AE 234/711 Aircraft Propulsion
Tutorial 3 - Propellers

1. Express the propeller efficiency in terms of J.
2. Verify that the power coefficient (C_P and advance ratio (J) are dimensionless.
3. Show that the optimum condition for propeller blade performance is

$$\left.\frac{V_a}{\omega r}\right|_{opt} = -\frac{C_{_D}}{C_{_L}} + \sqrt{\left(\frac{C_{_D}}{C_{_L}}\right)^2 + 1}$$

   where the propeller efficiency takes the value

$$\eta_{prop}|_{opt} = \left(\left.\frac{V_a}{\omega r}\right|_{opt}\right)^2$$

4. A light utility aircraft employs a $180hp$ normally-aspirated piston engine, with a $6ft$ diameter propeller. Assuming the ideal actuator disk power is 75% of the above, ascertain the static thrust at SSL conditions, and also at flight speeds of 60 and 120 ft/s.

   - V_a = 0.0 m/s: Thrust is 4.027 kN, w = 25.01 m/s, V_e = 50.02 m/s
   - V_a = 18.3 m/s: Thrust is 3.069 kN, w = 14.53 m/s, V_e = 47.34 m/s
   - V_a = 36.6 m/s, Thrust is 2.264 kN, w = 7.91 m/s, V_e = 52.39 m/s

5. Consider a twin-engine airplane that is powered by propeller engines. Let the flight speed be 120 ft/s. The propeller has a tip radius of $R = 6$ ft. Consider the propeller blade airfoil to have the following characteristics:

$$c_l = a_o\alpha, \text{ where } a_o = 5.7\text{rad}^{-1}, \text{ and } c_{l_{max}} = 1.2$$
$$c_d = 0.01 + 0.02\,(c_l - 0.15)^2 \text{ , where we maintain } c_l \geq 0.15$$

   Let the hub radius by $r_h = 0.2R$. If the propeller is rotating at an rpm of 2500, what should be the pitch angle variation along the propeller?
   L/D optimum is 42.9 , α_{opt} is 0.15 rad or 8.6^o

   - $r/R = 0.2$, $v_{th} = 96$ m/s, $\phi = 20.9^o$, $\beta = 29.5^o$
   - $r/R = 0.5$, $v_{th} = 239$ m/s, $\phi = 8.7^o$, $\beta = 17.3^o$
   - $r/R = 0.7$, $v_{th} = 335$ m/s, $\phi = 6.2^o$, $\beta = 14.8^o$
   - $r/R = 1.0$, $v_{th} = 479$ m/s, $\phi = 4.4^o$, $\beta = 13.0^o$