}{1000}}$

Results follow

	Deaths/100,000	Calc FAR	Pub FAR	Calc OSHA	Pub OSHA
Logging:	92.4	46.2		0.092	
Aircraft:	92.4	46.2		0.092	
Fishers	86.4	43.2		0.086	
Structural	47.0	23.5	5.0	0.047	1.28
Refuse	43.2	21.6		0.043	
Farmers	37.5	18.8	3.7	0.037	0.89
Roofers	34.9	17.5		0.035	
Electrical	30.0	15.0		0.030	
Truck	27.6	13.8		0.028	2.10
Taxi	24.2	12.1		0.024	

Difficult to compare since categories are not quite the same. FARs seem high. OSHA rate here is based only on fatalities while published rates include days away from work. If we multiply our OSHA fatality rate by a factor of 100 from accident pyramid (Fig. 1-3) we get closer values.