1. Investigate installing a wind turbine at a site with mean wind speed = 6 m/s. Electricity costs 0.15 $/kWhr. The turbine is $2.5 M to purchase and install plus $150,000 a year to operate and maintain. Use a MARR of 5 %. Determine the discounted Payback Period. Use the Table on the right and the Rayleigh distribution to determine wind turbine revenues. Use Excel to solve this problem, but handwrite sample calculations below your spreadsheet printout. CLEARLY document your solution. (10 pts)

Wind Range		**Power in Range, kW**
Low (L)	**High (H)**	
0	3	0
3	5	200
5	7	500
7	9	800
9	11	1200
11	13	1450
13	15	1500
15	18	1500

Solution: Rayleigh is $F(u,\overline{U}) = 1 - e^{-\frac{\pi}{4}\left(\frac{u}{\overline{U}}\right)^2}$; $\overline{U} = 6\ m/s$

Wind Range		**Power in Range, kW**	**Probability of Range**	**Hours/year**	**kWhr**
Low (L)	**High (H)**				
0	3	0	0.178	1561.7	0
3	5	200	0.242	2121.0	424201
5	7	500	0.236	2069.6	1034793
7	9	800	0.173	1511.3	1209069
9	11	1200	0.099	871.1	1045366
11	13	1450	0.046	405.8	588458
13	15	1500	0.018	154.7	232119
15	18	1500	0.007	57.2	85809
		Sum →	0.999	8752.5	4619815

Year	$k	PW, $k	Cml., $k		
				Annual Revenue, $	692972
0	-2,500	-2,500	-2,500		
1	543	517	-1983	Top Table:	
2	543	493	-1490	Col4 = F(col2,6) – F(col1,6)	
3	543	469	-1021	Col5 = Column 4 x 365 x 24	
4	543	447	-575	Col6 = Col3 x Col5	
5	543	425	-149	Annual Revenue = (Sum Col6) x 0.15	
6	543	405	256		

Bottom Table:
Col2: $543,000 = $692,972 - $150,000
Col3 = Col2 x (1+0.05)^Col1
Col4 is progressive sum on Col3

Payback is in 6 years.

2. Can a single scale house be used to weight trucks at a transfer station? The truck average arrival rate is 0.8 trucks/minute. The average scale service time is 1.2 trucks/minute. (a) Determine the utilization factor. (b) Determine the average number of trucks in the queue. (c) Determine the average wait time of trucks in the queue. (d) Determine the probability that ≤n trucks are in the system (queue + scale) for n = 0 to 7. Is the driveway long enough, it can hold 4 trucks (plus one on the scale), if the driveway capacity can be exceeded only 5 % of the time? (10 pts)

Solution:

0.8	Mean Arrival Rate, veh/min = (λ)		Given
1.2	Mean Service Rate, veh.min = (μ)		Given
0.7	Utilization Factor= (ρ)		
1.3	Average number of trucks in queue = E(m)		
1.7	Average waiting time of truck = E(w)		
n	p(n)	Sum(p(n))	
0	0.333	0.333	
1	0.222	0.556	
2	0.148	0.704	
3	0.099	0.802	
4	0.066	0.868	
5	0.044	0.912	
6	0.029	0.941	
7	0.020	0.961	

n = number of trucks in queue and on scale
m = number of trucks in queue (n = m + 1)
w = truck weight time

$\rho = \lambda/\mu$

$E(m) = \frac{\rho^2}{1-\rho}$ $\qquad E(w) = \frac{\lambda}{\mu(\mu-\lambda)}$

$p(0) = 1 - \rho$ $\qquad p(n) = \rho^n p(0)$

Is the driveway long enough? P(n≥5) = 1 - 0.912 = 0.088, so the driveway capacity is exceeded more than 5 % of the time. It is NOT long enough.

3. Investigate whether the exponential distribution can be used to model the time until the next breakdown of an excavator. Use the sample to the right. (a) What is the average time between breakdowns? Is this λ? (b) What is the average number of breakdowns per hour? Is this λ? (c) Determine the plotting position for each data point. (d) Estimate X' for each point, using the inverse of the exponential function ($t = -\ln(\alpha) / \lambda$, where α = the probability in the right tail, i.e., one minus the plotting position). (e) Plot X versus X' and add a trendline with equation and R^2.

T, Ranked time between breakdowns, hr
5
11
18
25
34
46
60
80
120

(f) Based on the plot, do you think the exponential distribution can be used to model the time until the next excavator breakdown? Use Excel to solve this problem, but handwrite sample calculations below your spreadsheet printout. CLEARLY document your solution. (10 pts)

I recommend actually completing the hand calculations, as a check of your spreadsheet.

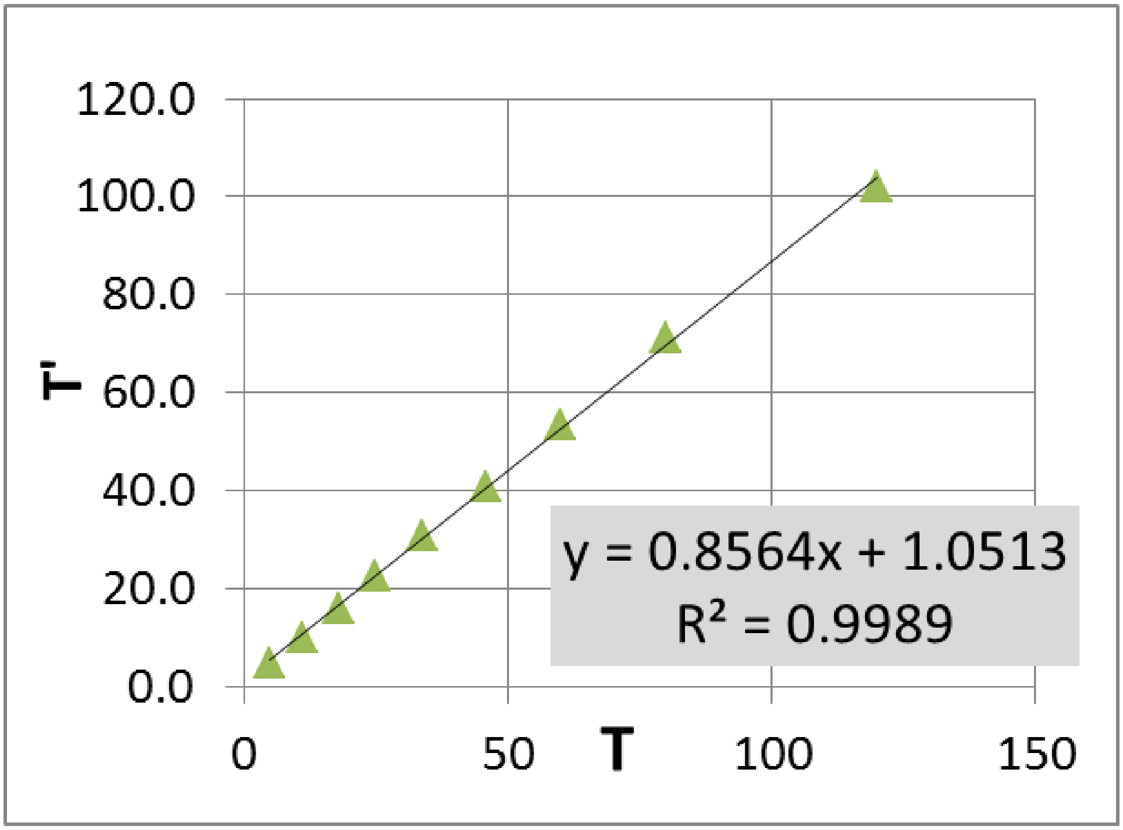
Solution:

(a) Average time between breakdowns = average of col2 = 44.3 hour between breakdowns
(b) λ = average breakdowns/hr = 1/part(a) answer = 0.0226 breakdowns/h
(c) (d)

Rank	T	PP	T'
1	5	0.1	4.7
2	11	0.2	9.9
3	18	0.3	15.8
4	25	0.4	22.6
5	34	0.5	30.7
6	46	0.6	40.6
7	60	0.7	53.4
8	80	0.8	71.4
9	120	0.9	102.1

PP = Rank/(9+1)
T' = -ln(1-PP) / 0.0226

(e)



(f) The R^2 is high. It appears that the exponential distribution models this data well.