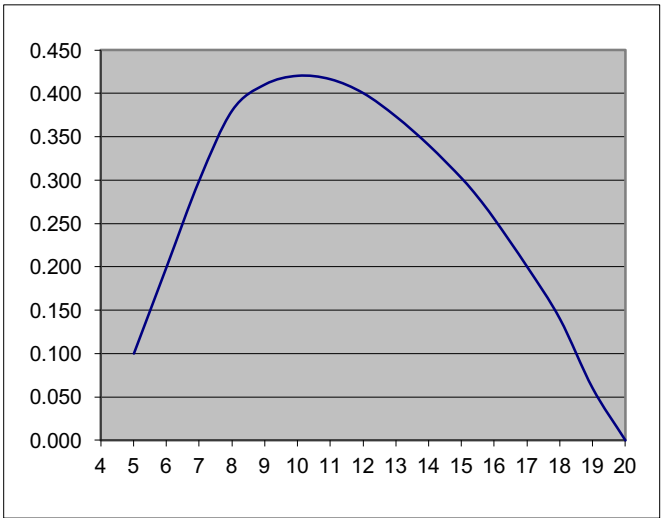
Determine operating parameters of a variable angular speed wind turbine from the Cp-λ characteristic

Consider a wind turbine designed to operate at variable angular speeds in order to maximize the energy extracted from the wind (C_p=const.=$C_{p\ max}$) between the *start-up speed* ($v_{cut\text{-}in}$ = 5 m/s) and the *nominal speed* (v_{rated}), the power remaining afterwards constant (rated power) up to the *maximal admissible speed* ($v_{cut\text{-}out}$ = 17 m/s). The diameter of the wind turbine is 34 m and its rated power ($\dot{W}_{rated}$) 310 kWe.

The C_p-λ curve is given below (remember that the power extracted by the turbine is expressed as : $\dot{W} = \frac{1}{2} \cdot \rho \cdot \pi R^2 \cdot C_p \cdot v^3$; and that λ = tip speed ratio = ωR / v). $C_{p,max}$ = C_p (λ=10) = 0.42.



λ	5,0	6,0	7,0	8,0	9,0	10,0	11,0	12,0	13,0	14,0	15,0	15,5	16,0	17,0	18,0	19,0	20,0
C_p	0,10	0,20	0,30	0,38	0,41	0,42	0,416	0,40	0,373	0,340	0,302	0,28	0,255	0,20	0,14	0,06	0,0

The exploited wind regime (5-17 m/s, operating hours) is given below.

v[m/s]	5	6	7	8	9	10	11	12	13	14	15	16	17
t[h/yr]	1212	1200	1092	948	780	600	480	312	240	144	96	60	36

Air density: ρ = 1.22 kg/m^3.

Question:

Determine the *rated speed* (such as C_p = $C_{p,max}$ at the rated power), then complete the table below *(T* is the couple (*Torque*) obtained from the wind) :

v [m/s]	C_p [-]	$\dot{W}$ [kW]	ω [rad/s]	λ [-]	T [kN]	W [kWh]
5						
…						
v rated	0.42	310		10		
…						
17						
					Total →	