Homework 1 – Radar Fundamentals

Name: ______________________________

Instructions and Grading Policy

Instructions:
This homework walks you, *individually*, through one complete detection-range calculation — the same pipeline your group runs across all aspects and threats in Project 1, here for a single condition. If you can do this page by hand, you can sanity-check everything your group's code produces. You may reference course notes and the Project 1 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** (ranges to the nearest 0.1 km). Include the sign where applicable.
- If a question does not meet standard, you may submit **one resubmission per question** to recover the full point.

Condition Alpha

A B-21 ingresses with the threat **45° off the nose** (front-quarter aspect). From the Project 1 threat table and RCS table:

Class	**Band**	f	P_t	$G_t = G_r$	$S_{\min}$
EW	UHF	0.5 GHz	2 MW	25 dBi	−140 dBW
TTR	X	10 GHz	100 kW	35 dBi	−140 dBW

B-21 RCS at 45°	**UHF**	**S**	**X**
(dBsm)	−17.8	−26.9	−32.1

Use $c = 3 \times 10^8$ m/s, free space, monostatic geometry, and

$$R_{\max} = \left[\frac{P_t\, G_t\, G_r\, \lambda^2\, \sigma}{(4\pi)^3\, S_{\min}} \right]^{1/4}.$$

Part 1 — The TTR, step by step

Questions 1–6 build the TTR's detection range against Condition Alpha one conversion at a time. Keep each intermediate result; you will reuse them.

Q1. Wavelength. The range equation wants λ, not f. Compute the TTR's wavelength from $\lambda = c/f$.

Answer: [ ] **m**

Q2. Gain, out of dB. Everything inside the bracket must be linear. Convert the TTR's antenna gain from 35 dBi to a linear (unitless) value.

Answer: [ ] **(unitless)**

Q3. Sensitivity, between dB conventions. Data sheets mix dBW and dBm constantly; the conversion is a single +30. Express the TTR's $S_{\text{min}} = -140$ dBW in dBm.

Answer: [ ] **dBm**

Q4. RCS, out of dB. Convert the B-21's X-band RCS at Condition Alpha (−32.1 dBsm) to square meters.

Answer: [ ] **m^2**

Q5. Detection range. Assemble the pieces (S_{min} in watts: $10^{-140/10} = 10^{-14}$ W) and compute the TTR's detection range against Condition Alpha, in km.

Answer: [ ] **km**

Q6. Uncertainty, in kilometers. The RCS table value carries a ±3 dB uncertainty. Compute the detection range at both edges of that interval (recall: dB of RCS divide by 40 on the way to range).

(a) at +3 dB: [ ] **km**

(b) at −3 dB: [ ] **km**

Part 2 — Now you fly the whole pipeline

Q7. The EW radar, in one go. Repeat Q1–Q5 for the EW radar at the same aspect — its own band, its own RCS column. Report its detection range against Condition Alpha, in km.

Answer: [ ] **km**

Q8. The gap. Compute the distance the B-21 travels between first detection by the EW radar and first detection by the TTR (the warning-vs-lethality gap your group briefed in Project 1).

Answer: [ ] **km**

Q9. Ambiguity check. The TTR operates at PRF = 10 kHz. Compute its unambiguous range $R_u = c/(2 \cdot \text{PRF})$, in km. Compare it (mentally) to your Q5 and Q6(a) answers — would this TTR ever see the B-21 beyond its unambiguous range?

Answer: [ ] **km**

Q10. Buying range with power. The adversary doubles the TTR's transmit power to 200 kW. Compute the new detection range against Condition Alpha, in km. Notice anything familiar about the factor? Doubling P_t and adding +3 dB of RCS are the same move.

Answer: [ ] **km**