Learning Objectives 1.1 and 1.2: I can articulate what I will learn and how I will be assessed in this course. I can articulate practical applications of electromagnetics.

Show your work. Write a **Documentation** line at the end (**None** if you did not collaborate). Use $c = 3 \times 10^8$ m/s.

1. **Wavelengths across the spectrum.**

   (a) Find the free-space wavelength of the 60 Hz power grid, the GPS L1 signal at 1575.42 MHz, and an X-band radar at 10 GHz.

$$\lambda_{60\text{ Hz}} = \frac{3 \times 10^8}{60} = 5 \times 10^6 \text{ m} = 5000 \text{ km}$$

$$\lambda_{\text{GPS}} = \frac{3 \times 10^8}{1.57542 \times 10^9} = 0.190 \text{ m}$$

$$\lambda_{\text{X}} = \frac{3 \times 10^8}{10^{10}} = 0.03 \text{ m}$$

$\lambda_{60\text{ Hz}}$ =	5000 km
λ_{GPS} =	19.0 cm
λ_{X} =	3 cm

   (b) A 1 m connection carries each of the three signals. For which of them is the connection a significant fraction of a wavelength? Explain in one or two sentences why that matters.

   At 60 Hz the connection is 2×10^{-7} of a wavelength, so it behaves as an ideal wire. At GPS and X-band frequencies it is about 5 and 33 wavelengths long, so the voltage differs from one end to the other at each instant, and circuit theory no longer describes it; Lesson 3 models it as a transmission line.

   (c) Name one Air Force system that uses electromagnetic waves, and state one question about it that this course will help you answer.

   Answers vary. Example: an aircraft radar. How much of the transmitter's power reaches the antenna through the feed cable, and how much reflects at a mismatched connection?

2. **The course, and where circuit theory comes from.**

   (a) How is each learning objective assessed, and what can you do if you earn a 0 on an assessment?

   Each objective has an assessment scored 1 (mastered) or 0 (not yet mastered). A 0 comes with feedback, and if you made a real attempt on time you may revise your work until you earn the 1.

   (b) A transformer steps 120 V down to 12 V. Which of Maxwell's equations explains how it works? Explain in one sentence.

   Faraday's law: the changing magnetic flux in the core, produced by the primary current, induces a voltage around the secondary winding.

   (c) Faraday's law in integral form is $\oint_C \vec{E} \cdot d\vec{\ell} = -\dfrac{d}{dt} \int_S \vec{B} \cdot d\vec{s}$. Explain how it reduces to Kirchhoff's voltage law, and under what condition.

   Around a circuit loop, the line integral of $\vec{E}$ across each element is the voltage across it, so the left side is the sum of the voltages around the loop. When the magnetic flux through the loop changes negligibly, the right side is zero, and the sum of the voltages around the loop is zero.

   (d) Kirchhoff's current law follows from conservation of charge. State the condition under which it holds, and give one situation in this course where it does not.

   It holds when no charge accumulates at the node, so the current in equals the current out. On a transmission line at high frequency, charge builds up and drains along the conductors as the wave passes, so the current varies along the line; the line's capacitance accounts for it.

Documentation: _____