Homework 3 – Signatures and IR EW

Name: ______________________________

Instructions and Grading Policy

Instructions:
Part 1 walks you, *individually*, through one aircraft against the Project 3 threats: blackbody physics, an IR seeker, an infrared countermeasure, a radar, and the loudest-band rule. If you can do this page by hand, you can sanity-check everything your group's trade study produces. Part 2 exercises the wider Block 3 toolkit. You may reference course notes and the Project 3 handout, but all work must be your own. **Use of GenAI is not authorized for any part of this assignment.**

Grading Policy:

- Each question is worth **1 point**, graded on the boxed number only. Total possible points: **10**.
- Report numeric answers to **three significant figures**. Include units where asked; keep sign on dB values.
- If a question does not meet standard, you may submit **one resubmission per question** to recover the full point. A **blank answer does not qualify** — resubmission recovers an attempted answer, not a skipped one.
- **Late policy:** coordinate with the instructor at least 24 hours before the deadline. Non-coordinated late submissions receive a zero, and that zero cannot be recovered by resubmission.

Aircraft and Threats

A notional B-21 variant flies against the Project 3 threat mix. Use these values throughout Part 1:

- **Hot parts** (nozzle/turbine) run at $T = 850$ K; the **skin** sits at $T = 300$ K.
- The stern **in-band intensity** is $J = 300$ W/sr.
- An **IR MANPADS** seeker detects $J_{\text{ref}} = 300$ W/sr at $R_{\text{ref}} = 8$ km, with detection range $R \propto \sqrt{J}$.
- An **X-band fire-control radar** detects $\sigma_{\text{ref}} = 0.03$ m^2 at $R_{\text{ref}} = 45$ km, with $R \propto \sigma^{1/4}$.
- A **VHF surveillance radar** detects the baseline aircraft at 90 km.

Part 1 — One aircraft, two threats

Questions 1–6 build the picture one piece at a time. Keep each intermediate result; you will reuse them.

Q1. Peak wavelength of the hot parts. Using Wien's law $\lambda_{\text{peak}} \approx 2898/T$ (with T in kelvin and λ in μm), compute the peak wavelength of the 850 K hot parts.

Answer: | | **μm**

Q2. Hot-parts versus skin output. By the Stefan–Boltzmann law the total radiant exitance scales as T^4. Compute the ratio of the hot parts' output (850 K) to the skin's output (300 K).

Answer: | | **(ratio)**

Q3. IR detection range after plume suppression. Plume/exhaust suppression cuts the stern intensity from 300 W/sr to 75 W/sr. With $R \propto \sqrt{J}$ and the seeker's 8 km reference at 300 W/sr, compute the new IR detection range.

Answer: | | **km**

Q4. Flare intensity to seduce the seeker. A reticle seeker is seduced when a flare presents at least 1.5× the target's in-band intensity inside the gate. For the 300 W/sr stern, compute the minimum flare in-band intensity required.

Answer: | | **W/sr**

Q5. Radar detection range after RCS reduction. Shaping and RAM cut the X-band RCS by 12 dB. With $R \propto \sigma^{1/4}$ and the radar's 45 km reference at 0.03 m^2, compute the new X-band detection range. (Hint: R scales by $10^{-\text{dB}/40}$.)

Answer: | | **km**

Q6. The loudest band. The VHF radar sees the aircraft at 90 km, the X-band radar at your Q5 range, and the MANPADS at your Q3 range. By the loudest-band rule $R_{\text{det}} = \max_b R_b$, compute the aircraft's detection range.

Answer: | | **km**

Part 2 — The trade and the toolkit

Q7. Decibels to halve a radar's range. Because $R \propto \sigma^{1/4}$, halving a radar's detection range requires a factor of 2^4 reduction in RCS. Express that reduction in decibels ($10 \log_{10}$).

Answer: ☐ **dB**

Q8. Moving the limiter. To reduce the Q6 detection range you must attack the VHF limiter. Planform realignment plus structural low-band treatment buy 10 dB of VHF RCS reduction. With $R \propto \sigma^{1/4}$, compute the new VHF detection range (the new R_{det}).

Answer: ☐ **km**

Q9. Quarter-wave absorber thickness. A Salisbury screen nulls the echo when its spacer is a quarter wavelength thick, $d = c/(4f_0)$. Compute the thickness for a design frequency $f_0 = 6$ GHz, in millimeters. (Use $c = 3 \times 10^8$ m/s.)

Answer: ☐ **mm**

Q10. The RCS budget. Three scattering contributors measure 0.02, 0.05, and 0.01 m^2. Summing them ($\sigma_{\text{tot}} = \sum_i \sigma_i$), express the total RCS in dBsm ($10 \log_{10} \sigma_{\text{tot}}$).

Answer: ☐ **dBsm**