1. Estimate the approximate ocean area needed for an offshore wind-farm that can produce 1 TWh electricity per year. Assume 5 MW turbines, with diameter 125 m and a capacity factor of 0.4. Assume equal distance between the turbines in both directions and a (almost) quadratic layout of the wind-farm. Choose a reasonable turbine distance.

   A normal turbine distance is 5 -9 turbine diameters. We choose 7D, corresponding to 875m. Further, we assume an average yearly capacity factor of 0.4. Each turbine will at average produce:

   *0.4*5*8760MWh/year = 17520MWh/year.*

   *To produce 1 TWh/year 1000/17.52 =57 turbines are needed. With a rectangular layout with 7*8 turbines (+1) the approximate space required is:*

   *(7-1)*0.875km*(8-1)*0.875km=32km^2*

2. Assume a wind turbine with a power curve as given in Figure 1 . The nacelle is located 85 m above sea level. During 24 hours the wind velocity at 10 m above sea level has a variation as shown in Figure 2. Estimate the power production during the 24 hours. State your assumptions

The wind velocity in Figure 2 must be scaled to hub height. For simplicity the power law is used, i.e.

$$U_{85} = U_{10}\left(\frac{85}{10}\right)^{0.12}$$

*(The exponent will be in the range 0.1 -0.14 depending upon surface roughness). For each hour, read the wind speed from Figure 2, correct to hub height and use Figure 1 to find the corresponding power production. Sum the contributions over the 24 hours. Make a check by computing the capacity factor. Maximum possible production during the 24 hours is 24*5MWh =120MWh.*

$$\frac{U_{85}}{U_{10}} = \left(\frac{Z}{Z_{ref}}\right)^{\alpha}$$

Z=85m

Z_{ref} =10m

$U_{85} = 1.24U_{10}$

$U(t)=26-0.18(x-12)^2$

$U_{85}(t)=1.24\,(26-0.18(x-12)^2)$

$26-a(x-12)^2 = U(t)$

$a=26/144=0.18$

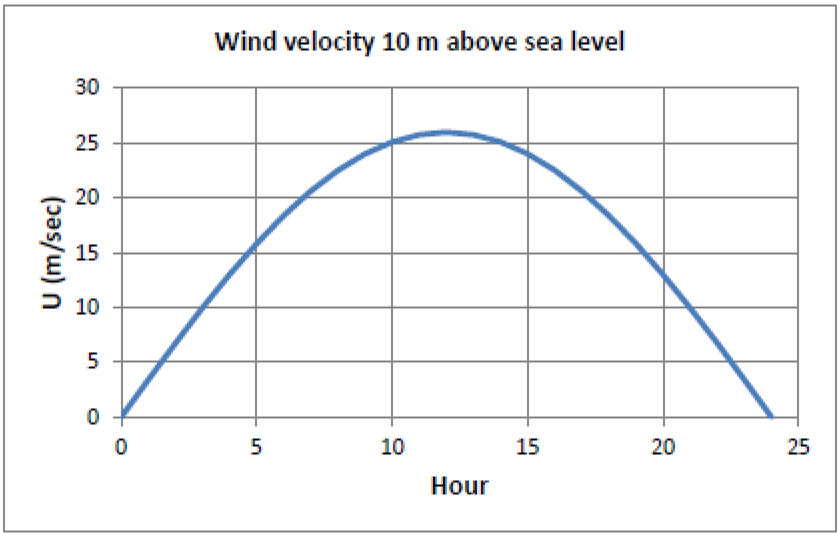
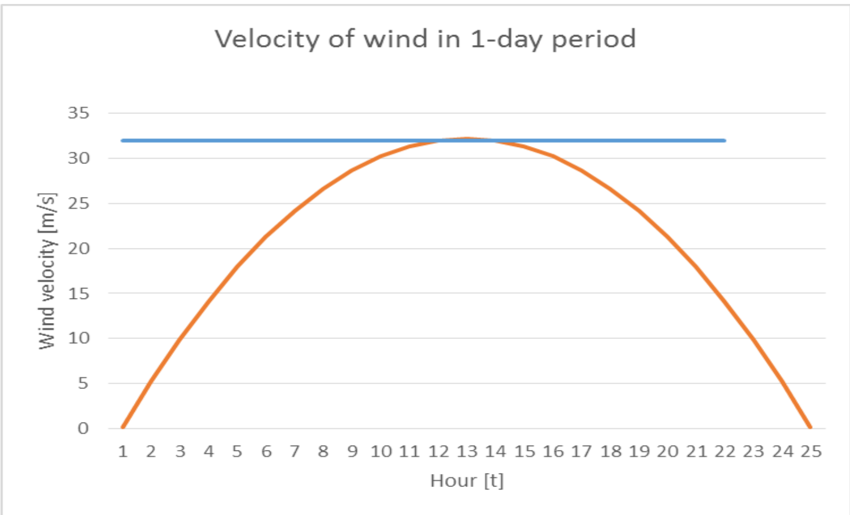
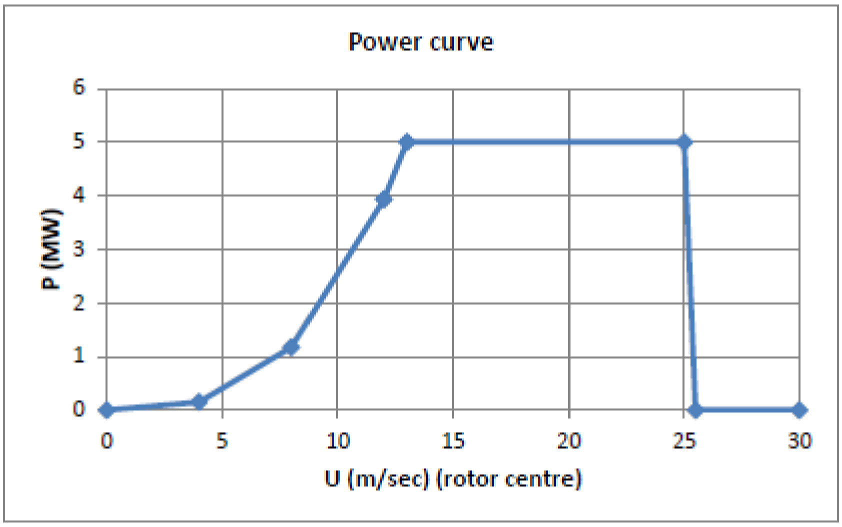


Figure 2

$U_{85}(t)=1,24(26-0.18(x-12)^2)$





U wind velocity [m/s]	Range of Time [h] (according to graph)	Power [MW]	Total time [h]	Total Energy [MWh]
U>26	8-17.2	0	0	0
13<U<26	2.7-6.8 17.2-21.3	5	8.2	41
8<U<13	1.5 – 2.7 21.3-22.54	3	2.48	7.2
0<U<8	0-1.5 22.54-24	0.5	3	1.5

Total Energy is 49.7 MWh

3. In the file wavedat_new.dat you will find a table containing the following columns of data

```
Month   Day   Hour   Minute   Hmo (m)  Tp (sec)  Wave dir.(deg)
U_10 (m/sec)   Wind dir (Deg)
```

Here

Month is the month of the year (value 1 -12),

Day is day of the month (value 1- 31)

Hour is the hour of the day (value 0 -23),

Minute is always zero,

Hm0 is significant wave height,

Tp is wave spectrum peak period.

Wave dir is the direction of the waves (waves coming from North corresponds to zero degrees, while coming from East corresponds to 90 degrees),

U_10 is average wind velocity 10 meters above sea level (1 hour average) and

Wind dir is the average wind direction, defined similarly as the wave direction.

The table contains data for one full year . Based upon the given data you shall estimate the monthly and yearly production of a wind turbine at the given location. Assume the power curve as given in Figure 1. Take into account a nacelle height giving a clearance between the rotor and the mean sea level of 20 meters. State how you extrapolate of the wind data to the actual height of the nacelle.

We assume a rotor diameter of 125m, With a tip clearance to sea of 20m, the hub height becomes 125/2+20 = 82.5m.

Read the wind velocity at each hour of the year and correct to hub height. Make a simple curve fitting to the power curve in Figure 1. For each hour compute the corresponding power production. Make summation over each month of the year and the full year. Check if a reasonable capacity factor is obtained. The analysis is most easily performed by writing a Matlab script or in Excel or

Matlab script:

```
clear all
load wavedat_new.dat;
data=wavedat_new;
if data<0
  %file wavedat_new contains damaged data -9.99e-02!!
end
%%U_10 is average wind velocity 10 meters above sea level (1
hour average)
data(:,8)=(82.5/10)^0.12.*(data(:,8));
a=(data(:,8));
%%Velocity cannot be negative
a=a(a>0);
```

```
%%
%%Compute power for all data
ll=length(a);
for j=1:1:ll;
     c = a(j);
    if ((c>0.00) &&(c<=8.00))
       p(j)=0.5;

    elseif ((c>8.00) &&(c<=13.00))
        p(j) = 3;

    elseif ((c>13.00) &&(c<=26))
       p(j) = 5;

    elseif c(c>26)
        p(j)=0;
    else
        p(j)=0;
    end
end

figure(1)
plot(a,p,'r*');ylabel('Power [MW]');xlabel('Velocity [m/s]')
%%
m=(data(:,1));
n=length(p');
mm=max(m);
%z=0;
%%Power sumation over the months
for j=1:1:mm
    for s=1:1:n
        if (m(s) == j)
            m01(:,j)=sum(p(s));
             %z=m01(:,j);
        end
end
end
%%
%%Year production in MW and Capacity of Powerhouse
year=sum(m01);%%months
Capacity = 5*12;
reasonable=year<Capacity;
year1=sum(p);%%hours
Cap1=5*365*24;
reas1=year1<Cap1;
%%
f=m01*12/Capacity;
%%
```

```
figure(2)

plot(1:12,m01');ylabel('Power [MW]');xlabel('Month');ylim([0
6]);xlim([0 13]);

%%Mean velocity over the month
j=1; s=1;
m=(data(:,1));
n=length(a);
mm=max(m);
z=1;
for j=1:1:mm
    for s=1:1:n
        if (m(s) == j)
            m02(:,j)=(sum(a(s))/z);
             z=z+1;
        end
        z=1;
end
end
figure(4)
plot(1:12,m02');ylabel('Mean Velocity
[m/s]');xlabel('Month');xlim([0 13]);
ylim([0 20]);
%%
figure(5)
plot(1:12,f);ylabel('Capacity factor');xlabel('Month');xlim([0
13]);
ylim([0 1.1]);
```