


# ECE 215/S – Principles of Electronic Cyber Warfare

## Block 3: Communication Systems, Radar, and Electronic Warfare
## Lesson 39: Course Review

Department of Electrical and Computer Engineering
United States Air Force Academy

Fall 2026

# Final Exam Logistics

- Held during **finals week**, as scheduled by the registrar
- **Handwritten** and submitted directly to the proctor — not Gradescope
- **Individual effort.** Authorized: any calculator, pencil or pen, the provided equation sheet, and scratch paper. Unlike the midterm, **no notes and no slides**
- Worth **30%** of your course grade — the single largest item
- Covers **all three blocks**

**One-time examination. There are no retakes on the final.**

# How the Final Is Graded

Each **objective-tagged part** of a problem earns one of three scores:

- **1** — correct framework, given data used correctly, neat and easy to grade. Trivial math errors only
- **0.5** — correct framework, but the given data is used *incorrectly*. Still neat and organized
- **0** — wrong framework, or work that is not neat and organized, or nothing attempted

**Choosing the right framework earns you at least half.**
**Show it clearly, even if the arithmetic goes wrong.**

The exam's cover adds: put each answer **in its box**; use **engineering notation with units** (12.43 $\mu$V) — no fractions or square roots, and improper notation loses points; **completely label** every diagram.

# Equation Sheet Tour

- You get the ECE 215 equation sheet. **Know its layout before you sit down**
- It gives you equations, **not methods**. Nothing on it tells you *which* current goes in $I^2R$, or whether a link is one-way or two-way
- It also uses its own names: the sheet writes $V_m$ for a peak $V_{pk}$, $RCS$ for $\sigma$, and $G_T^2$ for a radar's $G^2$. Same quantities
- Practice problems on the course website use the same sheet — work them with it in front of you
- Spend your first two minutes **reading the whole exam** before you start problem 1

# Block 1 Review: Circuits and Power

- **1.1** $V = IR$, $P = IV$; series $R_{eq} = \sum R$; parallel smaller than any branch. Voltage divider: the element's *own* $R$ on top, $V_x = (R_x/R_{eq})\,V_{\text{series}}$. Current divider: its *own* $R$ on the bottom, $I_x = (R_{eq}/R_x)\,I_{\text{parallel}}$ — the "other resistor" shortcut is for **two** branches only
- **1.2** Rating window $1.1\,I_{\text{nom}} < CB_{\text{value}} < 1.5\,I_{\text{nom}}$, with $I_{\text{nom}}$ the current **through the protected element** — not always the source current. Then pick from the table
- **1.3** $V_{\text{rms}} = V_m/\sqrt{2}$ **only when** $V_{\textbf{bias}} = 0$; a resistor dissipates $P = V_{\text{rms}} I_{\text{rms}}$
- **1.4** With $\phi = \phi_V - \phi_I$: $P = V_{\text{rms}} I_{\text{rms}} \cos\phi$ (W), $Q = V_{\text{rms}} I_{\text{rms}} \sin\phi$ (VAR), $S = V_{\text{rms}} I_{\text{rms}}$ (VA), $S^2 = P^2 + Q^2$
- **1.5** $\eta = P_{\text{out}}/P_{\text{in}}$; cascaded stages **multiply**; $1$ hp $= 745.7$ W
- **1.6** $a = N_1/N_2 = V_1/V_2 = I_2/I_1$; line loss $I^2R$ with the *segment* current
- **1.7** $P_{\text{in}} = P_{\text{out}}/\eta$; power factor on AC segments only
- **1.8** Normalize, weight to 1.0, score, test the winner against a weight change

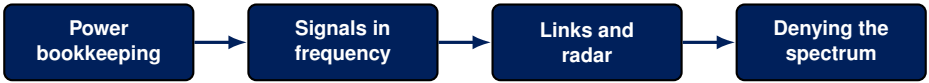
# Block 2 Review: Signals and Digital

- **2.1** Time versus frequency domain; $BW = f_{\text{high}} - f_{\text{low}}$, and $f_{\text{low}} = 0$ when DC is present
- **2.2** Four ideal filter types; output spectrum = input spectrum $\times$ filter response
- **2.3** $Z_R = R$, $Z_C = 1/(j\omega C)$, $Z_L = j\omega L$; dividers and Ohm's Law work unchanged in complex form
- **2.4** Filter type **from the gain**: evaluate $|V_{\text{out}}/V_{\text{in}}|$ as $f \to 0$ and as $f \to \infty$, and show it. Cutoff $f_{\text{cutoff}}$ at the $-3$ dB point, where the gain is $0.707$
- **2.5** Nyquist $f_s \geq 2f_{\text{high}}$; resolution $\Delta V = (V_{\max} - V_{\min})/2^b$; $QL = \text{floor}(EL)$, as a $b$-bit code
- **2.6** Anti-aliasing filter, clipping, gain and bias to match dynamic ranges
- **2.7** Gates, truth tables, SOP and POS
- **2.8** Moore versus Mealy; state diagram $\to$ transition table $\to$ logic equations

# Block 3 Review: Comms, Radar, and EW

- **3.1** $\alpha = \max(\text{message})/B$; $BW = 2f_{m,\max}$; sidebands at $f_c \pm f_m$
- **3.2** Single tone: $\eta = \alpha^2/(\alpha^2+2)$; envelope needs $\alpha \le 1$, synchronous works on anything
- **3.3** $\lambda = c/f$; dipole $G = 1.64$, monopole $3.28$, dish $G = (2\pi r_{\text{dish}})^2\eta/\lambda^2$
- **3.4** $R_{LOS,mi} = \sqrt{2h_{ft,1}} + \sqrt{2h_{ft,2}}$ — feet in, miles out; $\times 1.61$ for km
- **3.5** $P_R = P_T G_T G_R \lambda^2/(4\pi R)^2$
- **3.6** $P_R = P_T G^2 \sigma \lambda^2/[(4\pi)^3 R^4]$; every term under a fourth root
- **3.7** $PRI = 1/PRF$; $\Delta R = c\tau/2$; $R_{\text{unamb}} = c\,PRI/2$; $f_{\text{return}} = f_{\text{original}}(1 \pm 2v\cos\theta/c)$, + closing
- **3.8** $P_{\text{noise}} = kT_{sys}\,BW$; $SNR = P_{\text{signal}}/P_{\text{noise}}$; detect when $SNR \ge SNR_{\min}$, so $P_{R,\min} = SNR_{\min} \cdot P_{\text{noise}}$
- **3.9** Jammed link: $SNR_{comm} = P_{T,sig}G_{T,sig}R_{jam}^2/(P_{T,jam}G_{T,jam}R_{sig}^2)$. Jammer at the target's range: $SNR_{rad} = P_T G_T\,RCS/(P_{T,jam}G_{T,jam}\,4\pi R^2)$. Burn-through is where $SNR_{rad} = SNR_{\min}$

# The Threads That Connect the Blocks




- **Efficiency chains** (1.5) became **link budgets** (3.5) — the same accounting, over air instead of wire
- **Filters and bandwidth** (2.2, 2.4) set the **noise floor** (3.8)
- **Decision matrices** (1.8) turned your Project 1 analysis into a recommendation you could defend
- **Friis and the radar range equation** are the same spreading loss over a sphere, counted once (3.5) or twice (3.6)

# Errors Seen Across All Quizzes

- **Two-resistor current-divider shortcut on three branches** — use $I_x = (R_{eq}/R_x)\, I_{\text{parallel}}$
- **Breaker sized off the wrong current** — use the current through the protected element
- $P$ **and** $Q$ **added arithmetically** instead of as a right triangle
- **Peak used where RMS was required**, or the reverse
- **Turns ratio inverted for current** — $a = I_2/I_1$, not $I_1/I_2$
- **Load current used in a line-loss calculation** — use the current in *that* segment
- **One-way equation used for a two-way radar path**, or the reverse for an RWR
- **Diameter used where the dish formula wants radius**
- **A received power judged on its own** — compare it with the noise, or a sensitivity built on it

**Most lost points are method errors, not arithmetic. Name the framework first.**

# Worked Review Problem — Block 1

A $240$ V RMS bus feeds a motor drawing $18$ A RMS at pf $= 0.85$ lagging. The motor is 88% efficient. **Find $S$, $P$, $Q$, and the mechanical output in horsepower.**

**Apparent and real power**

$$S = (240)(18) = 4.32 \text{ kVA}$$

$$P = (4.32 \text{ kVA})(0.85) = 3.672 \text{ kW}$$

**Reactive power**

$$\phi = \cos^{-1}(0.85) = 31.8^\circ$$

$$Q = (4.32 \text{ kVA}) \sin(31.8^\circ) = 2.28 \text{ kVAR}$$

Lagging, so $Q > 0$. A *leading* pf of $0.85$ would make it $-2.28$ kVAR.

**Mechanical output**

$$P_{\text{out}} = (3.672 \text{ kW})(0.88) = 3.231 \text{ kW}$$

$$3231 \text{ W} \div 745.7 \text{ W/hp} = 4.33 \text{ hp}$$

Objectives 1.4 and 1.5 in one problem — every answer in engineering notation, with its unit.

# Worked Review Problem — Block 3

A 3 GHz radar with $P_T = 5$ kW and $G = 1500$ (a linear ratio) faces a target with $\sigma = 2$ m$^2$. The receiver needs $SNR_{\min} = 8$, with $T_{sys} = 300$ K and $BW = 2$ MHz. **Find the range at which the radar first detects the target.**

**Noise and minimum signal**

$$P_{\text{noise}} = k\,T_{sys}\,BW$$

$$= (1.38{\times}10^{-23})(300)(2{\times}10^{6}) = 8.28 \text{ fW}$$

$$P_{R,\min} = SNR_{\min} \cdot P_{\text{noise}}$$

$$= 8(8.28 \text{ fW}) = 66.2 \text{ fW}$$

**Detection range**

$$\lambda = c/f = 0.1 \text{ m}$$

$$R = \sqrt[4]{\frac{(5000)(1500)^2(2)(0.1)^2}{(4\pi)^3(66.2{\times}10^{-15})}}$$

$$R = 36.2 \text{ km}$$

Objectives 3.8 and 3.6 chained. **Always compute the noise floor first**: it defines $P_{R,\min}$. Given antenna heights, also find the line-of-sight range (3.4): the smaller of the two is the limit.

# Wrap-Up

Due at this lesson:

- **Project 3 design** — the file the EW Simulator exported — to Gradescope **"Project 3"**, due **Fri 4 Dec, 2359** (L39 T-day)

Next lesson:

- **Lesson 40 — Project 3 Discussion**, in our classroom: the debrief, and the individual questions in class (due Thu 10 Dec, 2359, L41 T-day)
- Then **Lesson 41 — Final Exam Review**, which works the Block 2 problem today did not

**No late submissions: upload, then read every PASS and FAIL.**