# Unified Engineering Spring Term 2004

Problem P9. (Propulsion) **(L.O. G)**

Consider the turbine rotor shown below. The velocity (V_1) and absolute frame flow angle (β_1) entering the rotor are fixed. The flow angle leaving the rotor in the relative frame (β_2') is also fixed. Further, $\beta_1 = \beta_2'$. The rotor speed ($r\omega$) can be changed by varying the load on the shaft. Assume the axial velocity (w) entering and exiting the blade row is the same.

a) Draw velocity triangles in the relative and absolute frames for the different blade speeds shown below for both the inlet and exit to the rotor. (Note the inlet velocity components form a 3-4-5 triangle.)
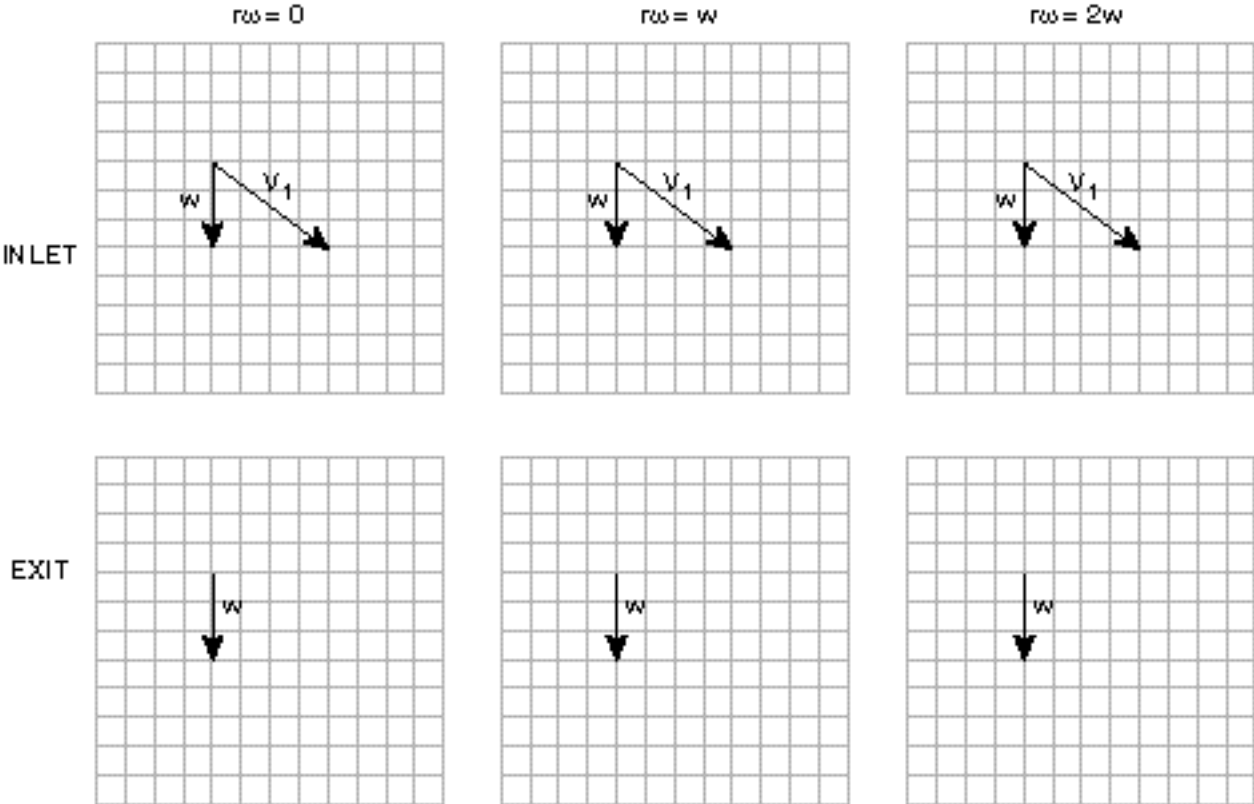
b) For the three cases drawn in part a), which extracts the most power from the flow and why?

c) If you were asked to design for maximum power extraction and could choose any blade speed between 0 and $r\omega = 2w$, what speed would you choose?

You can argue this either graphically or with reference to the Euler Turbine Equation:

$$c_p\left(T_{T1} - T_{T2}\right) = (\omega r)^2 \left[\frac{w}{\omega r}\tan\beta_1 + \frac{w}{\omega r}\tan\dot{\beta_2} - 1\right]$$

d) For what rotational speed does the "turbine" in this example, begin to act like a compressor? What might you expect the aerodynamic performance to be for the blades in such a situation - good or bad, and why?