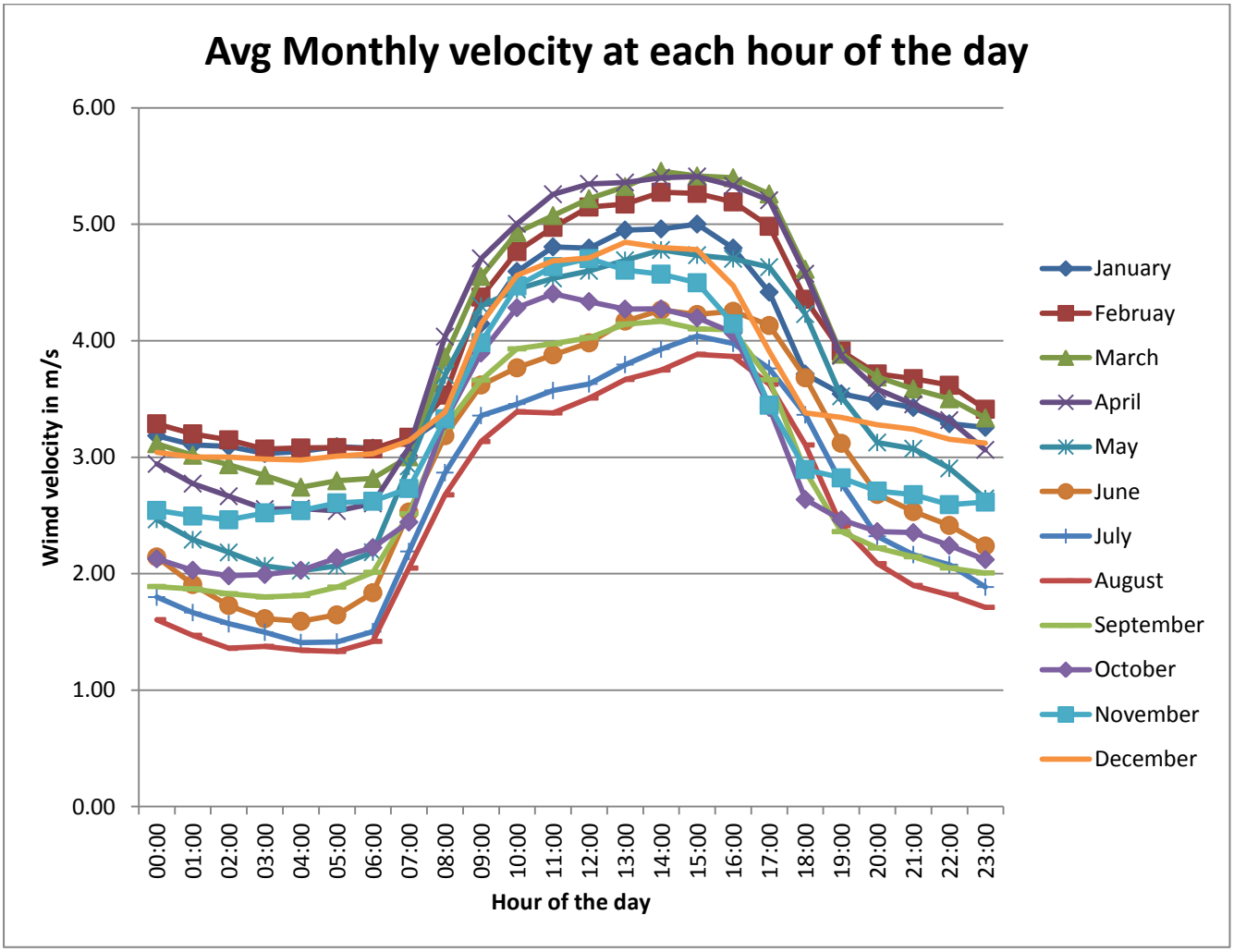
Question 1

The Wind hourly average wind speed for the year of 2010 has been obtained for the BATON ROUGE RYAN AIRPORT, LA, US. *Data obtained from http://www.ncdc.noaa.gov/cdo-web/ . Data was interpreted using info available in ftp://ftp.ncdc.noaa.gov/pub/data/globalsod/readme.txt.*

Site:	BATON ROUGE RYAN AIRPORT, LA, US.
Wind Station:	GHCND:USW00013970
Elevation:	19.5 m
Latitude:	30.53722
Longitude:	-91.14694

Question 2

The overall mean is **3.34** and the overall standard deviation is **1.07**
The energy pattern factor is **0.76** which indicates slight skewness in the velocity.
The graph of the mean value of wind velocity at different hours of the day for each month is shown below.



The complete table is shown in the following section, the mean and the Standard deviations have also been calculated.

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	Month													
	Hours	January	February	March	April	May	June	July	August	September	October	November	December	Overall
Mean	00:00	3.18	3.29	3.12	2.94	2.47	2.14	1.80	1.60	1.89	2.13	2.54	3.04	2.51
Std Dev	00:00	0.06	0.06	0.15	0.11	0.13	0.20	0.14	0.04	0.09	0.07	0.20	0.11	0.58
Mean	01:00	3.10	3.20	3.02	2.77	2.29	1.91	1.67	1.47	1.87	2.03	2.50	3.00	2.40
Std Dev	01:00	0.05	0.05	0.11	0.17	0.14	0.18	0.09	0.07	0.10	0.06	0.21	0.14	0.60
Mean	02:00	3.09	3.15	2.94	2.66	2.18	1.73	1.57	1.36	1.83	1.98	2.46	3.00	2.32
Std Dev	02:00	0.06	0.05	0.11	0.16	0.23	0.16	0.08	0.06	0.13	0.12	0.17	0.17	0.63
Mean	03:00	3.03	3.07	2.84	2.56	2.07	1.61	1.50	1.38	1.80	1.99	2.52	2.98	2.27
Std Dev	03:00	0.05	0.05	0.07	0.17	0.26	0.11	0.07	0.06	0.13	0.10	0.18	0.19	0.62
Mean	04:00	3.05	3.08	2.74	2.56	2.03	1.59	1.41	1.34	1.81	2.03	2.54	2.98	2.26
Std Dev	04:00	0.04	0.07	0.09	0.19	0.24	0.10	0.05	0.08	0.12	0.10	0.18	0.13	0.63
Mean	05:00	3.09	3.08	2.80	2.54	2.07	1.65	1.41	1.33	1.88	2.14	2.61	3.01	2.30
Std Dev	05:00	0.06	0.05	0.09	0.15	0.22	0.11	0.07	0.08	0.15	0.12	0.14	0.10	0.63
Mean	06:00	3.08	3.07	2.82	2.60	2.18	1.84	1.50	1.42	2.01	2.22	2.62	3.03	2.36
Std Dev	06:00	0.06	0.08	0.08	0.15	0.21	0.08	0.10	0.11	0.13	0.07	0.15	0.15	0.58
Mean	07:00	3.14	3.17	3.00	3.08	2.92	2.53	2.19	2.05	2.51	2.44	2.73	3.14	2.74
Std Dev	07:00	0.08	0.11	0.05	0.07	0.14	0.17	0.07	0.09	0.13	0.11	0.10	0.15	0.39
Mean	08:00	3.35	3.53	3.86	4.03	3.71	3.18	2.87	2.68	3.26	3.31	3.33	3.39	3.37
Std Dev	08:00	0.06	0.07	0.10	0.11	0.17	0.24	0.10	0.08	0.18	0.09	0.04	0.08	0.39
Mean	09:00	4.15	4.37	4.55	4.71	4.30	3.62	3.36	3.13	3.66	3.89	3.98	4.15	3.99
Std Dev	09:00	0.08	0.10	0.07	0.13	0.24	0.28	0.08	0.04	0.24	0.04	0.07	0.08	0.48
Mean	10:00	4.60	4.77	4.93	5.00	4.44	3.77	3.46	3.39	3.93	4.28	4.47	4.56	4.30
Std Dev	10:00	0.05	0.07	0.04	0.12	0.26	0.22	0.07	0.04	0.22	0.05	0.05	0.08	0.54
Mean	11:00	4.81	4.97	5.07	5.26	4.54	3.88	3.57	3.38	3.97	4.40	4.64	4.68	4.43
Std Dev	11:00	0.06	0.08	0.07	0.08	0.34	0.18	0.11	0.07	0.27	0.06	0.09	0.08	0.60
Mean	12:00	4.80	5.15	5.22	5.35	4.60	3.98	3.63	3.51	4.03	4.34	4.71	4.71	4.50
Std Dev	12:00	0.09	0.09	0.05	0.10	0.33	0.18	0.12	0.06	0.21	0.09	0.12	0.07	0.60
Mean	13:00	4.95	5.17	5.32	5.36	4.69	4.17	3.80	3.67	4.14	4.27	4.61	4.85	4.58
Std Dev	13:00	0.09	0.07	0.09	0.08	0.29	0.25	0.09	0.10	0.11	0.07	0.18	0.08	0.57
Mean	14:00	4.96	5.27	5.45	5.40	4.78	4.26	3.93	3.75	4.17	4.27	4.57	4.80	4.63
Std Dev	14:00	0.09	0.10	0.10	0.08	0.22	0.12	0.11	0.12	0.07	0.10	0.12	0.08	0.56
Mean	15:00	5.00	5.27	5.41	5.41	4.73	4.23	4.04	3.88	4.10	4.20	4.50	4.78	4.63
Std Dev	15:00	0.09	0.10	0.04	0.09	0.25	0.18	0.05	0.10	0.06	0.07	0.15	0.09	0.54
Mean	16:00	4.80	5.19	5.40	5.33	4.70	4.25	3.98	3.86	4.09	4.07	4.14	4.47	4.52
Std Dev	16:00	0.10	0.11	0.08	0.12	0.19	0.17	0.08	0.11	0.06	0.05	0.08	0.11	0.54
Mean	17:00	4.42	4.98	5.26	5.21	4.63	4.13	3.76	3.63	3.66	3.43	3.45	3.91	4.20
Std Dev	17:00	0.14	0.19	0.04	0.09	0.20	0.16	0.06	0.04	0.04	0.13	0.11	0.16	0.66
Mean	18:00	3.71	4.36	4.61	4.58	4.23	3.68	3.36	3.10	2.88	2.64	2.89	3.38	3.61
Std Dev	18:00	0.10	0.22	0.05	0.07	0.13	0.28	0.08	0.07	0.08	0.05	0.22	0.12	0.68
Mean	19:00	3.54	3.91	3.88	3.87	3.52	3.12	2.78	2.41	2.36	2.46	2.82	3.34	3.16
Std Dev	19:00	0.10	0.08	0.03	0.07	0.12	0.21	0.13	0.07	0.06	0.09	0.15	0.11	0.58
Mean	20:00	3.48	3.72	3.69	3.58	3.13	2.68	2.32	2.09	2.22	2.36	2.71	3.28	2.93
Std Dev	20:00	0.06	0.08	0.05	0.12	0.12	0.17	0.09	0.11	0.06	0.09	0.15	0.18	0.60
Mean	21:00	3.43	3.67	3.59	3.45	3.07	2.53	2.16	1.90	2.15	2.35	2.68	3.24	2.85
Std Dev	21:00	0.10	0.08	0.07	0.11	0.11	0.21	0.12	0.06	0.08	0.07	0.16	0.18	0.61
Mean	22:00	3.29	3.62	3.50	3.32	2.90	2.41	2.08	1.82	2.05	2.24	2.59	3.15	2.74
Std Dev	22:00	0.10	0.09	0.13	0.14	0.07	0.22	0.09	0.10	0.13	0.06	0.16	0.14	0.61
Mean	23:00	3.26	3.41	3.34	3.06	2.65	2.24	1.89	1.71	2.01	2.12	2.62	3.12	2.61
Std Dev	23:00	0.08	0.07	0.09	0.13	0.13	0.27	0.10	0.05	0.09	0.07	0.21	0.17	0.60
Mean	**Overall**	**3.80**	**4.02**	**4.02**	**3.94**	**3.45**	**2.96**	**2.67**	**2.49**	**2.85**	**2.98**	**3.30**	**3.67**	**3.34**
Std Dev	**Overall**	**0.75**	**0.85**	**1.01**	**1.12**	**1.05**	**0.99**	**0.95**	**0.95**	**0.95**	**0.94**	**0.87**	**0.73**	**1.07**

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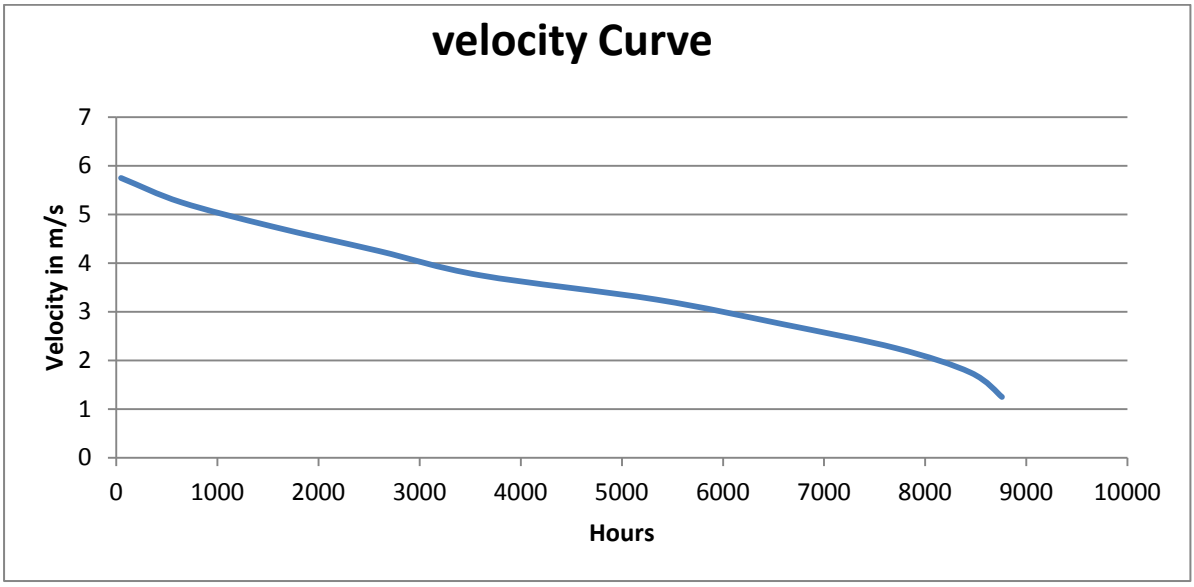
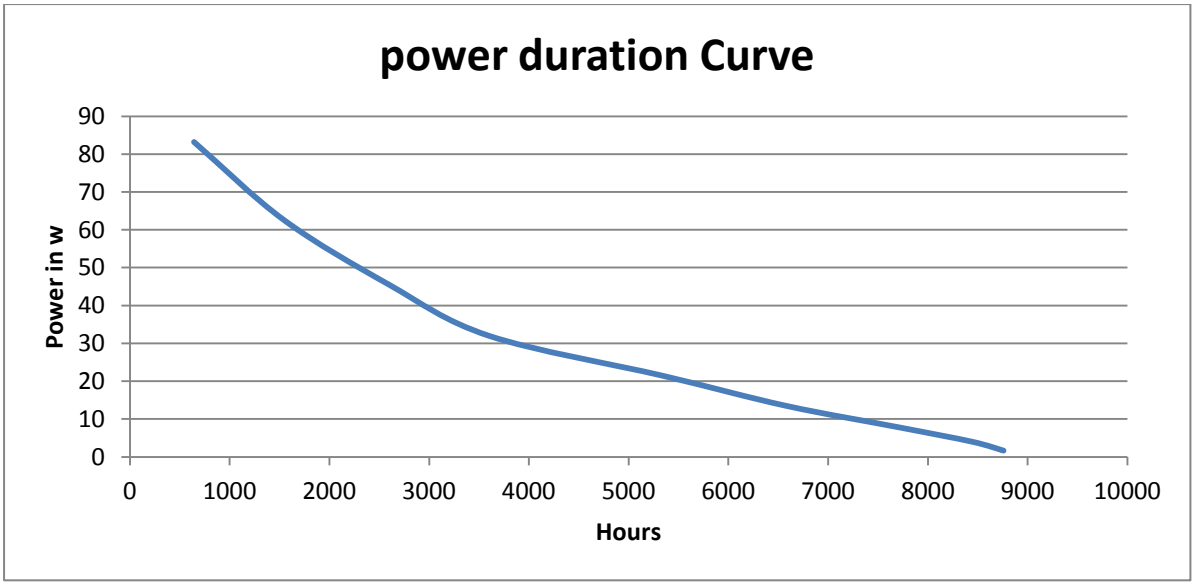
Question 3

The velocity and power duration curves have been shown below.





Question 4

The Power curve of the Enercon 70 has been obtained from the internet.

Technical Specifications

Rated Power:	2.3 KW
Swept Dia:	71m
No. of blades:	3
Swept area:	3,959 m
Cut-out wind speed:	28 - 34 m/s
Rotational speed:	6 - 21.5 rpm

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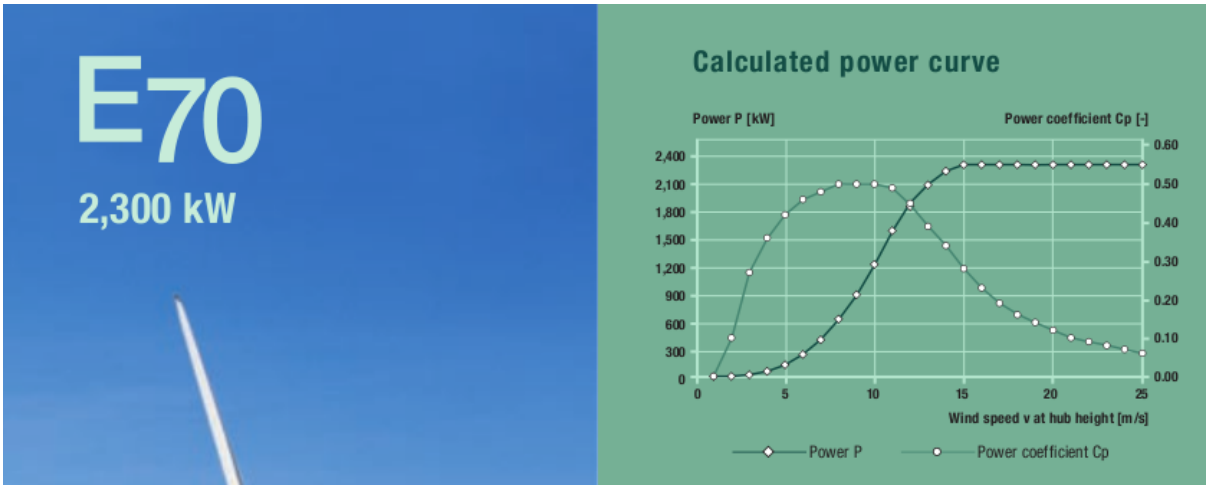

The Power curve values were also specified; hence no software was used to extract values from the graph specified here.

Wind Velocity m/s	Power P in KW	Coefficient Cp
1.00	0.00	0
3.00	18	0.27
4.00	56	0.36
5.00	127	0.42
6.00	240	0.46
7.00	400	0.48
8.00	626	0.5
9.00	892	0.5
10.00	1223	0.5
11.00	1590	0.49
12.00	1900	0.45
13.00	2080	0.39
14.00	2230	0.34
15.00	2300	0.28
16.00	2310	0.23
17.00	2310	0.19
18.00	2310	0.16
19.00	2310	0.14
20.00	2310	0.12
21.00	2310	0.1
22.00	2310	0.09
23.00	2310	0.08
24.00	2310	0.07
25.00	2310	0.06

Question 5

The histogram plotted for the obtained data is shown here.

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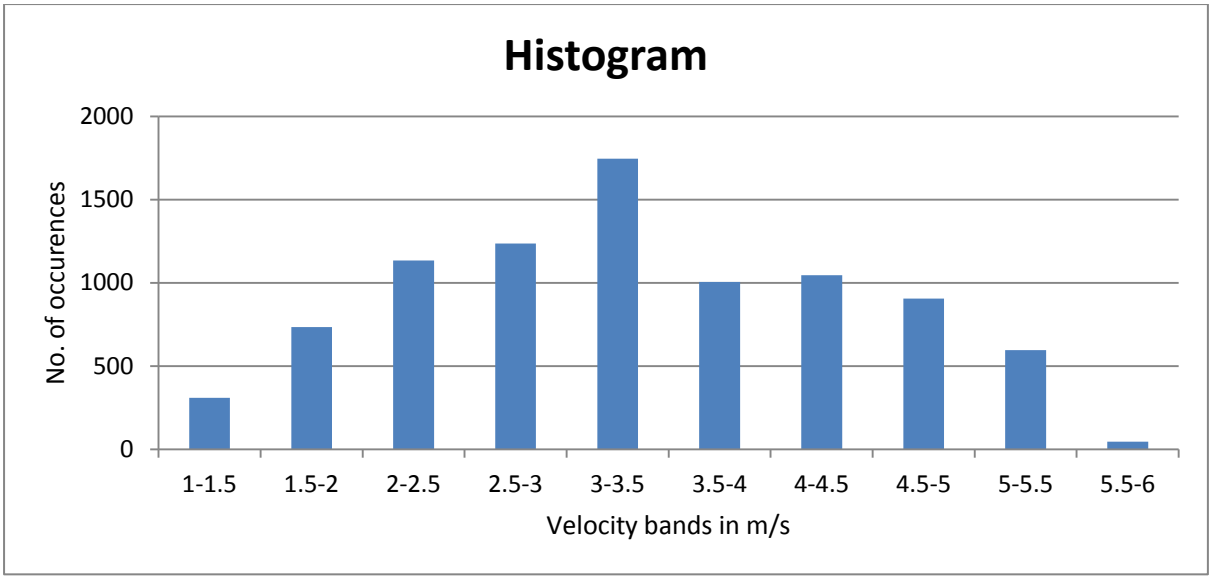

Question 6

A weibull Distribution has been fitted to the obtained data, as per the method discussed in class. The values of k and c obtained were,

k=3.0367

c=3.063841

The probability density function and relative speed of wind calculated is shown below.

Bins	f(u) - From Wind data	Pdf – (weibull)
1.0	0.035	0.098
1.5	0.084	0.206
2.0	0.129	0.316
2.5	0.141	0.382
3.0	0.199	0.372
3.5	0.115	0.291
4.0	0.119	0.180
4.5	0.103	0.087
5.0	0.068	0.032
5.5	0.005	0.009

A graph has been plotted for the same

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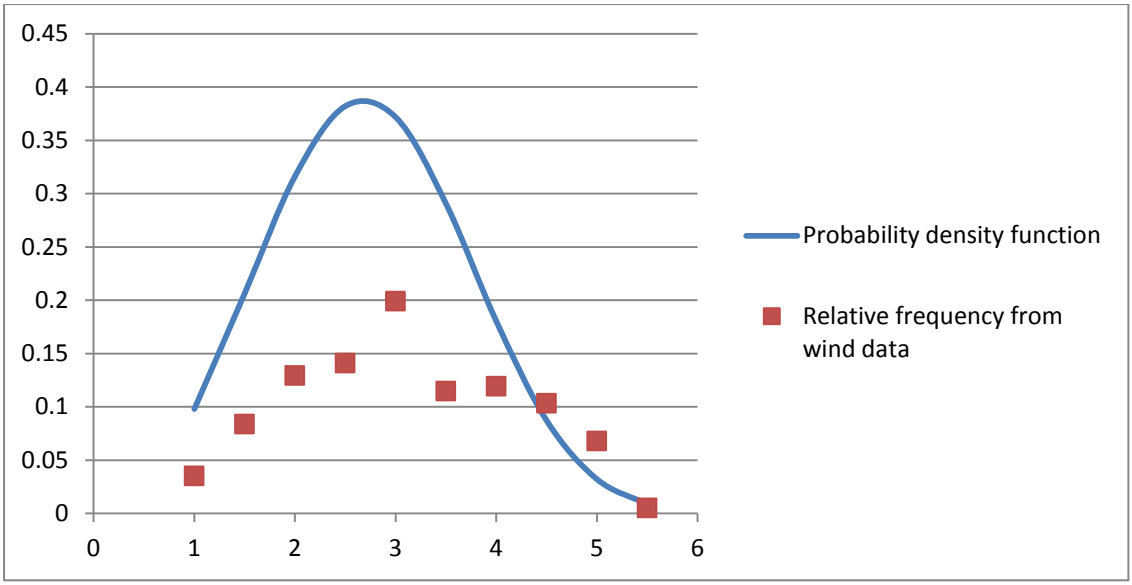


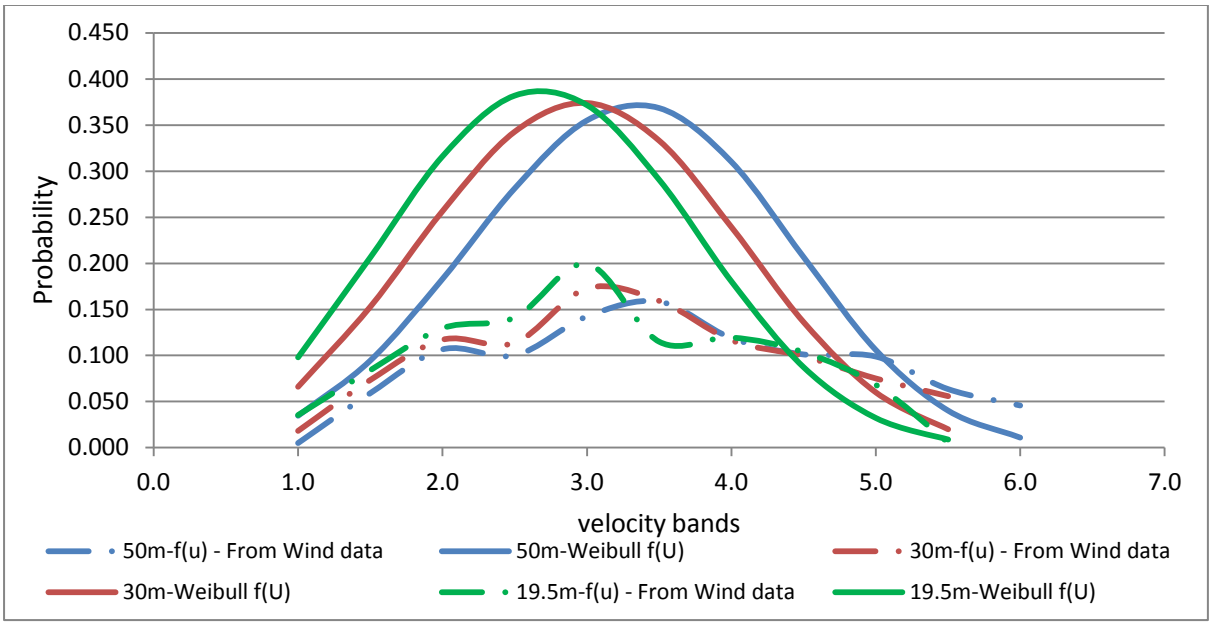
Question 7

As we were unable to find online data for different vertical elevations at the same site, the wind speed at two different heights has been found out using power law. Neutral stability conditions have been assumed and the value of alpha has been taken to be 1/7. The current data has been measured at 19.5m, further measurements has been made at 30m and 50m.

The calculated parameters for the weibull distribution are,

	50m	30m	19.5m
c	3.67	3.33	3.06
k	3.55	3.21	3.04

Where k is the shape parameter and c the scale parameter. The variation of probability distribution of the data and the corresponding weibull fits, with the height has been shown here.



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Question 8

The value for the power curve has been shown earlier as a part of Question 4. The Cp value of the machine has been approximated as a 9th order polynomial function of velocity, so that the power at different velocities can be calculated.

The coefficients for the same were calculated using matlab. The function is

Cp(v)=-4.0466*10^-10*V^9 + 4.922*10^-8*V^8 + -2.5148*10^-6*V^7 + 7*10^-5*V^6 - 0.0011521*V^5 + 0.011395*V^4 - 0.065593*V^3 + 0.19205*V^2 - 0.12057*V - 0.016113

The average power coefficient at each hour has been calculated for the whole year using the above function. And using Cp and velocity the power has also been calculated.

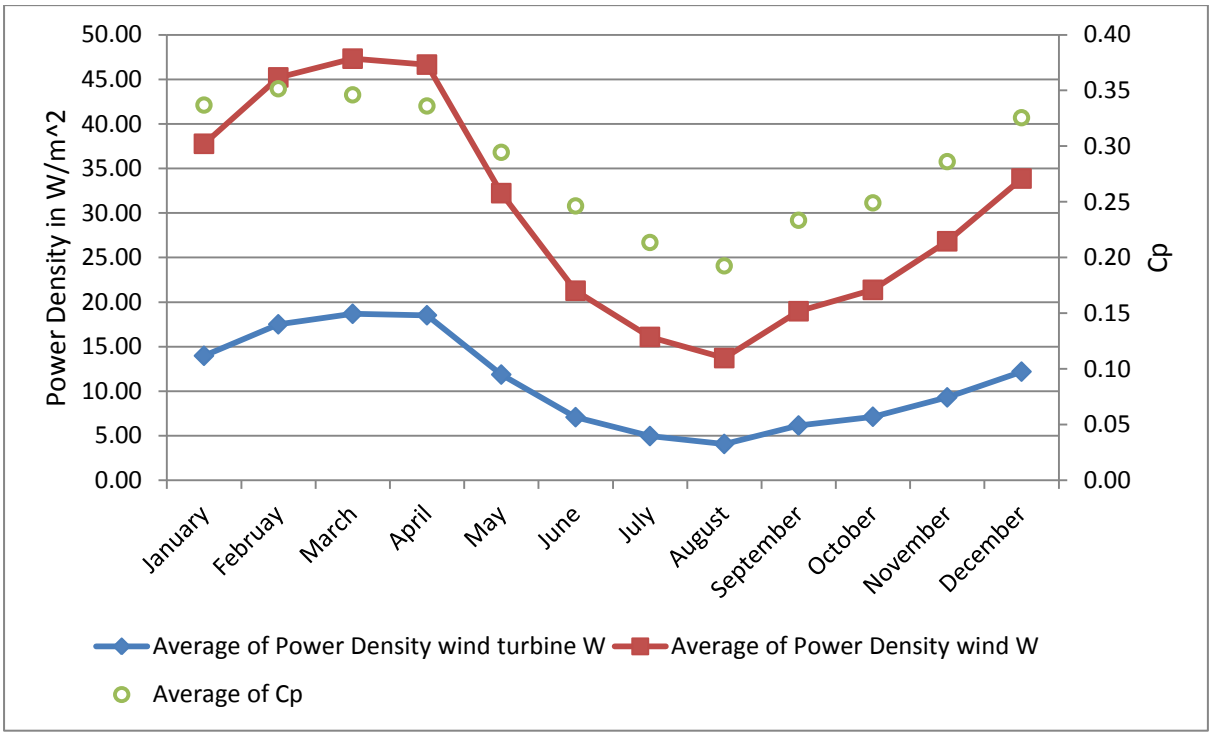
Average of Power Density of wind turbine W =10.91

Average of Power Density of wind W = 30

Average of Cp = 0.28

The variation of the above values with the monthly has been plotted in the following graph.

A look at the power curve of the turbine considered here, reveals that the optimum operating speed is around 8-10 m/s, however the average value of wind speed at this site is 3.34. The power curve shows a maximum Cp of 0.5 while from the site data it can be seen that the maximum obtainable is about 0.45. Obviously the selected turbine is suitable only for a particular period for the current site.



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