Assignment #1:
This assignment deals with applying the BEM algorithm to learn the basic operation of a variable speed pitch regulated wind turbine. The DTU 10 MW virtual experimental wind turbine is used, since all aerodynamic and structural data are publicly available and most details can be found in the report "Description of the DTU 10 MW Reference Wind Turbine", DTU Wind Energy Report-I-0092.

Overall data for the DTU 10 MW WT:
Rotor radius R= 89.17 m
Number of blades 3
Rated electrical power 10 MW
Cut in wind speed 4 m/s
Cut out wind speed 25 m/s
Air density ρ=1.225 kg/m^3

The blade is described with following table:

r [m]	c [m]	β [deg]	t/c [%]
2,80	5,38	14,50	100,00
11,00	5,45	14,43	86,05
16,87	5,87	12,55	61,10
22,96	6,18	8,89	43,04
32,31	6,02	6,38	32,42
41,57	5,42	4,67	27,81
50,41	4,70	2,89	25,32
58,53	4,00	1,21	24,26
65,75	3,40	-0,13	24,10
71,97	2,91	-1,11	24,10
77,19	2,54	-1,86	24,10
78,71	2,43	-2,08	24,10
80,14	2,33	-2,28	24,10
82,71	2,13	-2,64	24,10
84,93	1,90	-2,95	24,10
86,83	1,63	-3,18	24,10
88,45	1,18	-3,36	24,10
89,17	0,60	-3,43	24,10

The airfoils used are the FFA-W3-xxx, where the last three digits indicate the profile thickness. When estimating the lift and drag coefficients one must interpolate in both angle of attack and thickness.

Tip: **Avoid placing the last blade element too close to the tip since this will cause numerical problems caused by Prandtl's tip loss correction. However, when integrating the loads to determine the thrust and torque an element should be placed at the tip and the loads put 0 N/m.**

Q#1 Using following recommended Glauert correction determine the highest obtainable power coefficient, $C_{p,\,max}(\lambda_{max},\,\theta_{p,\,max})$, and the corresponding values of the tip speed ratio and pitch angle, λ_{tmax} and θ_{max}. Make also contour plots $C_p(\lambda,\theta_p)$ and $C_T(\lambda,\theta_p)$.

$$C_T = \begin{cases} 4aF(1-a) & a \le 0.33 \\ 4aF(1-\frac{1}{4}(5-3a)a) & a > 0.33 \end{cases}$$

Tip: The optimum pitch lies between -2 and 5 degrees and the optimum tip speed ratio between 5 and 10.

Q#2 Imagine that we want the turbine to run at the maximum $C_p = C_{p,max}$ all the way to rated power P_{mech}=10.64 MW. What is the rated wind speed, $V_{o,rated}$ and the maximum rotational speed needed, ω_{max}. Also plot $\omega(V_o)$.

Q#3 To limit the power at high wind speeds one can pitch the blades either to lower (feathering) or to higher angles of attack (stall). Below rated power assume that the pitch is constant at $\theta_{p,opt}$ to obtain $C_p = C_{p,max}$.
Compute and plot the necessary pitch setting as a function of wind speed, $\theta_p(V_o)$, to limit the mechanical power at 10.64 MW up until cut-out at 25m/s, both when you pitch to higher and lower angles of attack.
Compare your result with the report describing the DTU 10MW WT.
Plot and comment as function of the wind speed the power, $P(V_o)$, and thrust, $T(V_o)$, as function of wind speed, and their corresponding non-dimensional coefficients $C_p(V_o)$ and $C_T(V_o)$ for the two different pitch strategies.

Q#4 Run the Ashes program and compare the aerodynamic loads with your own BEM code for Vo=5, 9, 11, and 20 m/s. Try and explain the source of any differences you may see.

Q#5 Compute the annual energy production for the pitch regulated wind turbine erected at a site with following Weibull parameters, A=9 m/s and k=1.9. How much energy is lost if the wind turbine is stopped at V_o=20 m/s instead of 25 m/s, and why could that in some cases be a good idea.