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. Have a look in this report especially section 3, where you can find tables and Figures that you can use when validating your code.

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 Compute 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_{max} and θ_{max}. Try both equation (1) and (2) for momentum equation and compare the two solutions. Make and discuss the contour plots $C_p(\lambda,\theta_p)$ and $C_T(\lambda,\theta_p)$.

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

$$a = 0.246 \cdot C_T + 0.586 \cdot C_T^2 + 0.0883 \cdot C_T^3 \qquad (2)$$

Tip: The optimum pitch lies between -4 and 3 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.
Compute and plot the pitch setting, $\theta_p(V_o)$ between cut-in and cut-out wind speed when the mechanical power is limited to 10.64 MW and the rotational speed to ω_{max}.
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, $T(V_o)$ and their corresponding non-dimensional coefficients $C_p(V_o)$ and $C_T(V_o)$.

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.

Q#6 Try and find the chord and angle with the rotor plane that will maximize the local C_p at r=80.14m using a tip speed ration λ=8. The optimum chord value is between 0 and 3 m.