HLK201 Helicopter Design Solution Set 3
Rotorcraft Design and Optimization

Q1 (8 pts)

Correct answer: b) 10%

From $\vartheta_i = \sqrt{\frac{T}{2\rho A}}$, with ρ and A constant, $v_i \propto \sqrt{T}$.

Calculation / Steps:

- If thrust increases by 21%, $\frac{T_2}{T_1} = 1.21$.
- $\frac{v_{i,2}}{v_{i,1}} = \sqrt{1.21} \approx 1.10$.
- So induced velocity increases by about 10%.

Common pitfall: Assuming ϑ_i scales linearly with T (it scales with $\sqrt{T}$.

Q2 (12 pts)

Correct answer: c) 73%

Given $P_i \propto {\vartheta_i}^3$, a 20% increase in ϑ_i implies $(1.2)^3$ increase in induced power.

Calculation / Steps:

- Compute multiplier: $(1.2)^3 = 1.728$.
- Increase $= 1.728 - 1 = 0.728 \approx 73\%$.

Common pitfall: Using a linear approximation for a cubic scaling law.

Q3 (8 pts)

Correct answer: c) 0.71

For fixed thrust, $P_{,} \propto \frac{1}{\sqrt{A}}$. If A doubles, P_i scales by $\frac{1}{\sqrt{2}}$.

Calculation / Steps:

- $A_B = 2A_A$.
- $\frac{\mathrm{P}_{i,B}}{P_{i,A}} = 1/\sqrt{2} \approx 0.707 \approx 0.71$.

Q4 (14 pts)

Correct answer: c) Increase induced power

Reducing rotor radius reduces area A, increasing disk loading and induced velocity, which increases induced power in hover.

Q5 (8 pts)

Correct answer: c) To avoid compressibility effects and noise

High tip Mach numbers introduce $compressibility/shock\ formation$, increased noise, vibration, and efficiency loss; hence practical limits are used.

Q6 (16 pts)

Correct answer: c) Induced power dominates in hover

At zero forward speed, parasite power is minimal; induced power is the dominant term for producing thrust. Profile power is present but typically smaller than induced power in hover.

Q7 (8 pts)

Correct answer: c) Climb rate, range, endurance

Excess power ($P_{exc} = P_{ava} - P_{req}$) directly governs climb capability and the margin for mission performance.

Q8 (18 pts)

Correct answer: c) Momentum Theory alone is sufficient for blade design (FALSE)

Momentum theory gives disk-averaged quantities; blade design requires $geometry/airfoil\ effects$ (e.g., via Blade Element Theory or BEMT).

Q9 (8 pts)

Correct answer: c) Reduce induced power

For constant thrust, increasing disk area reduces induced velocity and thus reduces induced power.

Q10 (20 pts)

Correct answer: c) Larger rotor disk area

Hover efficiency improves when disk loading decreases. Larger rotor disk area (for the same weight/thrust) reduces induced velocity and induced power.

Q11 (20 pts)

Correct answer: b) 0.77

For constant thrust and density, $P_i \propto \frac{1}{\sqrt{A}}$. and $A \propto R^2$, so $P_i \propto \frac{1}{R}$..

Calculation / Steps:

- $R_B = 1.30\ R_A$.
- $\frac{P_{i,B}}{P_{i,A}} = \frac{R_B}{R_A} = 1\ /\ 1.30 \approx 0.769 \approx 0.77.$

Common pitfall: Forgetting that area scales with R^2, so power scales with $1/R$ (not $1/R^2$).