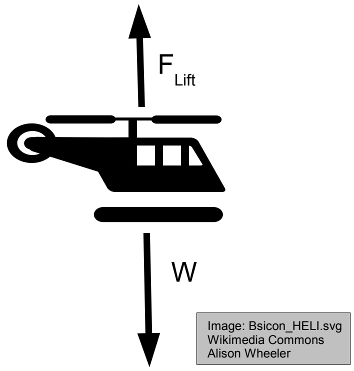
Chapter 4 Problem 54 †



Given

$m = 4300\ kg$

Solution

Find the downward force exerted on the air by the blades of the helicopter.

By Newton's 3rd law, the force exerted on the air by the blades is equal and opposite to the force exerted on the blades by the air. This force we will call F_{Lift}. Therefore, the magnitude of F_{Lift} is the same as the force exerted on the air by the blades.

From the free-body diagram illustrated above and Newton's 2nd we get

$$\Sigma\vec{F} = m\vec{a}$$

$$\vec{F}_{Lift} + \vec{W} = m\vec{a}$$

Weight is given by the equation $W = mg$, so F_{Lift} is

$$\vec{F}_{Lift} - mg\hat{j} = m\vec{a}$$

$$\vec{F}_{Lift} = mg\hat{j} + m\vec{a}$$

a) What is F_{Lift} when hovering at constant altitude?

In this case $a = 0\ m/s^2$; therefore,

$$\vec{F}_{Lift} = mg\hat{j} + m\vec{a} = (4300\ kg)(9.80\ m/s^2)\hat{j} + 0 = 42,100\hat{j}\ N$$

Therefore, the force on the air by the blades is $42,100\ N$ or $42.1\ kN$ in the downward direction.

b) What is F_{Lift} when dropping at $21\ m/s$ with speed decreasing at $3.2\ m/s^2$?

Since the speed is decreasing and it is traveling downward, the acceleration must be in the upward direction; therefore, $\vec{a} = 3.2\hat{j}\ m/s^2$ and

$$\vec{F}_{Lift} = mg\hat{j} + m\vec{a} = (4300\ kg)(9.80\ m/s^2)\hat{j} + (4300\ kg)(3.2\hat{j}\ m/s^2) = 55,900\hat{j}\ N$$

The force on the air by the blades is $55,900\ N$ or $55.9\ kN$ in the downward direction.

c) What is F_{Lift} when rising at $17\ m/s$ with speed increasing at $3.2\ m/s^2$?

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†Problem from Essential University Physics, Wolfson

Since the speed is increasing and it is traveling upward, the acceleration must be in the upward direction; therefore, $\vec{a} = 3.2\hat{\jmath}\ m/s^2$ and

$$\vec{F}_{Lift} = mg\hat{\jmath} + m\vec{a} = (4300\ kg)(9.80\ m/s^2)\hat{\jmath} + (4300\ kg)(3.2\hat{\jmath}\ m/s^2) = 55,900\hat{\jmath}\ N$$

The force on the air by the blades is $55,900\ N$ or $55.9\ kN$ in the downward direction.

d) What is F_{Lift} when rising at a constant rate of $15\ m/s$?

Since the speed is constant, the acceleration must be zero; therefore,

$$\vec{F}_{Lift} = mg\hat{\jmath} + m\vec{a} = (4300\ kg)(9.80\ m/s^2)\hat{\jmath} + 0 = 42,100\hat{\jmath}\ N$$

The force on the air by the blades is $42,100\ N$ or $42.1\ kN$ in the downward direction.

e) What is F_{Lift} when rising at $15\ m/s$ with speed decreasing at $3.2\ m/s^2$?

Since the speed is decreasing and it is traveling upward, the acceleration must be in the downward direction; therefore, $\vec{a} = -3.2\hat{\jmath}\ m/s^2$ and

$$\vec{F}_{Lift} = mg\hat{\jmath} + m\vec{a} = (4300\ kg)(9.80\ m/s^2)\hat{\jmath} - (4300\ kg)(3.2\hat{\jmath}\ m/s^2) = 28,400\hat{\jmath}\ N$$

The force on the air by the blades is $28,400\ N$ or $28.4\ kN$ in the downward direction.