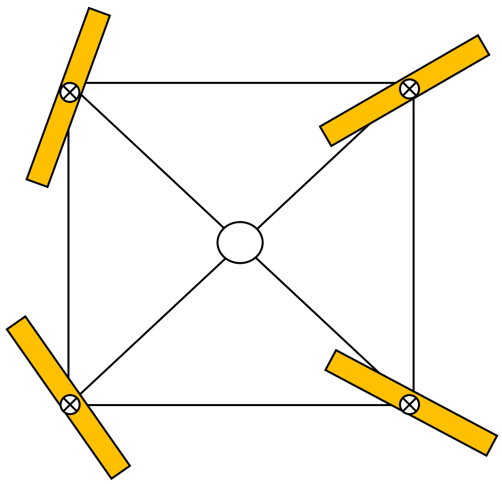
Teacher notes
Topic A

A human powered helicopter (HPH)

It is proposed to construct a helicopter which will be powered by a human.

Is this possible?

Let us assume the combined mass of helicopter and pilot to be M = 128 kg. We have four blades of radius r = 10 m and the air density is ρ = 1.2 kg m^{-3}.



As the rotor blades turn, they push air downwards with speed v. In time Δt, the air that moves is within a cylinder of radius r and height $4\rho\pi r^2 v\Delta t$ (the factor of 4 is there because there are 4 blades); its momentum changes within this time by $\Delta p = 4\rho\pi r^2 v^2 \Delta t$. Thus, the force exerted on air is $F = \frac{\Delta p}{\Delta t} = 4\rho\pi r^2 v^2$. By Newton's third law this is the upward force on the helicopter. To just hover we need this to equal the weight and so

$$4\rho\pi r^2 v^2 = Mg$$

This gives

$$v = \sqrt{\frac{Mg}{4\rho\pi r^2}} \approx \sqrt{\frac{1254}{4\times 1.2\times \pi \times 100}} \approx 0.9 \text{ m s}^{-1}$$

The power developed by the lift force is $Fv = Mgv = 1254\times 0.9 \approx 1.1\text{ kW}$

We have assumed no losses. With losses the power that must be provided by the person exceeds 1.1 kW.

This is at the limit of what a fit athlete can produce. A person of mass *m* running up the stairs to a vertical height *h* in time *t* develops a power $\frac{mgh}{t}$ and for a young fit person this is about 1 kW. (Try this.)

However, on June 13, 2013, the AeroVelo HPH was kept in the air for 64 seconds reaching a height of about 3 m. It was built by students at the University of Toronto and won the Sikorski competition and $250 000 in prize money. The numbers used in the estimate above correspond roughly to the AeroVelo HPH.