

## Human-powered Helicopter

**Many proposals have been made for a human powered helicopter. Consider the case of such a machine with a rotor 10 metres in diameter. Could a human create enough power to overcome gravity? The density of air is  $1.23 \text{ kg m}^{-3}$ .**

Answer

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Let the mass of air forced down per unit time be  $m$  and let the air move at a speed  $v$ . The net downward momentum flow will be  $mv$ . From Newton's third law, the upward force on the human will be  $mv$ . Let the radius of rotor be  $R$  and the density of air  $\rho$ , then  $m = \rho \pi R^2 v$ . Therefore, the net upward force on the human will be  $F = \rho \pi R^2 v^2$ . For this force to overcome gravity we need  $Mg = \rho \pi R^2 v^2$  where  $M$  is the total mass of the human plus rotor and  $g$  is the acceleration due to gravity. Make a reasonable guess  $M = 200 \text{ kg}$  gives  $v = 4.5 \text{ ms}^{-1}$ . We can then calculate the rate of transfer of kinetic energy to the air as  $\frac{1}{2} mv^2$ . This gives a power of 5 kW. Think about how long it takes to run up a flight of stairs of height 10 m to decide if this is humanly possible.