Propulsion

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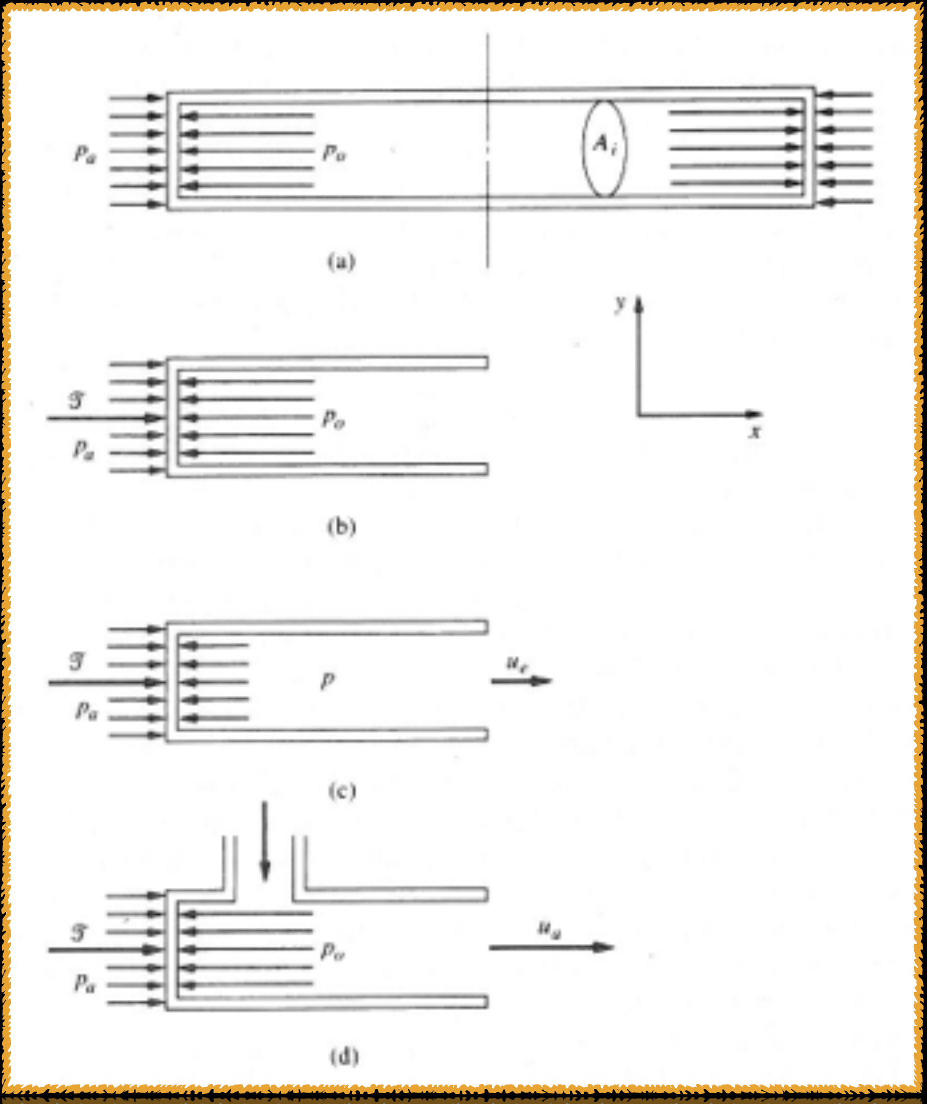
Fluid Momentum and Reactive Force

- *Propulsion devices*
  - *Propellers*
  - *Chemical rockets*
  - *Turbojet engines, fan jets, ramjets, scram jets, etc*



- *The thrust generated is given by:*

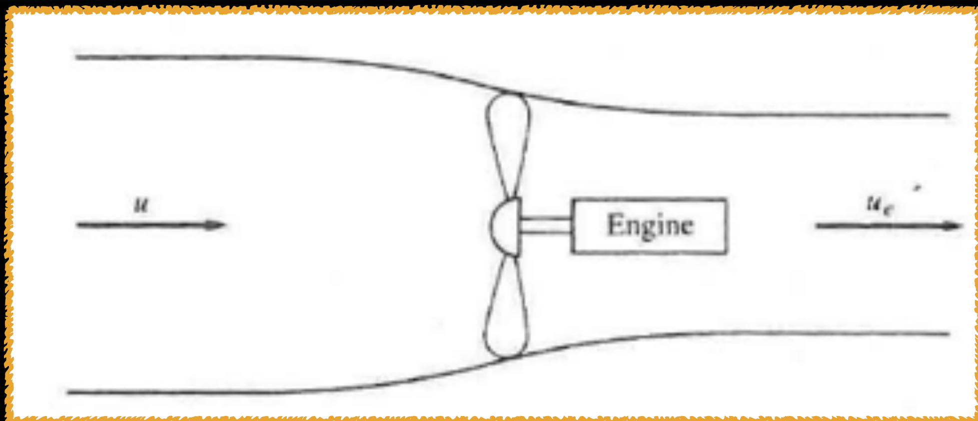
$$T = \dot{m}u_e$$

- *The above equation is true only if the exit pressure equals the atmospheric pressure.*

Propellers

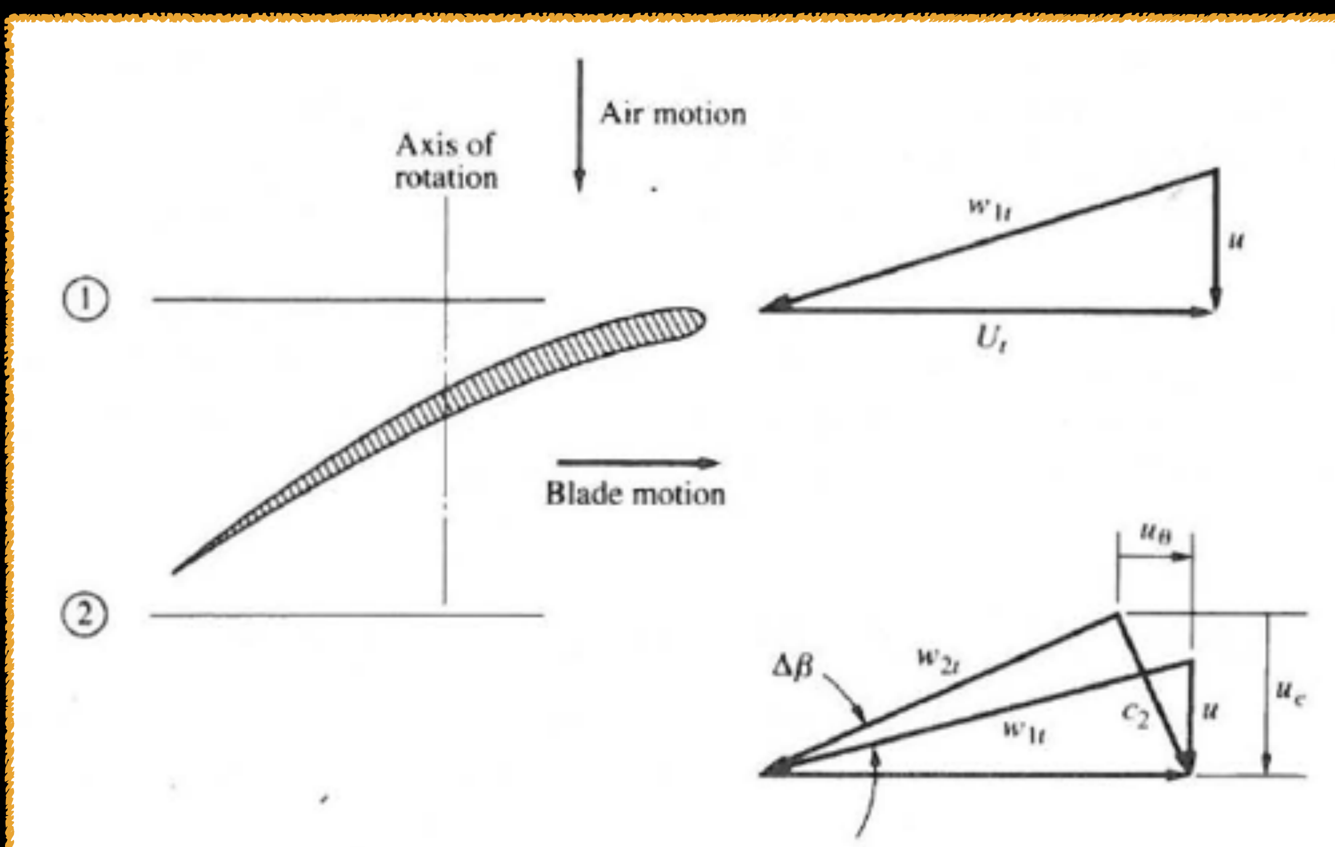
- *For an aircraft, the big advantage of using a propeller rather than rocket is that most of the propellent need not be carried on the vehicle.*
  - *It implies that aircraft can travel greater distances before refueling.*
- *Much better propulsion efficiency is possible with a propeller than with a rocket.*

Propellers



Acceleration of a streamtube through a propeller

- *The task of a propeller is to accelerate an airstream from approach velocity* u *to exhaust velocity* u_e.
- *The thrust developed by a propeller is given by:* $T = \dot{m}_a(u_e - u)$



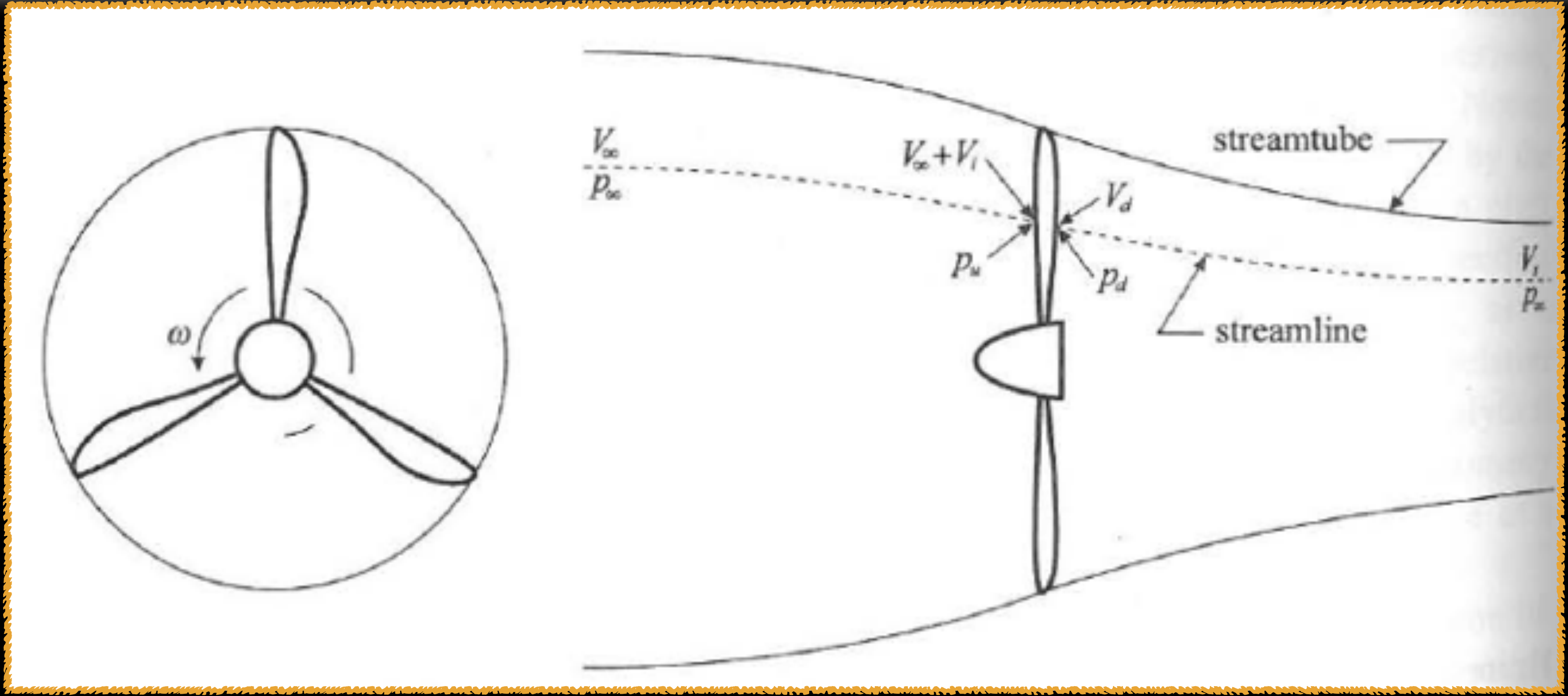
U_t: *blade speed*

u: *air approach velocity*

u_e: *axial component of leaving velocity*

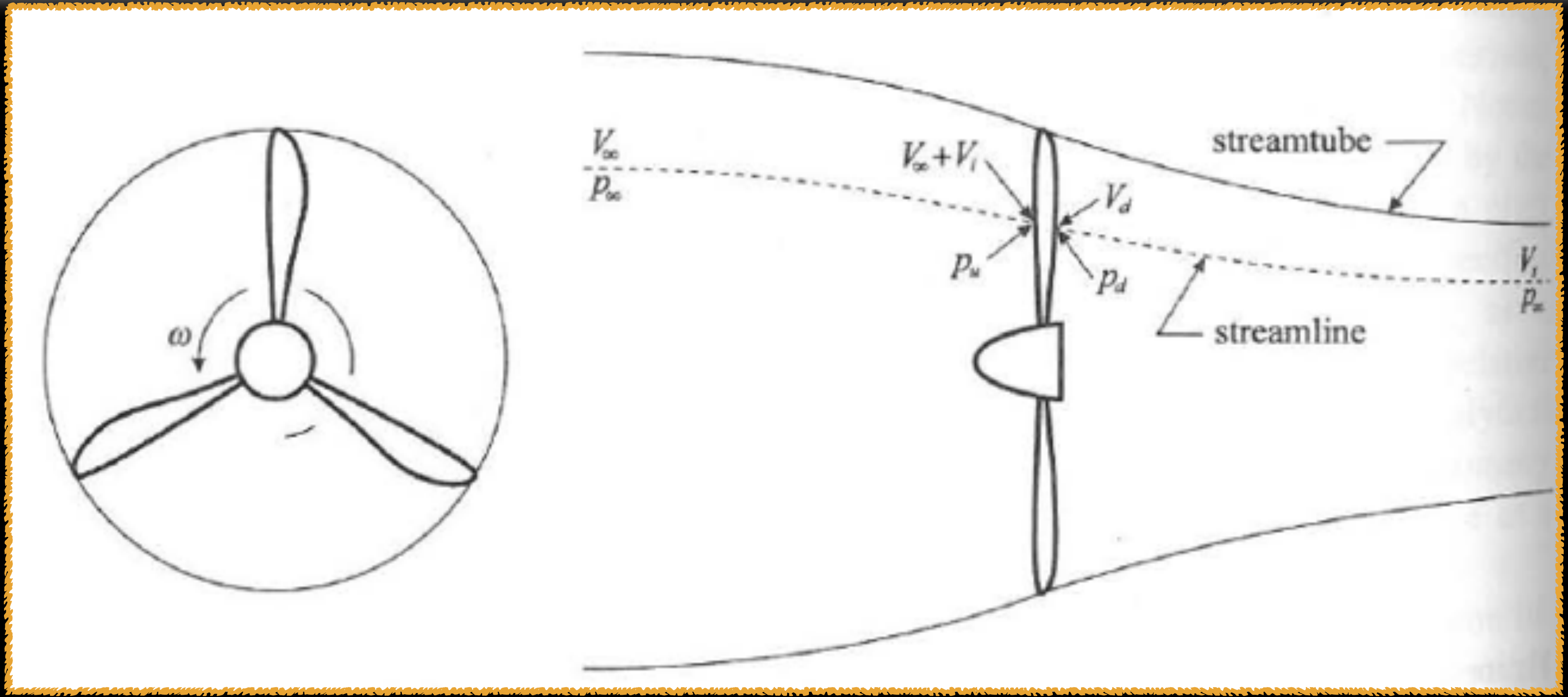
$w_{1,2t}$: *velocities relative to blade - approaching & leaving*

Propeller Momentum Theory



- *Momentum theory is based on inviscid, incompressible flow.*
  - *A streamtube, extending to infinity, exactly encompasses the propeller disk.*
  - *All rotation within the stream tube is neglected.*
  - *The flow velocity is assumed uniform over each cross section of the streamtube.*
  - *The pressure is assumed uniform over each cross section of the streamtube.*

Propeller Momentum Theory



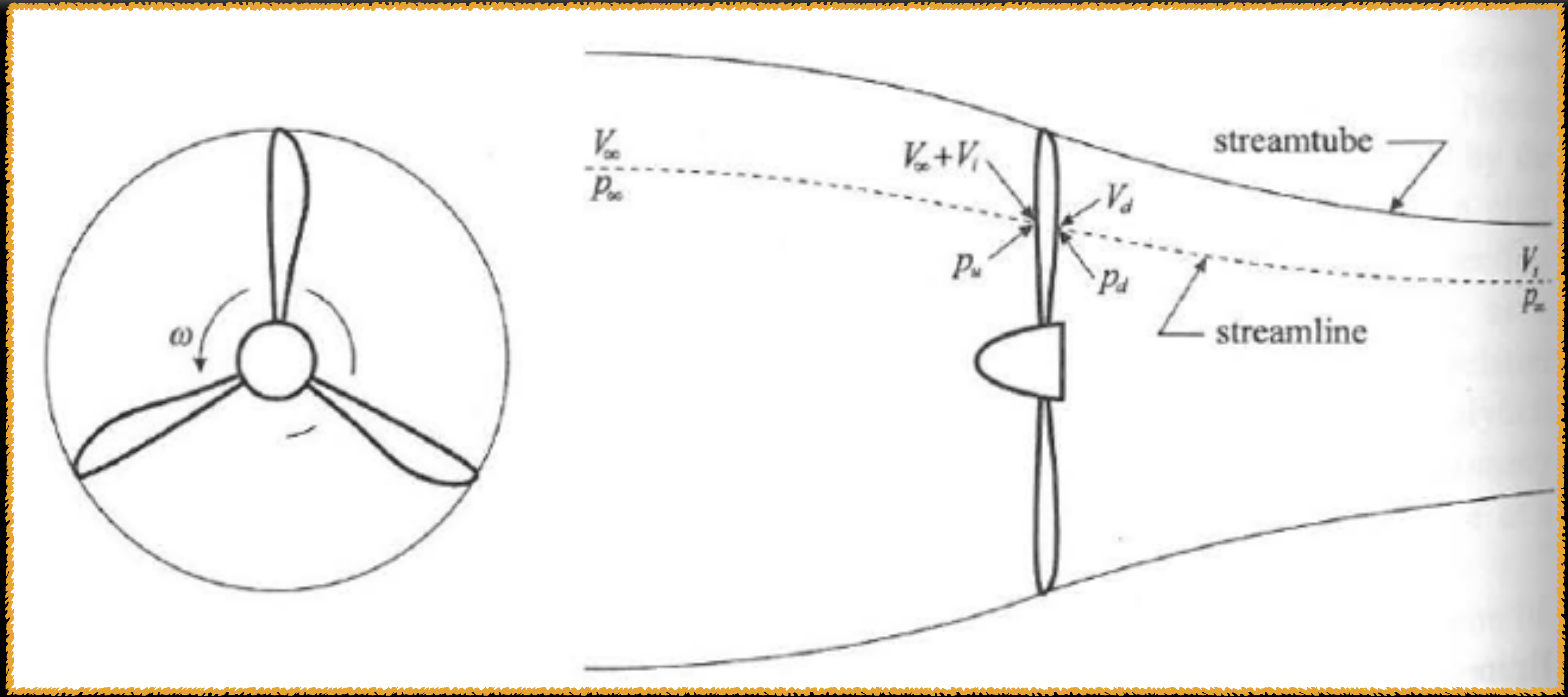
Using conservation of mass, $\rho V_d A_p = \rho(V_\infty + V_i)A_p$

Now, $V_d = V_\infty + V_i$

Applying Bernoulli's equation along the streamline shown above,

$$\frac{p_\infty}{\rho} + \frac{V_\infty^2}{2} = \frac{p_u}{\rho} + \frac{(V_\infty + V_i)^2}{2}$$

Propeller Momentum Theory



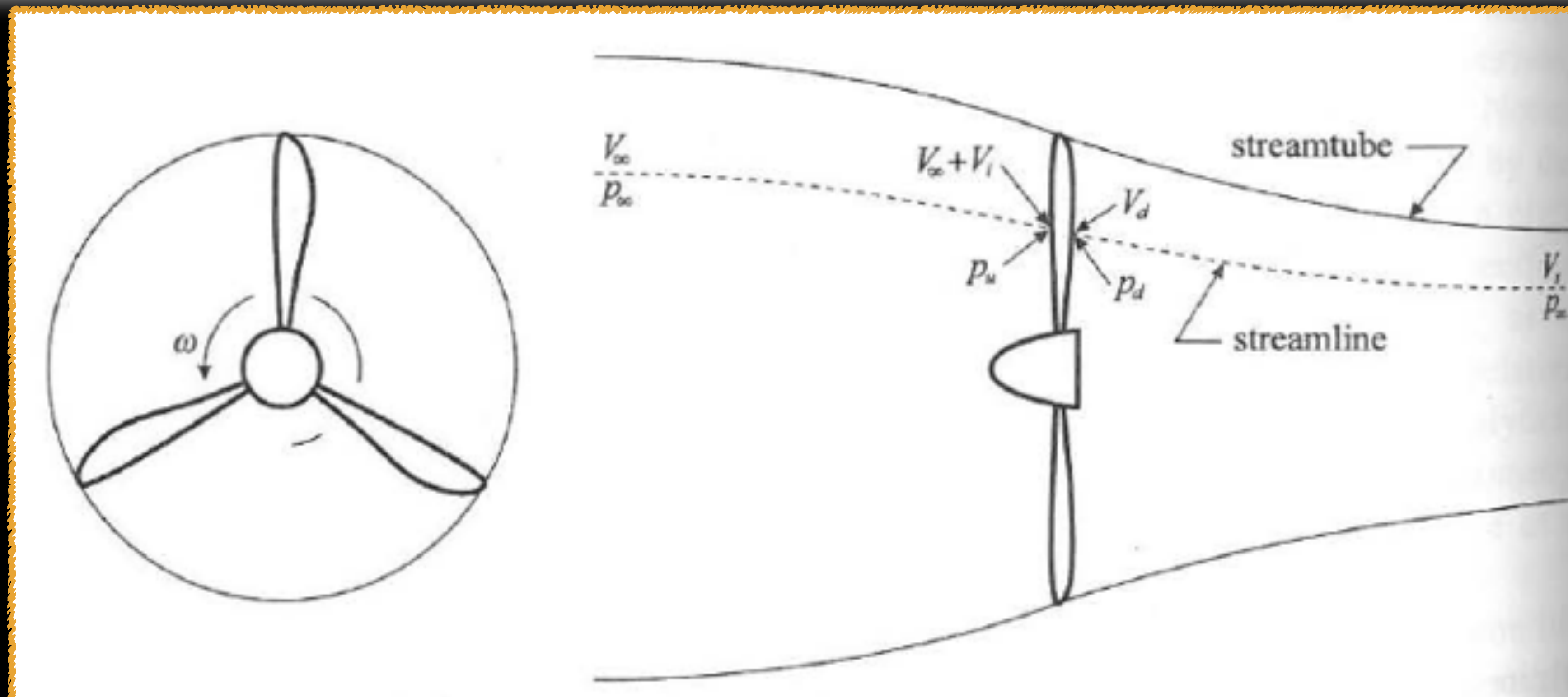
Likewise, for the streamline on the aft side of the propeller disk,

$$\frac{p_\infty}{\rho} + \frac{V_S^2}{2} = \frac{p_d}{\rho} + \frac{(V_\infty + V_i)^2}{2}; \quad V_s: \ \textit{slipstream velocity}$$

The thrust acting on the prop circle can be written as

$$T = A_p(p_d - p_u)$$

Propeller Momentum Theory



The brake power, P, that is required to turn the propeller is given by:

$$P = \dot{m}\left(h_s - h_\infty + \frac{V_s^2}{2} - \frac{V_\infty^2}{2}\right)$$

The induced velocity is given by

$$V_i = \sqrt{\frac{V_\infty^2}{4} + \frac{T}{2A_p\rho}} - \frac{V_\infty}{2}$$

Propeller Momentum Theory

- *The major drawback of the propeller momentum theory is the failure to account for the rotation of the fluid within the slipstream.*