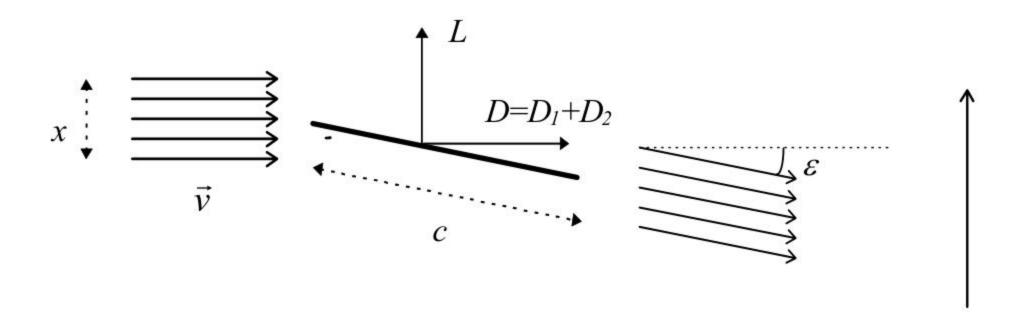
Side view of wing (in a frame of reference moving with the aircraft):



incident air

wing section

air leaving wing vertical(up)

Ignore the modification of the airflow due to the propeller.

- (a) Consider the change in momentum of the air moving past the wing, with *no* change in speed while it does so. Derive expressions for the vertical lift force L and the horizontal drag force D_I on the wing in terms of wing dimensions, v, ε , and the air density ρ . Assume the direction of air flow is always parallel to the plane of the side-view diagram. (3 marks)
- (b) There is an additional horizontal drag force D_2 caused by the friction of air flowing over the surface of the wing. The air slows slightly, with a change of speed Δv (<< 1% of v) given by:

$$\frac{\Delta v}{v} = \frac{f}{A}$$

The value of f is independent of ε .

Find an expression (in terms of M, f, A, S, ρ and g- the acceleration due to gravity) for the flight speed v_0 corresponding to a minimum power being needed to maintain this aircraft in flight at constant altitude and velocity. Neglect terms of order $(\varepsilon^2 f)$ or higher. (3 marks)

You may find the following small angle approximation useful:

$$1 - \cos \varepsilon \approx \frac{\sin^2 \varepsilon}{2}$$

(c) On the answer sheet, sketch a graph of power P versus flight speed v. Show the separate contributions to the power needed from the two sources of drag. Find an expression (in terms of M, f, A, S, ρ and g) for the minimum power, P_{min} . (2 marks)